RPP-RPT-59379
Revision 0

Waste Management Area C Phase 2 Corrective Measures Study Report

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Date Published
November 2016

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

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EXECUTIVE SUMMARY

This corrective measures study was prepared in support of Hanford Federal Facility Agreement and Consent Order (Ecology et al. 1989) Milestone M-45-61A. The purpose of this study is to identify and evaluate alternatives that reduce potential impacts to human health and the environment from vadose zone soil contamination at Waste Management Area C. Past leaks at Waste Management Area C have resulted in soil contamination distributed in both the shallow (upper 4.6 meters [15 feet]) and deep (greater than 4.6 meters [15 feet]) vadose zone soils. Shallow soil contamination in localized areas represents a human health and ecological risk from direct-contact exposure, while deep soil contamination associated with mobile contaminants represents a potential impact to groundwater quality.

A conceptual site model for the corrective measures study was developed using available characterization data presented in the Phase 2 Resource Conservation and Recovery Act of 1976 (RCRA) Facility Investigation report[1], historical data, inventory estimates for past leaks[2], and the baseline risk assessment for Waste Management Area C[3]. Localized areas were identified where unplanned releases resulted in shallow soil contamination at concentrations that exceed risk thresholds. The contamination at depth (at or near the water table) is widely distributed and not well defined spatially. The potential groundwater impacts described in the baseline risk assessment indicate that peak groundwater impacts from past releases at Waste Management Area C are anticipated to occur in approximately 2019. This indicates that the mobile contaminants associated with past leaks at Waste Management Area C have migrated to depth and are near the groundwater.

A range of technologies were considered for both shallow and deep soil contamination, and it was concluded that no practicable or effective technologies were readily available to mitigate peak impacts to groundwater from mobile contaminants at Waste Management Area C. The corrective measures that were evaluated focused on addressing shallow soil contamination. After developing corrective measures alternatives, performance was assessed – relative to protecting human health and the environment, implementability, and cost – to identify which alternative best meets the corrective action objectives.

The corrective measures study recommendation for a preferred alternative for Waste Management Area C is implementation of an isolation barrier and infiltration barrier system (Alternative 4). The estimated cost to implement Alternative 4 is between approximately $19 and $41 million dollars. Implementation of Alternative 4 would mitigate human health and environment risks by placing concrete isolation barriers over localized areas where shallow soil contamination levels exceed risk thresholds. The infiltration barrier system would reduce infiltration and slow the migration of contaminants to the groundwater. While the infiltration barrier would not reduce the anticipated peak impacts to groundwater, there would be a reduction in contaminant flux over the long-term. The isolation barriers would reduce the risk of

[1] RPP-RPT-58339, "Phase 2 RCRA Facility Investigation Report for Waste Management Area C," Draft A.
[2] RPP-ENV-33418, "Hanford C-Farm Leak Inventory Assessments Report," Rev. 3.
[3] RPP-RPT-58329, "Baseline Risk Assessment for Waste Management Area C," Rev. 2.

direct-contact exposure to acceptable human health risk levels and reduce infiltration, pending placement of the final closure cap that will be installed as a part of Waste Management Area C closure. This final closure cap represents the permanent risk-mitigation measure for protecting human health and the environment for Waste Management Area C and will be installed as part of the closure process after implementing the preferred alternative (Alternative 4) of this corrective measures study.

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TERMS

AEA	Atomic Energy Act of 1954
ARAR	applicable or relevant and appropriate requirement
AUF	area use factor
bgs	below ground surface
BRA	baseline risk assessment
CAO	corrective action objective
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cm	centimeter
CMS	corrective measures study
COC	constituent of concern
COPC	constituent of potential concern
COPEC	constituent of potential ecological concern
CTA	container transfer area
DOE	U.S. Department of Energy
DWS	drinking water standard
EA	exposure area
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	estimated exposure point concentration

ERA	ecological risk assessment
ERDF	Environmental Restoration Disposal Facility
FS	feasibility study
ft	feet or foot
ft^2	feet squared
ft^3	cubic feet
gal.	gallon
GRA	general response action
HFFACO	Hanford Federal Facility Agreement and Consent Order
HQ	hazard quotient
L	liter
m	meter
mrem/hr	millirems per hour
MTCA	Model Toxics Control Act
OSWER	Office of Solid Waste and Emergency Response
Phase 2 RFI	Phase 2 RCRA facility investigation
PrHA	Process Hazards Analysis
PUREX	Plutonium Uranium Extraction (facility)
RCRA	Resource Conservation and Recovery Act of 1976
RCW	Revised Code of Washington
RFI	RCRA facility investigation
RI	remedial investigation
RME	reasonable maximum exposure
ROM	rough order of magnitude

SGE	Surface Geophysical Exploration
SLERA	screening level ecological risk assessment
SMDP	scientific management decision point
SSL	soil screening level
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases (computer code)
TBC	to be considered
TEDE	total effective dose equivalent
TPA	Tri-Party Agreement
UCL	upper confidence limit
UPR	unplanned release
WAC	Washington Administrative Code
WMA	waste management area
WRPS	Washington River Protection Solutions

1.0 INTRODUCTION AND BACKGROUND

Waste Management Area (WMA) C is located in the central area of the U.S. Department of Energy (DOE)'s Hanford Site. WMA C will be the first of seven WMAs at Hanford that will undergo closure. WMA C will be landfill closed as discussed in RPP-RPT-58858, "Tier 1 Closure Plan Single-Shell Tank System." Conceptually, landfill closure of WMA C will include filling tanks with grout and as much of the ancillary equipment as practicable, and installing a final Modified Resource Conservation and Recovery Act of 1976 (RCRA) Subtitle C barrier (final closure cap), followed by post-closure care. The final closure cap would be installed after most closure activities are completed at Tank Farms 241-C, 241-A, 241-AN, 241-AP, 241-AW, 241-AX, 241-AY, and 241-AZ, as discussed in Appendix E, Section E.1.2.5.4.1 of DOE/EIS-0391, "Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington." Placement of the final closure cap will not occur for many decades.

This corrective measures study (CMS) report documents the development and evaluation of remedial alternatives designed to protect human health and the environment from vadose zone contamination at WMA C until final closure actions are implemented. This CMS report recommends a preferred remedial alternative for potential implementation at WMA C. Implementation of the preferred remedial alternative will support closure of WMA C, along with other closure actions documented in closure plans and other decision documents.

Waste Management Area C closure actions are integrated through the following documents:

- DOE/EIS-0391;
- Hanford Federal Facility Agreement and Consent Order (HFFACO) (Ecology et al. 1989) Action Plan Appendix I Performance Assessment;
- RCRA Closure Plan;
- DOE O 435.1, Radioactive Waste Management Closure Plan;
- RCRA Facility Investigation;
- Corrective Measures Study; and
- Remedial Investigation/Feasibility Study.

This CMS implements commitments made in RPP-PLAN-39114, "Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C" (Phase 2 work plan). The remedial alternatives developed for evaluation in this CMS are based on the results of the Phase 2 RCRA facility investigation (RFI) reported in RPP-RPT-58339, "Phase 2 RCRA Facility Investigation Report for Waste Management Area C," Draft A (Phase 2 RFI report).

Closure of WMA C, including the development of this CMS report, is subject to the requirements of the HFFACO (Ecology et al. 1989). The HFFACO, commonly referred to as the Tri-Party Agreement or TPA, is a consent order and agreement among the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA), and DOE. Completion and submittal of the CMS report meets the requirements of HFFACO Milestone M-045-61A (see Appendix A of this document for a copy of the change package).

1.1 PURPOSE AND APPROACH

The purpose of this CMS is to develop, evaluate, and recommend remedial alternatives designed to protect human health and the environment from vadose zone soil contamination until a final WMA Closure action is implemented at WMA C. While this CMS follows the RCRA and Model Toxics Control Act (MTCA) (Revised Code of Washington [RCW] 70.105D, "Hazardous Waste Cleanup—Model Toxics Control Act") requirements for evaluating a corrective measures alternative, the equivalency components of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) were used for the development and evaluation of the alternatives.

The preferred remedial alternative, when implemented as part of a corrective action strategy, will reduce the risk of exposure to human health and ecological receptors. Details regarding exposure risks are provided in the baseline risk assessment (BRA) RPP-RPT-58329, "Baseline Risk Assessment for Waste Management Area C," summarized in Section 1.6.2. The BRA analyzes and describes how radiological and non-radiological constituents released at WMA C pose unacceptable risk to humans and the environment, and threaten groundwater beneath WMA C. Additional risk assessment was performed to address exposure risks associated with three unplanned releases (UPRs) with elevated levels of contamination in the shallow vadose zone. See Section 1.7 for additional information.

This CMS report documents the development, evaluation, and selection of a recommended remedial alternative for WMA C soil. The recommended remedial alternatives for soil are designed to mitigate risk to receptors and to support landfill closure of WMA C. Additionally, the performance standards for RCRA closure as set forth in Washington Administrative Code (WAC) 173-303-610, "Closure and Post-Closure" were reviewed for consistency. This CMS report also summarizes Phase 2 RFI activities and results, and develops corrective measures objectives, also known as corrective action objectives (CAOs), for soil.

Available, viable technical options are identified and evaluated for potential suitability for use at WMA C to mitigate vadose zone soil direct-contact risks to meet acceptable risk levels. Remedial alternatives that meet CAOs are developed and evaluated, and costs are estimated for the candidate remedial alternatives. A comparative analysis of alternatives is performed, and one alternative, the preferred alternative, is recommended for selection to the lead agency, in this case, Ecology. The preferred alternative is then evaluated by the lead agency for development of a statement of basis for a draft RCRA permit modification, with the intent of eventual incorporation of the selected corrective measure into the corrective action portion of the permit. Additionally, Ecology as the lead regulatory agency will recommend the CERCLA remedial action(s) it deems appropriate to EPA. The EPA Administrator, in consultation with the DOE

and Ecology, shall make final selection of the CERCLA remedial action(s) in accordance with HFFACO Article XIV, paragraph 54.

The process used to develop and evaluate alternatives in this CMS to support WMA C closure is consistent with EPA's guidance documents on implementing corrective actions, the MTCA cleanup regulations (WAC 173-340, "Model Toxics Control Act—Cleanup"), CERCLA (Title 40, Code of Federal Regulations [CFR], Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan" [40 CFR 300]), and the HFFACO Action Plan, Appendix I, Section 2.3, "WMA Corrective Actions", which states:

> "Closure decisions for SST system soils will be made through the RCRA corrective action process pursuant to Agreement Milestones M-45-55 through -62 and its established process for the development of interim measures where appropriate, RCRA facility investigation/corrective measures study (RFI/CMS) work plans, remedial field investigations, and corrective measures studies."

Corrective measures studies typically include the following elements: site-specific characterization information, applicable or relevant and appropriate requirements (ARARs), corrective/remedial action objectives, risk assessment results, detailed cost estimates, detailed and comparative analysis of alternatives, and a justification for a recommended alternative.

Evaluation criteria under RCRA, CERCLA and MTCA are combined in principal for alternatives analysis as provided in RPP-PLAN-37243, "Phase 2 RCRA Facility Investigation/Corrective Measures Study Master Work Plan for Single-Shell Tank Waste Management Areas," the RFI/CMS master work plan. The MTCA evaluation criteria are found at WAC 173-340-360, "Selection of Cleanup Actions." These criteria are consistent with CERCLA and RCRA corrective action evaluation criteria, although the MTCA criteria are arranged in a slightly different manner.

This CMS will be used to support decisions under RCRA corrective action (as implemented through the MTCA), RCRA closure, and CERCLA. The evaluation criteria for decision making under these three programs are functionally equivalent in most cases, although they are arranged in a slightly different manner. RCRA corrective action/MTCA evaluation criteria are found in WAC 173-303-360, RCRA closure performance standards are found in WAC 173-303-610 subsection (2) "Closure performance standard," and CERCLA evaluation criteria are found in 40 CFR 300, Subpart E—Hazardous Substance Response, § 300.430, subsection (e) Feasibility study, (9) Detailed analysis of alternatives, (iii) Nine criteria for evaluation. In order to demonstrate compliance with these three similar authorities, alternative evaluations in this CMS are performed using evaluation criteria and performance standards of each, consistent with the approach established in RPP-PLAN-37243.

1.2 SITE LOCATION AND DESCRIPTION

Consistent with the Phase 2 RFI report, WMA C is an approximately 3.4-hectare (8.5-acre) site located in the 200 East Area on the Central Plateau of the Hanford Site (Figure 1-1). WMA C includes the 241-C Tank Farm (C Farm), which is surrounded by security fencing. Although the

WMA C boundary is typically represented by the fenceline surrounding C Farm, WMA C includes media contaminated by releases from the RCRA-regulated C Farm tank system.

The C Farm fenceline is irregular in shape, with the overall extent of the footprint at 204 m by 239 m (670 ft by 785 ft). C Farm consists of 16 single-shell tanks (SSTs) (i.e., twelve 100-series 2,006,000-L [liters] [530,000-gallon (gal)] capacity tanks, and four 200-series 208,000-L [55,000-gal] capacity tanks), and various waste transfer systems and supporting facilities. The general layout of the C Farm tanks and structures is shown in Figure 1-2.

The footprint of the twelve 100-series tanks covers an area 91 by 122 meters (m) (300 by 400 feet [ft]). Four smaller 200-series tanks are located toward the northeast of the 100-series tanks. The C Farm system also encompasses waste transfer lines and tank ancillary equipment and support structures such as diversion boxes, catch tanks, the process vault, and facilities such as a cesium loadout station.

Four diversion boxes (241-C-151, 241-C-152, 241-C-153, and 241-C-252) were originally constructed in C Farm. Another three diversion boxes (241-CR-151, 241-CR-152, and 241-CR-153), the 244-CR Vault, the 271-CR Control House, the 271-CRL Laboratory, and the 241-C-801 Cesium Loadout Facility (Cesium Loadout Facility) were built later.

Tank waste retrieval activities have added temporary surface facilities that include process skids, transfer piping, and ventilation systems along with process support trailers and associated utility infrastructure.

1.3 SITE OPERATIONAL HISTORY

From 1946 through the 1970s, WMA C was used for receiving, storing, and processing a variety of waste streams associated with spent fuel reprocessing at the Hanford Site. Following active use of the SSTs for receiving waste, pumpable liquids were removed from the SSTs, and the SSTs were declared inactive. Waste remained in the SSTs until later waste retrieval actions were initiated to retrieve waste. These operations are further described in the Phase 2 RFI report. Figure 1-3 shows site conditions in a 2013 oblique aerial photograph of WMA C.

Unplanned releases at WMA C have led to soil contamination. Most of the UPRs occurred in the 1960s and 1970s during active tank farm operations and were discovered through monitoring activities. The UPRs are further described in RPP-ENV-33418, “Hanford C-Farm Leak Inventory Assessments Report.”

1.4 REGULATORY AUTHORITY AND FRAMEWORK

The WMA C corrective action process is an integral part of a larger undertaking to close WMA C. The corrective action process is used for decision making for the soil component of WMA C in order to facilitate closure actions. WMA C tank waste retrieval actions performed under the HFFACO, consistent with the Hazardous Waste Management Act (RCW 70.105,

"Hazardous Waste Management"), and SST system closure actions performed under the Hazardous Waste Management Act, are addressed in separate but related documents developed in tandem with additional WMA C closure actions, which are described in the HFFACO Action Plan, Appendix I.

DOE is the responsible Federal agency for the closure of WMA C as the owner of the treatment, storage, and disposal facilities, and Ecology is the lead regulatory agency. Per the HFFACO, Part One, Article V, Definitions, paragraph 22, R, the lead regulatory agency is "that agency (EPA or Ecology) assigned regulatory oversight responsibility with respect to actions under this Agreement regarding a particular Operable Unit, TSD Unit/Group or Milestone pursuant to Section 5.6 of the Action Plan. The designation of a lead regulatory agency shall not change the jurisdictional authorities of the Parties."

Consistent with WAC 173-303-64620, "Requirements," section (1) requirements, the "owner or operator of a facility must institute corrective action as necessary to protect human health and the environment for all releases of dangerous waste and dangerous waste constituents, including releases from all solid waste management units at the facility." Additionally, per WAC 173-303-64620 subsection (4)(a), "Information that is adequate to support selection of a cleanup action consistent with WAC 173-340-360 but was developed under a different authority (for example, as part of closure under WAC 173-303-610 or as part of a federally overseen cleanup) may be used."

This CMS complies with applicable RCRA closure guidance and CERCLA cleanup guidance, and follows the processes used to evaluate and compare alternatives established by MTCA. The HFFACO Action Plan states:

> "The parties recognize that hazardous waste compliance, permitting, closure and postclosure action, and remedial and corrective action at the Hanford Site will require a fully integrated effort involving the Federal RCRA, CERCLA, and the Washington State Hazardous Waste Management Act."

Because WMA C is included on the CERCLA National Priorities List as part of the Hanford Site 200 Areas, remediation of the 200 Areas eventually will be supported through CERCLA decisions made by the EPA, and RCRA permitting decisions made by Ecology.

EPA is authorized under the Hazardous and Solid Waste Amendments to RCRA to require corrective action through an order, such as the HFFACO, when there has been a release of hazardous waste or constituents from an interim status facility. Corrective action components include an initial site assessment, characterization, interim actions, evaluation of remedial alternatives, remedy selection, and remedy implementation. This is consistent throughout EPA RCRA guidance, CERCLA guidance, and WAC 173-340-370, "Expectations for Cleanup Action Alternatives" (MTCA).

Section 7 of the HFFACO Action Plan lays the foundation for equivalency between the RCRA CMS process and the CERCLA feasibility study process. Therefore, the criteria for evaluating alternatives in this CMS are consistent with the CERCLA feasibility study criteria. The MTCA

evaluation criteria are found at WAC 173-340-360. These criteria are consistent with RCRA corrective action and CERCLA evaluation criteria with emphasis on protection of human health and the environment. The preferred alternative supports RCRA closure standards as part of a more extensive closure action supporting compliant landfill closure requirements.

Section 7 of the HFFACO Action Plan lays the foundation for equivalency between the RCRA CMS process and the CERCLA feasibility study process. Therefore, the criteria for evaluating alternatives in this CMS are consistent with the CERCLA feasibility study criteria. The MTCA evaluation criteria are found at WAC 173-340-360. These criteria are consistent with RCRA corrective action and CERCLA evaluation criteria with emphasis on protection of human health and the environment. The preferred alternative supports RCRA closure standards as part of a more extensive closure action supporting compliant landfill closure requirements.

1.5 WASTE MANAGEMENT AREA C CLOSURE STRATEGY

WMA C is to be landfill closed as discussed in RPP-RPT-58858. The HFFACO Action Plan, Appendix I describes the SST closure strategy and how that strategy integrates with the overall Hanford Site closure strategy. The SST closure strategy addresses and is driven by requirements of the Atomic Energy Act of 1954, RCRA, Hazardous and Solid Waste Amendments to RCRA, CERCLA, and DOE orders.

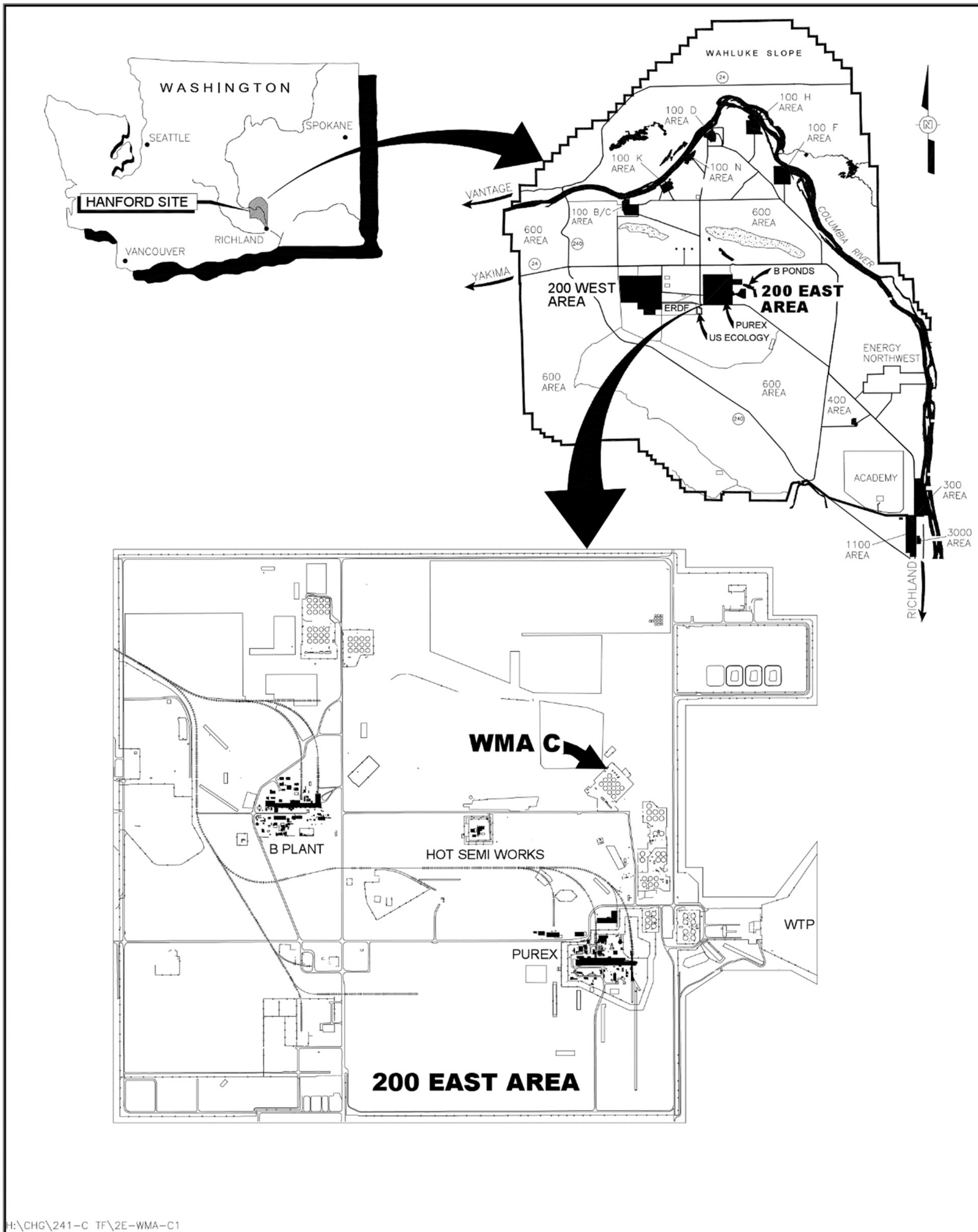
Conceptually, landfill closure of the SST system will include filling tanks and as much of the ancillary equipment as practicable with grout, and installing a final Modified RCRA Subtitle C barrier (final closure cap), followed by post-closure care. A final closure cap will be installed after retrieval and most closure activities are completed at Tank Farms 241-C, 241-A, 241-AN, 241-AP, 241-AW, 241-AX, 241-AY, and 241-AZ. Appendix E, Section E.1.2.5.4.1 of DOE/EIS-0391 describes the final closure cap concept for WMA C.

RCRA closure standards are performance-based regulations that mandate performance criteria without specifying design, construction materials, or operating parameters. EPA has provided guidance documents to aid in interpreting the code to determine the level of performance required to design, construct, and operate a compliant closure system. The closure performance standard is defined in WAC 173-303-610(2).

The final WMA C closure strategy will influence the selection of corrective measures. Corrective measures recommended for implementation here are designed not to affect DOE's ability to reach final closure of WMA C. Corrective measures considered in this CMS will occur after the tanks are grouted. The corrective measures will address both short- and long-term risks and provide environmental protection until completion of WMA C component closure actions and until the final closure cap is installed, after which post-closure activities will be conducted.

As required by the HFFACO Action Plan, Appendix I, Section 2.3, the corrective action master work plan RPP-PLAN-37243 describes the overall corrective action process and sequencing approach for closing the Hanford SST farms. Integration of the vadose zone and the groundwater programs is described in Section 5 of RPP-PLAN-37243.

Figure 1-1. Location Map of Waste Management Area C at the Hanford Site.



PUREX = Plutonium Uranium Extraction (facility)
WTP = Waste Treatment and Immobilization Plant
WMA = waste management area

Figure 1-2. Waste Management Area C Features.

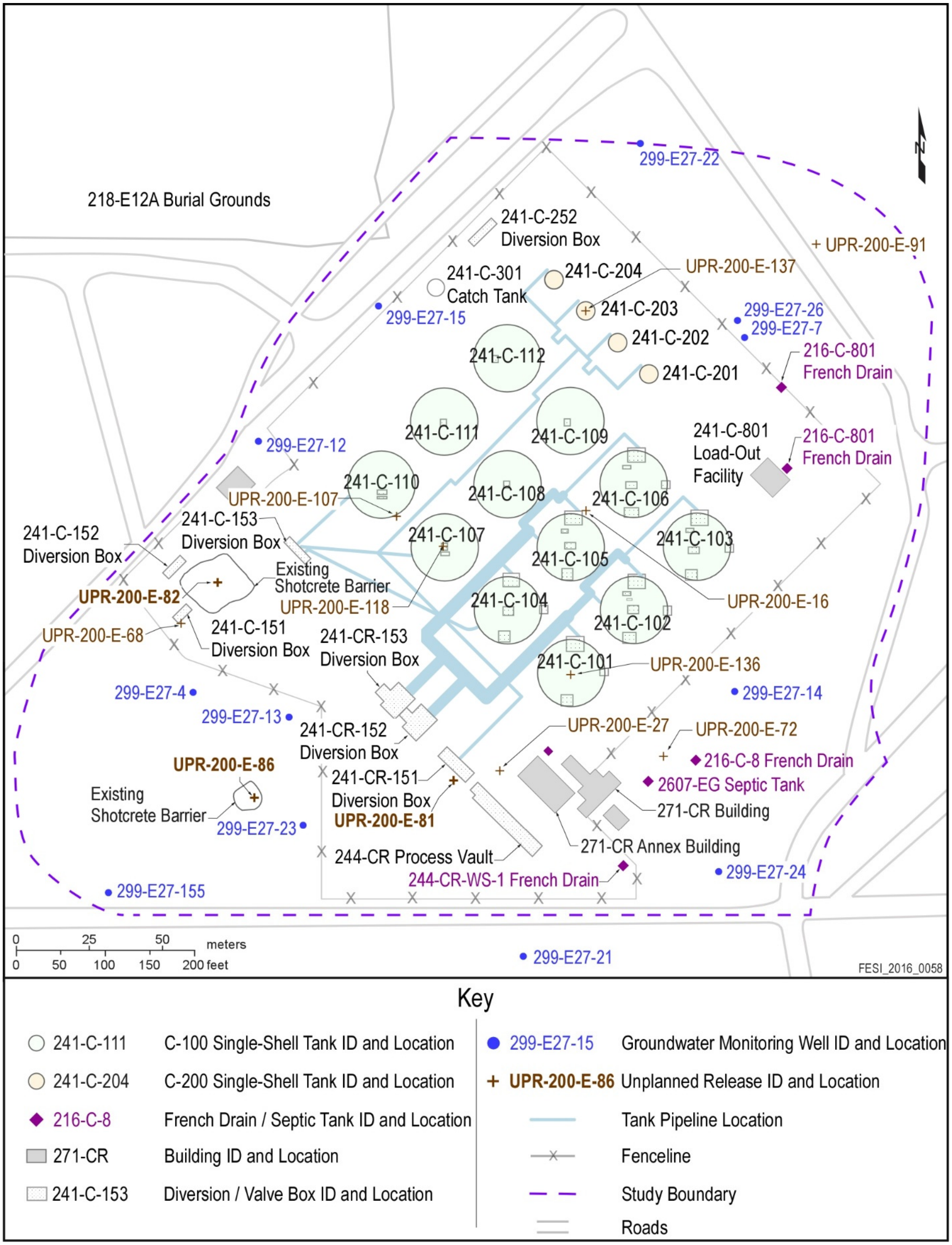


Figure 1-3. 2013 Aerial Photo of Waste Management Area C.

1.6 SUMMARY OF BACKGROUND INFORMATION

This section summarizes information provided in the Phase 2 RFI report. The Phase 2 RFI report describes and summarizes WMA C history and operations, contaminant nature and extent, contaminant fate and transport, and human health and ecological risk assessment (ERA) conditions. Per the provisions of HFFACO, Appendix I Action Plan, RFI activities can be conducted in multiple phases. Based on agreements between DOE and Ecology, the SST WMA RCRA corrective action program was divided into Phase 1 and Phase 2. The Phase 1 investigation activities were supplemented by field work that focused on specific issues, as the Phase 2 work plan was being developed. While development of this CMS focuses on the results of the Phase 2 RFI, Pre-Phase 2 RFI activities are also briefly summarized in the following subsection.

1.6.1 Summary of Waste Management Area C Investigations

Investigation activities conducted before the Phase 2 RFI are summarized in Section 4.0 of the Phase 2 RFI report. These investigation activities include the following:

- The Pre-Phase 1 investigations were performed as part of C Farm operations to address waste releases to soil, and response actions to UPRs
- The Phase 1 field investigations focused on identifying and confirming major release sites

- The Phase 1.5 near-term characterization included conducting geophysical logging in direct-push borings, installing deep electrodes to support resistivity characterization, and collecting soil samples for analysis.

The results of these investigations were used to develop the scope of Phase 2 activities. The primary objective of the Phase 2 RFI was to analyze data generated during pre-Phase 2 RFI activities, and collect additional data to be used to develop remedial alternatives in the CMS.

Phase 2 RFI investigation activities in and around the WMA C were scoped to include the following.

- Support the risk assessment by collecting direct-push soil samples for analysis from three vadose zone intervals:

    - Surface at 0 to 0.3 m (0 to 1 ft) below ground surface (bgs),
    - Shallow at 0.3 to 4.6 m (1 to 15 ft) bgs, and
    - Deep at greater than 4.6 m (15 ft) bgs to the water table.

- Collect geophysical logging data at the surface, and in borings, drywells, and groundwater monitoring wells for use in modeling ^{60}Co mobility, spectral gamma activity, and soil moisture content, and in evaluating the extent of vadose zone contamination related to releases to soil.

- Collect plant and animal tissue samples for evaluating impacts to flora and fauna.

- Interpret and evaluate soil data, and their relationship to groundwater contamination beneath WMA C.

- Develop and improve the understanding of the vadose zone contamination nature and extent, and fate and transport at WMA C.

The Phase 2 RFI activities resulted in the following.

- Based on evaluating constituents with various sorbing and mobility properties, nature and extent of soil contamination remains within the boundary of the RFI/CMS study area and exists from the surface to groundwater. Volumes and masses are provided for constituents of interest including soil and groundwater COPCs.

- Vadose zone contamination was confirmed from the ground surface to approximately 73 m (240 ft) bgs. Concentrations of 39 inorganic and radionuclide constituents were detected in excess of background concentrations applicable to the Hanford Site. The data were used to evaluate the risk of exposure to humans and ecological receptors.

- The plant and animal tissue evaluation results provide a data set too small to be useful in a risk assessment and are provided as information only.

- The nature and extent of contamination evaluation indicates evidence of widespread, shallow to relatively deep vadose zone contamination, a discontinuity between soil constituents and groundwater contamination, and a limited understanding of the relationship between sources and contaminants at WMA C.

- Unplanned releases were confirmed during the Phase 2 RFI activities. There was not sufficient data to evaluate the risk for UPR-200-E-82 (UPR-82) and UPR-200-E-86 (UPR-86) with respect to the CMS activities. The UPRs are discussed in Section 1.7 of this CMS.

1.6.2 Baseline Risk Assessment Summary

The BRA report presents the potential health impacts to human and ecological receptors from exposure to both non-radiological and radiological contaminants present in the soil at WMA C. Past operations at the Hanford Site have resulted in releases of chemicals and radionuclides to environmental media that may pose risks to human and ecological receptors. The BRA was developed in support of the Phase 2 RFI.

Soil sampling results collected from 13 judgment sampling locations (A, B, C, E, F, G, H, I, J, L1/L2, P, R, and U) were validated, evaluated and segregated into 10 exposure areas (EAs) (A+B, C, E, F+G, H+I, J, L1/L2, P, R, and U), as illustrated in Figure 1-4. Two screening steps – data reduction screen and weight of evidence – were performed to identify constituents of potential concern (COPCs) for both human health and ecological receptor at each EA.

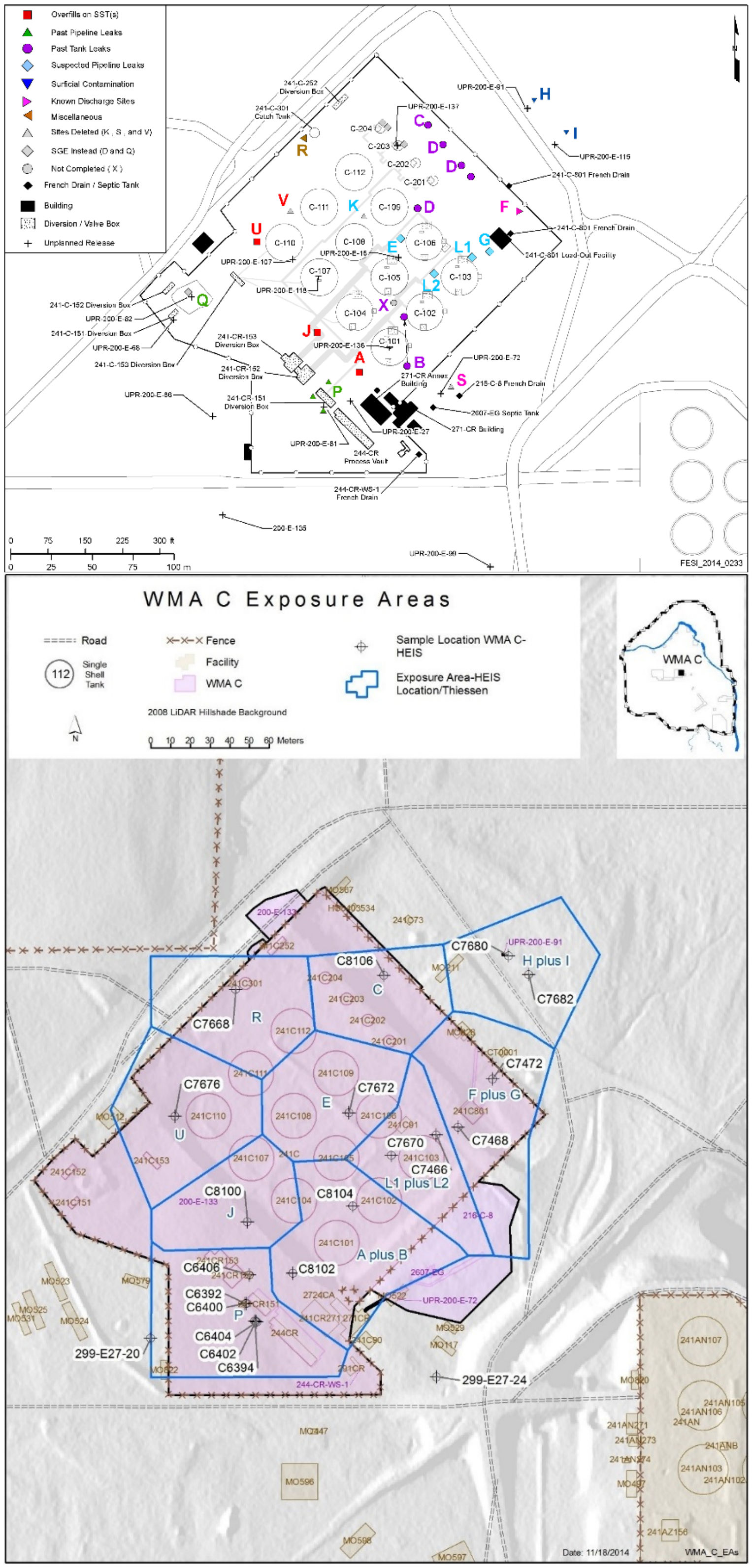
Human health risk assessment addresses potential exposures to industrial worker, construction worker, maintenance/surveillance worker, trespasser, hypothetical on-site residential receptors and two Native American residential receptors. Potential exposures to non-radiological and radiological contaminants detected in shallow vadose soils have been evaluated for various exposure pathways. The exposure point concentration (EPC) for each COPC within each EA was determined.

The EPA's Risk Assessment Guidance for Superfund and modified WAC equations were used to perform risk assessment for non-radiological COPCs. The RESidual RADioactivity computer code (version 6.5)[4] was used to perform radiological risk assessment to all receptors for contamination that is present in the soil.

The results of both non-radiological and radiological risk assessments for each EA were then compared against their corresponding acceptable risk criteria established by Federal and State regulatory agencies.

[4] The RESidual RADioactivity (RESRAD) computer code was developed by Argonne National Laboratory, Lemont, Illinois under sponsorship of DOE's Office of Environment, Safety and Health, and the Office of Environmental Management, with support from EPA and the U.S. Nuclear Regulatory Commission. Code and version control are currently maintained by DOE through Argonne National Laboratory as part of the RESRAD family of codes.

Figure 1-4. Waste Management Area C Exposure Area Map.



HEIS = Hanford Environmental Information System
SGE = Surface Geophysical Exploration
SST = single-shell tank
WM = waste management area

For the industrial worker and maintenance/surveillance worker scenarios, the total excess lifetime cancer risks (ELCRs) for five EAs (A plus B, C, E, L1 plus L2 and P) are greater than the EPA upper risk threshold of 1×10^{-4}. For the youth trespasser scenario, the total ELCRs for EAs A plus B and C are greater than the EPA upper risk threshold of 1×10^{-4}. For all three human receptors, two major risk contributors, ^{137}Cs and ^{126}Sn, are retained as radiological COPCs for further evaluation. For the residential receptor scenario, except for EA R, the total ELCRs for all EAs are greater than the EPA upper risk threshold of 1×10^{-4}. Cesium-137, ^{60}Co, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{126}Sn and ^{99}Tc were identified as major risk contributors at various EAs. No non-radiological COPCs were identified as major hazard contributors for each EA within WMA C.

A screening level ecological risk assessment (SLERA) for WMA C was prepared in accordance primarily with the framework developed using the tiered process outlined in CHPRC-00784, "Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site" and CHPRC-01311, "Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site." This SLERA used a three-tiered risk assessment approach: Generic Screening, Tier 1 Screening and Tier 2 SLERA. Due to two toxicity reference values (No-Observed-Adverse-Effect-Level and Lowest-Observed-Adverse-Effects-Level [LOAEL]) for non-radiological contaminants of potential ecological concern (COPECs), two types of screens were performed during the Tier 1 screening. Both generic screening and the Tier 1 screening were performed for radiological and non-radiological contaminants. The Tier 2 SLERA was performed using Tier 2 Screening Values for plants, soil invertebrates and wildlife to assess the potential for ecological risk resulting from exposure to non-radiological contaminants present in the soil at WMA C.

The results of the Tier 1 assessment showed that the maximum detected concentrations for cadmium within EAs E and R and hazard quotients (HQs) for vanadium and zinc within EA P are 2 to 5 times higher than corresponding soil screening levels (SSLs) based on LOAEL. That means that the HQs for cadmium within EAs E and R and HQs for vanadium and zinc within EA P are greater than 1. The results of Tier 1 screening for radiological COPECs identified a potential for ecological risk at EA P. Among all radiological COPECs, ^{90}Sr, ^{3}H and ^{137}Cs contribute more than 99% of the risk; hence, they are considered as radiological COPECs for EA P.

The results of the evaluation showed that the HQs for six COPECs (boron, molybdenum, selenium, thallium, sulfate and Bis [2-ethylhexyl] phthalate) are greater than 1. These non-radiological COPECs were considered for further evaluation as part of the scientific management decision point (SMDP) before retaining them.

An evaluation was performed during SMDP for both non-radiological and radiological COPECs identified at the completion of Tier 1 screening and Tier 2 SLERA. SMDP evaluation for Tier 1 COPECs showed that the site-wide EPCs for cadmium and zinc are less than their corresponding LOAEL-based Tier 1 screening values; hence, the resulted HQs for cadmium and zinc are less than 1. For vanadium, even though the site-wide EPC is greater than its LOAEL-based Tier 1 screening value, it is less than its background concentration. Therefore, the results of HQ and background evaluation showed that none of those non-radiological constituents are expected to

pose a potential risk to ecological resources and are therefore not proposed for retention or further ecological evaluation at WMA C for the BRA. For radiological COPECs, based on site-wide EPCs ^{90}Sr, ^{3}H and ^{137}Cs and their corresponding LOAEL-based Tier 1 screening values, the sum-of-the-fractions for all radiological COPECs at EA P is equal to 0.3. Therefore, none of those radiological COPECs were retained for further evaluation for the BRA.

SMDP evaluation for Tier 2 COPECs showed that the site-wide EPCs for six COPECs (boron, molybdenum, selenium, thallium, sulfate and Bis [2-ethylhexyl] phthalate) are less than their corresponding Tier 2 screening values; hence, resultant HQs are less than 1. Therefore, none of these chemicals are expected to pose a potential risk to ecological resources and are not proposed for retention or further ecological evaluation at the baseline level for WMA C. The BRA has determined that, following a generic Tier 1 and Tier 2 screen, none of the chemicals identified initially as COPECs are recommended for further baseline risk evaluation at WMA C.

The "protection of groundwater pathway" assessment was performed as part of the WMA C BRA to understand the potential impacts to groundwater from migration of non-radiological and radiological contaminants in contaminated soil through the vadose zone to the aquifer. The EPCs for non-radiological contaminants in the vadose zone were evaluated to their corresponding 2007 WAC 173-340-747, "Deriving Soil Concentrations for Groundwater Protection," subsection (4) "Fixed-parameter three-phase partitioning model" (hereinafter referred to as the three-phase model) cleanup levels and 90th percentile background concentration. The results of the data evaluations showed that the EPCs for three COPCs (cadmium, beta-BHC and lindane) exceeded their corresponding three-phase model concentrations and background levels at a number of EAs.

The site-wide EPC (1 mg/kg) for cadmium is below its maximum soil background concentration. Therefore, cadmium is not present at levels that could potentially impact groundwater due to migration through the vadose zone to the unconfined aquifer. For lindane and beta-BHC, a site-specific fate and transport model was developed using the software Subsurface Transport Over Multiple Phases (STOMP)©[5] to determine whether soil concentrations within WMA C will impact groundwater under WMA C above drinking water standards (DWSs). The results showed that both lindane and beta-BCH did not reach the water table within 1,000 years. However, at year 3010, lindane, which is detected about 62 m above the water table, is above the comparison value (0.08 ug/L).

The aqueous concentrations for beta-BHC, which detected around 51 m above the water table, are higher than its comparison value (0.049 ug/L). Therefore, based on the results of the STOMP© model, both lindane and beta-BHC concentrations might impact groundwater in the distant future but their measured concentrations are not elevated sufficiently to impact groundwater over the next 1,000 years.

Protection of groundwater at WMA C was also evaluated for all contaminants released from WMA C by utilizing the STOMP© three-dimensional groundwater flow and transport model

[5] Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.

documented in RPP-RPT-59197, "Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington." The model was used to determine the peak concentrations for the following radiological and non-radiological contaminants – ^{99}Tc, NO_3, ^{3}H, ^{60}Co, ^{79}Se, ^{126}Sn, ^{129}I, ^{238}U and total uranium – over a period of 10,000 years. The results were compared against their corresponding DWSs to determine whether they impacted the groundwater. The results show that the peak concentrations for ^{99}Tc and ^{129}I are greater than their corresponding DWSs. For ^{99}Tc, the peak concentrations are much higher as compared to its DWS and they will occur around 2019. However, for ^{129}I, the peak concentrations are slightly higher than its DWS and they will occur after about 6,000 years. Based on this evaluation, it is clear that groundwater under WMA C has already been impacted by past releases of ^{99}Tc and this constituent has been retained for further evaluation as a COPC.

In summary, the BRA resulted in four COPCs being retained as constituents of concern (COCs) to be addressed. These four COCs are ^{99}Tc, NO_3, ^{137}Cs, and ^{126}Sn. Cesium-137 and ^{126}Sn in soil are retained based on direct contact pathway. Technetium-99 in groundwater is retained based on the Past Leak Evaluation data (RPP-RPT-59197), and NO_3 in groundwater is retained based on the presence of NO_3 in groundwater.

1.6.3 Current and Likely Future Land Use

WMA C is located within Hanford's Central Plateau. Central Plateau land use has been designated as Industrial-Exclusive. The nearest inhabited residences are used for residential farming on land approximately 13 miles to the north and east of WMA C. The nearest City of Richland corporate boundary is approximately 13 miles southeast of WMA C. The nearest residential community is within the City of Richland, approximately 16 miles to the south-southeast.

In 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," DOE establishes land use for the Central Plateau geographic area (including WMA C) as Industrial-Exclusive. 64 FR 61615 defines "Industrial-Exclusive" as an area "suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, nonradioactive wastes, and related activities."

The Industrial-Exclusive designation allows for continued waste management operations occurring within the Central Plateau geographic area. The Tri-Parties agree to assume the Industrial-Exclusive designation for at least 50 years beyond issue of 64 FR 61615, issued in 1999, and that this land use is not anticipated to change substantially up to that point, in accordance with DOE/EIS-0222-SA-01, "Hanford Comprehensive Land-Use Plan Environmental Impact Statement Supplement Analysis."

1.6.4 Groundwater Monitoring

Groundwater beneath the Hanford Central Plateau is contaminated and is not withdrawn for beneficial uses. Groundwater in the 200 East Area is managed as part of the 200-PO-1 Groundwater Operable Unit or the 200-BP-5 Groundwater Operable Unit. WMA C overlies a portion of the 200-BP-5 Groundwater Operable Unit. Groundwater remediation activities

beneath WMA C will be addressed as part of a broader corrective action strategy developed for the 200-BP-5 Groundwater Operable Unit.

Groundwater monitoring has been conducted at the WMAs in accordance with the requirements of WAC 173-303-400, "Interim Status Facility Standards," subsection (3) "Standards" and by reference in Subpart F of Title 40, CFR, Part 265, "Interim Status Standards for Owners Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (40 CFR 265), since the early 1990s. These regulations require monitoring to determine whether dangerous waste or dangerous waste constituents from WMA C have entered groundwater. A RCRA groundwater monitoring program for WMA C was initiated in 1989 (WHC-SD-EN-AP-012, "40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks"). Since 2001, monitoring has been conducted in accordance with PNNL-13024, "RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site."

Groundwater beneath WMA C is monitored under a RCRA interim status groundwater quality assessment monitoring program. The assessment program is described in DOE/RL-2009-77, Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C.

1.6.5 Air Monitoring

Air quality data are collected at the Hanford Site. The data are used to evaluate compliance with air quality standards. These standards were developed to protect human health and the environment from airborne contaminants. Air quality monitoring results are published annually in DOE/RL-2014-52, Hanford Site Environmental Report for Calendar Year 2014. Hanford Site air quality is monitored to evaluate: 1) specific facility effluent emissions, and 2) ambient air (diffuse emissions) near facilities that have the potential to discharge, or have discharged, stored or disposed radioactive or hazardous materials. The purpose of Hanford Site air monitoring program is to protect the environment and public health via the air pathway.

Ambient air is monitored continuously for radioactive constituents around Hanford Site facilities and operations (near-field), at locations away from Site facilities, off site around the Site perimeter, and in nearby and distal communities. The near-field network of samplers is located primarily in the prevailing downwind directions of various facilities. Near-field ambient monitoring is conducted to protect workers and the environment adjacent to nuclear facilities, waste storage, treatment, and disposal sites, and remediation sites in accordance with Federal, State, and local environmental radiation protection requirements.

Airborne particulate samples are collected bi-weekly at each near-field location, field-surveyed for gross radioactivity, held for at least five days, and then analyzed for gross alpha and beta activity. The five-day holding period allows for the decay of naturally occurring short-lived radionuclides that would otherwise obscure detection of longer-lived radionuclides associated with emissions from facilities. For most isotopic radionuclide analyses, the amount of radioactive material collected on a single filter during a two-week period is too small to measure accurately. Therefore, air samples collected during the year are combined into semiannual, location-specific, composite samples to increase the accuracy of analysis. Composite samples are analyzed for radioactive isotopes, ^{90}Sr, ^{234}U, ^{235}U, ^{238}Pu, ^{238}U, and $^{239/240}$Pu.

1.6.6 Historical Tank Waste Inventories and Release Records

Historical tank waste inventories, past release records, and vadose zone characterization data have been used to estimate the amount of waste released or leaked to soil from past tank operations (RPP-RPT-42294, "Hanford Waste Management Area C Soil Contamination Inventory Estimates"). Other releases, such as pipeline leaks, also occurred, but insufficient information is available to estimate their inventories or release volumes, except for those documented in RPP-ENV-33418.

Prior characterization scopes have focused on locations where releases were known or suspected to have occurred. In some cases, inventory calculations using characterization data support the estimated release inventories, but in many locations, little or no evidence of a release was observed.

Table 1-1 summarizes information provided in RPP-ENV-33418 for known tank waste loss events that occurred in WMA C. The release volume and time frame information provides insight to when and how much waste was released. It should be noted that as of 2016, all of the releases have been in the environment in excess of 40 years and subject to migration. Release type and depth information is provided to identify the initial depth of the release and the release mechanism. A number of the tank leaks are believed to have resulted from overflows at spare inlet lines, cascade line leaks, or from the tank sidewalls. These types of releases would migrate into the soils under gravity flow conditions and would migrate primarily downward. The waste releases at UPR-81, UPR-82, and UPR-86 were the result of pressurized transfer line leaks that resulted in waste being injected into the vadose zone and migrating to the surface. These transfer line leaks resulted in an initial distribution of contamination in the shallow vadose zone and are further described in Section 1.7.

1.7 UNPLANNED RELEASES EVALUATION

The BRA utilized characterization data collected with a focus on determining the extent of migration. Maximum concentrations of non-mobile contaminants were not characterized in and around the leak zone. An evaluation of historic UPRs was conducted to supplement the information provided in the BRA for the purposes of this CMS. Using the information in Table 1-1, three target areas were identified for further evaluation because the nature of the releases are expected to result in elevated concentrations of non-mobile contaminants in the shallow vadose zone. The three target areas (UPR-81, UPR-82, and UPR-86) are described in this section.

These UPRs were caused by pressurized, subsurface pipeline leaks that resulted in contamination that rose to the ground surface. Other UPRs were typically caused by deeper releases (e.g., cascade line leaks at 6 m [20 ft] or potentially migrated below the base of the tanks) that did not cause contamination at the surface. These UPRs are discussed in RPP-ENV-33418.

Table 1-1. Summary of Waste Releases at Waste Management Area C.

Location	Release Volume/ Time Frame	Characterization Results	Release Type and Depth*
Tank 241-C-101	Up to 37,000 gallons between 1965 and 1969.	Low drywell activity (<1,000 pCi/g) at 20 ft bgs. Minimal gamma activity in slant push. Characterization does not support 37,000 gallons release of assumed waste type.	Release likely occurred from an overflow at spare inlet, cascade line, or high up on tank sidewall. Depth of release was approximately 20 feet below ground surface.
Tank 241-C-104	28,000 gallons in ~1965.	Low Cs drywell activity at ~ 20 ft bgs. Deep Co-60.	Release likely occurred from a cascade line leak. Depth of release approximately 20 feet below grade.
Tank 241-C-105	Up to 20,500 gallons between 1963 and 1968.	Clear evidence of a release with >1E8 pCi/g of Cs-137 in drywell and direct push.	Release likely occurred from multiple sources. Primary source was a cascade line leak. Depth of release between 20-40 feet below grade.
Tank 241-C-108	18,000 gallons in approximately 1965.	Low Cs drywell activity at ~ 20 ft bgs. Mostly based on deep Co-60 plume.	Release likely occurred from a cascade line leak. Depth of release approximately 20 feet below grade.
Tank 241-C-110	<2,000 gallons between 1970 and 1971.	Low drywell activity (<1,000 pCi/g) at 20 ft bgs.	Release likely occurred from a spare inlet overflow. The depth of release approximately 20 feet below grade.
Tank 241-C-112	7,000 gallons some time before 1974.	Low Cs, deep cobalt plume.	Release likely occurred from a transfer line leak. Depth of release approximately 20 feet below grade.
UPR-200-E-81	36,000 gallons in 1969.	Near surface, high chemicals and Total C.	Release occurred from a pressurized transfer line. Liquid waste migrated to the surface creating a puddle (~6 ft by 40 ft).
UPR-200-E-82	2,600 gallons in 1969.	Cs mound, near surface covered by concrete.	Release occurred from a pressurized transfer line. Liquid waste migrated to the surface. Backfill placed over leak area. A shotcrete cap placed approximately 20 years later.
UPR-200-E-86	17,000 gallons in 1971.	Near surface. Release estimate may be high based on characterization.	Release occurred from a pressurized transfer line approximately 8 feet below grade. Liquid waste migrated to the surface. A shotcrete cap installed a number of years later to cover contaminated soils.
Surfaces Releases	1,000 gallons allocation with no specific release date.	~10 pCi/g in top 2 ft of surface. Most drywell surface gamma gone at >2 ft bgs. Low waste risk.	Not tied to a specific release. Waste volume estimated assuming uniform 10 pCi/g in the top 10 ft of soil.
216-C-8	>30,000 gallons between 1960 and 1965.	Condensate release, low waste risk.	Treated process condensate sent to French drain.

*Source: RPP-ENV-33418, "Hanford C-Farm Leak Inventory Assessments Report."

Note: meters = feet/3.2808.

1.7.1 UPR-200-E-81

UPR-200-E-81 was caused by a 1961 pipeline release of Plutonium Uranium Extraction (PUREX) cladding waste, aluminum clad fuel (1961-1972) near the 151-CR diversion box (RPP-RPT-33418). The release was from a pipeline buried approximately 3 m (10 ft) bgs, but was observed to pool above the release point at the ground surface (RPP-RPT-33418).

At UPR-81, waste release volume and constituent estimates were compared with the results of direct-push logging, and soil sample collection and analysis. Calculations using the data collected indicated agreement with previously estimated waste release volumes. The UPR-81 release accounts for approximately 49% of the estimated chemical inventory of releases at WMA C. Resistivity measurements in nearby wells indicate that the release extended to approximately 9 m (30 ft) bgs. Elevated levels of gamma contamination observed through borehole logging would also indicate a likely area of elevated concentrations of the potential non-mobile RCRA COCs, which were part of the same process stream, namely chromium, nickel, NO_2, lead, and total uranium, as identified in RPP-RPT-42294. Recent data collection locations are shown in Figures 1-5, 1-6, and 1-7.

1.7.2 UPR-200-E-82

UPR-200-E-82 was caused by a subsurface pipeline leak discovered in December 1969 (ARH-1945, “B Plant Ion Exchange Feed Line Leak”), and is often referred to as the “cesium pile”. The leak was characterized by 1971. The waste released was PUREX high-level waste supernate with an ion exchange feed concentration of 4.3 Ci/gal of ^{137}Cs at the release time (RPP-ENV-33418). Several years after the release, the area was covered by a shotcrete cover to shield radioactivity exposure.

The results of Phases 1 and 2 direct-push logging and sample analysis data show elevated gamma activity and slightly elevated nitrate and ^{99}Tc concentrations in the soil. Elevated gamma levels observed through borehole logging would also indicate a likely area of elevated concentrations of the non-mobile RCRA COCs. Based on characterization results, a release of approximately 9,850 L (2,600 gal) of PUREX high-level waste supernate was estimated. Higher gamma activity was anticipated in the direct-push borings surrounding the shotcrete cover. Elevated levels of gamma contamination observed through borehole logging would also indicate a likely area of elevated concentrations of the potential non-mobile RCRA COCs, which were part of the same process stream, namely chromium, nickel, NO_2, lead, and total uranium, as identified in RPP-RPT-42294.

However, higher gamma activity may occur directly underneath the cover. Based on the results of subsurface investigation activities, the majority of the ^{137}Cs waste appears to reside between 0.6 and 6 m (2 and 20 ft) bgs. Nitrate and ^{99}Tc were detected to 24 m (80 ft) bgs. The extent of contamination from this release is defined through data collected from direct-push soil samples surrounding the shotcrete cover.

Figure 1-5. Characterization Locations at UPR-200-E-81.

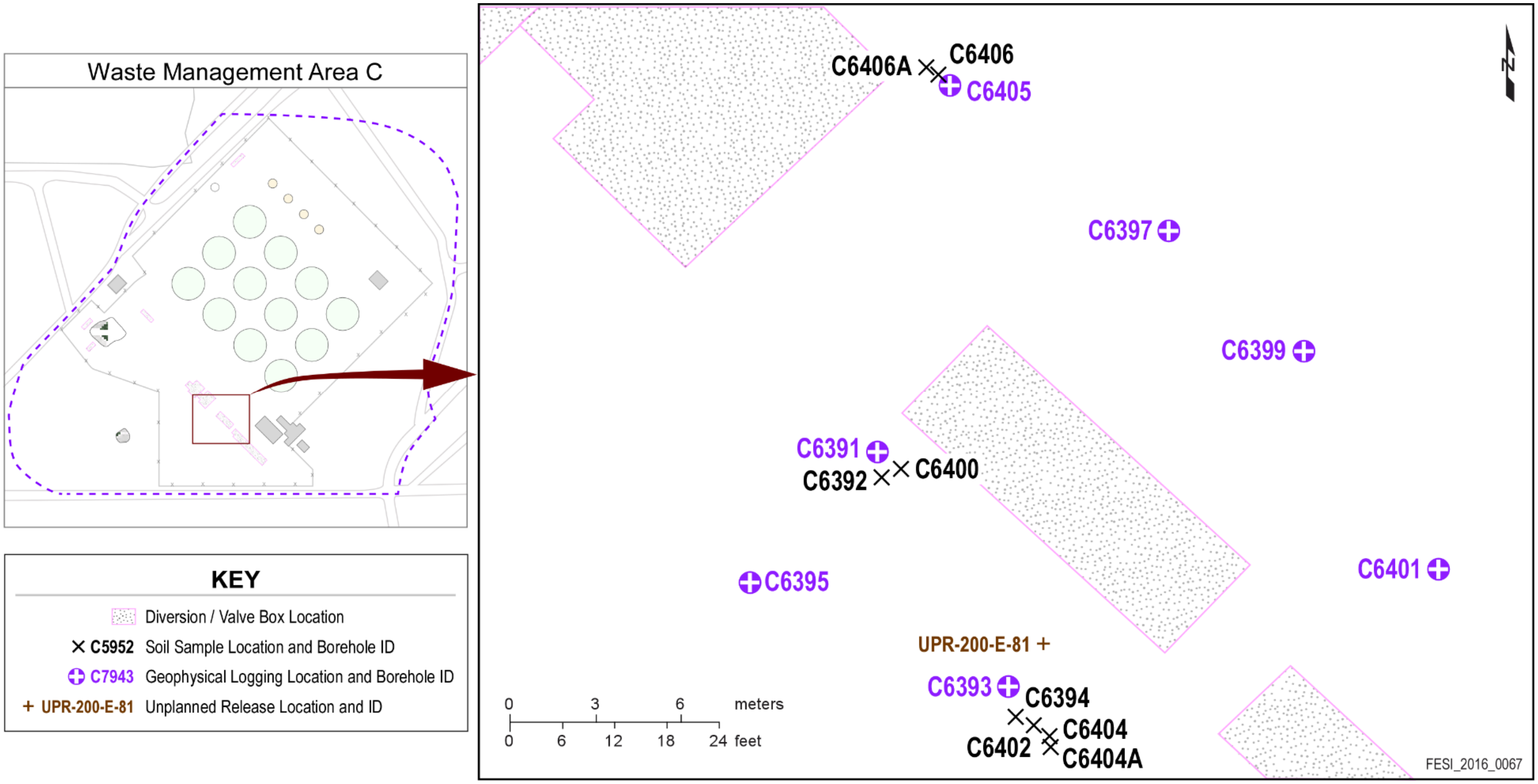


Figure 1-6. Characterization Locations at UPR-200-E-82.

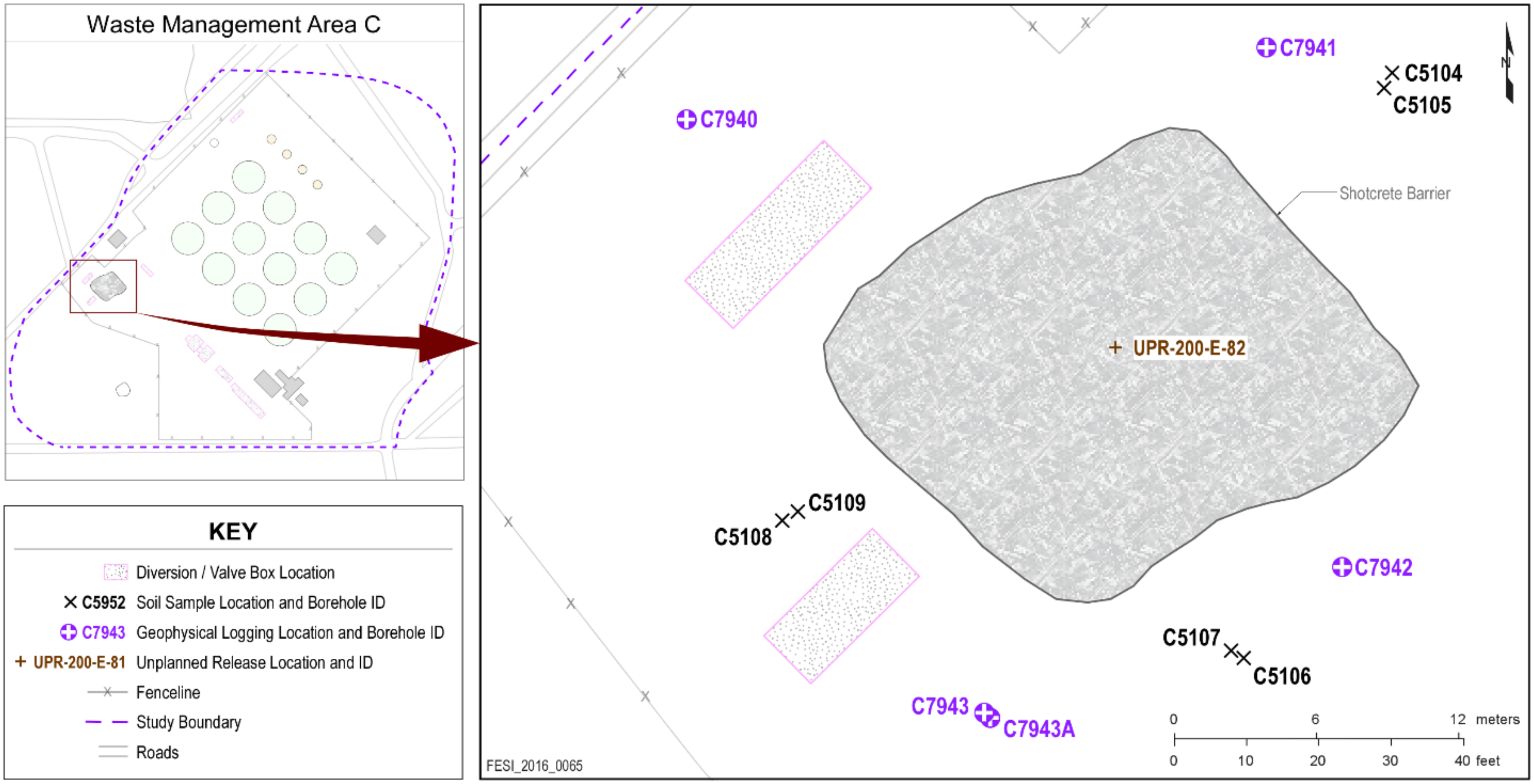
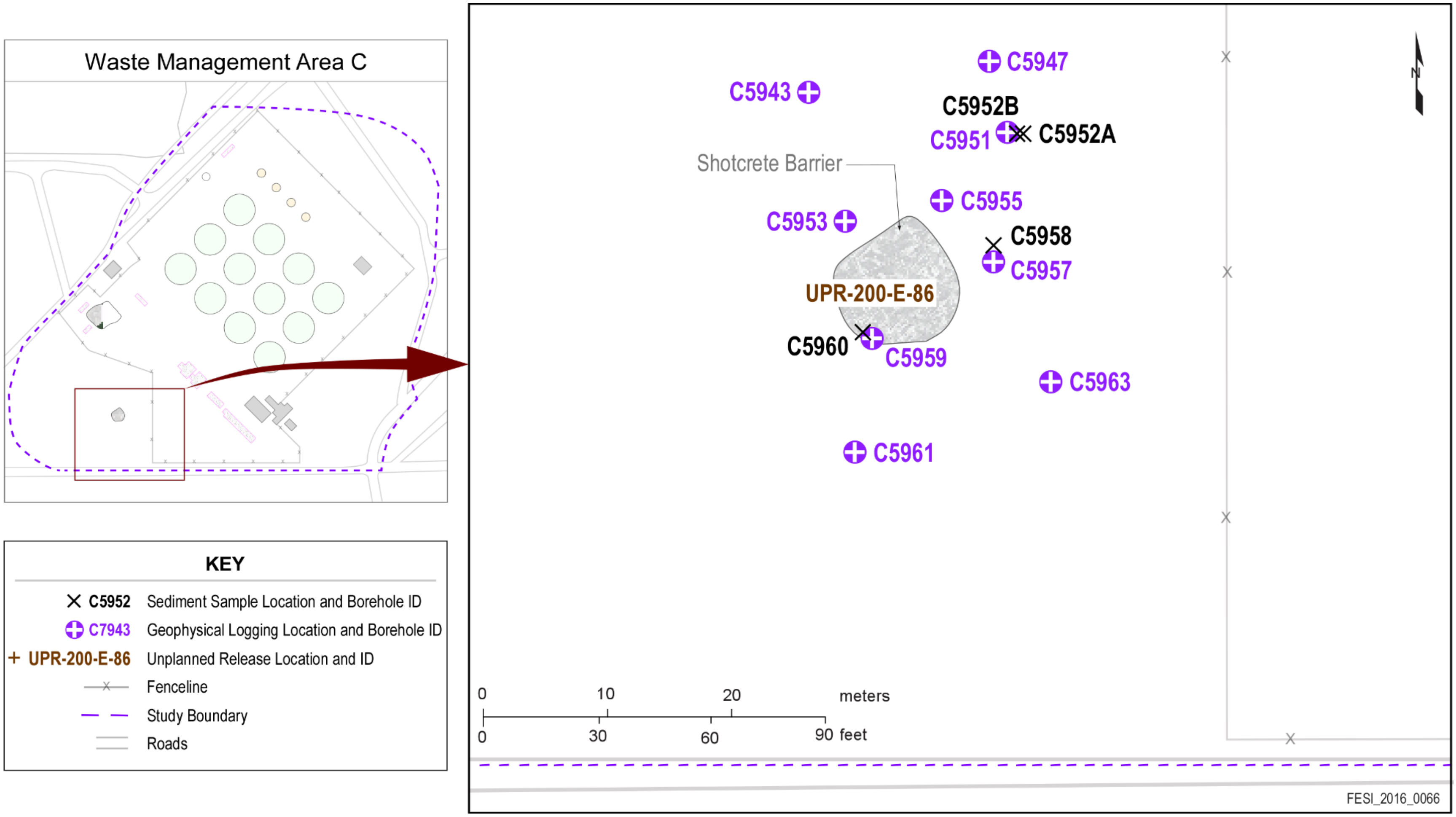


Figure 1-7. Characterization Locations at UPR-200-E-86.



1.7.3 UPR-200-E-86

UPR-200-E-86 was caused by a 1971 pipeline release of PUREX sludge supernate waste identified in soil from 2.4 to 6 m (8 to 20 ft) bgs. Supernate analysis indicated ^{137}Cs at an estimated concentration of 1.35 Ci/gal (RPP-RPT-33418). The release volume was estimated at approximately 17,000 gal. A contamination zone was estimated at approximately 1,300 cubic feet (ft^3). Eventually, a shotcrete cover was placed over the release area.

During Phase 1 and Phase 2 investigations, direct-push borings were advanced around the shotcrete cover to facilitate radioactivity logging. The results yielded relatively low radioactivity data that were used to re-estimate a substantially smaller release volume. However, the investigation data may indicate the bulk of the contamination remains directly beneath the shotcrete cover. Elevated levels of gamma contamination observed through borehole logging would also indicate a likely area of elevated concentrations of the potential non-mobile RCRA COCs, which were part of the same process stream, namely chromium, nickel, NO_2, lead, and total uranium, as identified in RPP-RPT-42294.

1.7.4 Unplanned Release Risk Assessment

A BRA (RPP-RPT-58329) was performed to determine the potential health impacts to human and ecological receptors from exposure to both non-radiological and radiological contaminants present in the soil at WMA C and considered six separate exposure scenarios. The results of the radiological BRA showed that the total ELCRs for five EAs (A plus B, C, E, L1 plus L2, and P) are greater than the EPA upper risk threshold of 1×10^{-4} for the industrial worker receptor and the maintenance/surveillance worker receptor. The results showed that the external gamma pathway is the predominant exposure pathway for contaminated soils associated with the WMA C EAs. Therefore, several remedial alternatives such as isolation barriers and/or infiltration barriers are being considered to minimize the risk associated with the external gamma pathway in support of this CMS.

1.7.4.1 Supplemental Human Health Risk Assessment for Waste Management Area C Exposure Areas. To support the CMS alternatives evaluation process, a radiological risk assessment, RPP-CALC-61057, "Radiological Risk Assessments for Exposure Areas Covered with Isolation Barrier and Nonradiological Risk Assessment for Three Unplanned Releases under Industrial Worker Scenario" was performed for the CERCLA industrial worker scenario to determine the risk reduction provided by placement of an isolation barrier over select locations within WMA C. The results of the assessment showed that the total cumulative ELCR assuming post-remediation conditions (i.e., a 4-in. isolation barrier is in place) for each EA evaluated is within or less than EPA's acceptable target risk range of 10^{-4} to 10^{-6}. A 4-in. isolation barrier is used to evaluate risk reduction while the CMS isolation barrier alternative includes a nominal 6-in. thick barrier for constructability reasons. Note: an isolation barrier is included in the CMS evaluation for a portion of WMA C and not the entire WMA.

1.7.4.2 Supplemental Human Health Risk Assessment for Waste Management Area C Unplanned Releases. Due to very high levels of radiological contamination, soil samples were not collected during WMA C Phase 2 characterization activities at three UPR locations within

WMA C: 200-E-81 (UPR-81), 200-E-82 (UPR-82), and 200-E-86 (UPR-86). Therefore, risk assessments of these UPRs were not performed as part of the BRA. Subsequent to issuance of the BRA, supplemental human health risk assessments were performed to determine the potential impacts from exposure to both non-radiological and radiological contaminants present in the soil at the three UPR locations.

A human health radiological risk assessment was performed under baseline conditions (assuming no soil cover) for a CERCLA industrial worker exposure scenario. To support the CMS alternatives evaluation process, the reduction in human health risk following placement of a 3-ft thick concrete isolation barrier was also assessed. The radiological risk assessment was performed under post-remediation conditions for a CERCLA industrial worker exposure scenario to determine the impacts of the isolation barrier to the total risk at the three UPRs. The radiological risk assessments used source term concentrations based on inventory information obtained from RPP-ENV-33418. The derivation of the source term concentrations associated with the three UPRs is documented in RPP-CALC-61238, "Radiological Risk Assessments for Three Unplanned Releases Within Waste Management Area C." The results of both baseline and post-remedial action radiological risk assessments are also presented in RPP-CALC-61238. The results of the radiological risk assessment under baseline conditions showed that the total cumulative ELCRs for UPR-81, UPR-82 and UPR-86 (1×10^0, 2×10^2 and 8×10^1, respectively) are well above the EPA's acceptable target risk range of 10^{-4} to 10^{-6}. The risk assessment results under post-remediation conditions showed that the total cumulative ELCRs for the three UPRs (9×10^{-9}, 2×10^{-6}, and 6×10^{-7}, respectively) are within or less than EPA's acceptable target risk range of 10^{-4} to 10^{-6}.

Non-radiological human health risk assessments were performed for the three UPRs under two receptor scenarios: (1) CERCLA industrial worker scenario; and (2) an adult industrial worker receptor scenario, as defined in WAC 173-340 Method C. The results of both risk assessments are presented in RPP-CALC-61057. For carcinogenic COPCs, the total ELCRs for the three UPRs were less than the EPA's acceptable target risk range of 10^{-4} to 10^{-6} and 2007 MTCA (WAC 173-340-708, "Human Health Risk Assessment Procedures," subsection (5) "Multiple hazardous substances") cumulative risk threshold of 1×10^{-5}. Therefore, non-radiological risk contributors were not identified. For noncarcinogenic COPCs, the hazard index for all UPRs was less than the 2007 MTCA (WAC 173-340-708(5)]) target hazard index of 1. Therefore, non-radiological non-cancer hazard contributors were not identified.

1.7.4.3 Supplemental Ecological Risk Assessment for Waste Management Area C Unplanned Releases and Surface Releases. An ERA was performed for both radiological and non-radiological contaminants present in three UPR locations (UPR-81, UPR-82, and UPR-86), surface releases within the WMA C and the 216-C-8 French drain. Since the biologically active zone for ecological receptors at the Hanford Site is around 10 ft, no ERA was performed for six past tank leak locations where the contamination is located at least 20 ft bgs. As a part of the ERA, an HQ was calculated by comparing the estimated concentrations of contaminants (radiological, non-radiological) against their corresponding SSL for ecological receptors. This is done to identify contaminants that clearly pose no potential for ecological risk and require no further evaluation versus those constituents for which additional evaluation may be warranted.

In addition, a Sum-of-the-Fraction evaluation is performed to determinate the cumulative impact of all radiological contaminants. The results of the ERA are presented in RPP-CALC-61128, "Ecological Risk Assessment for UPRs."

For non-radiological contaminants, the HQ for nickel (1.1) is slightly higher than 1 at UPR-81. The HQ values were less than 1 for all non-radiological constituents at UPR-82 and UPR-86. It should be noted that the SSL used for nickel is based on a Tier 2 preliminary remediation goal for vegetation. For soil invertebrates and wildlife, the estimated soil concentration of nickel at UPR-81 is less than their respective (and unrefined) Tier 2 SSLs of 280 mg/kg and 247 mg/kg. Therefore, the HQs for nickel estimated for soil invertebrates and wildlife do not indicate a potential for risk for these receptors at UPR-81.

Among radiological contaminants, the Sum-of-the-Fractions for the three UPRs and 216-C-8 French drain are greater than 1. Americium-241, ^{14}C, ^{137}Cs and ^{90}Sr are identified as major dose-contributor radiological contaminants. It should be noted that the SSLs for all dose-contributor radiological contaminants are derived based on the most sensitive wildlife receptor (a badger) and incorporate an underlying assumption that the area use factor (AUF) for any given site is 100%. The home range for a badger is considerable at 160 hectares. Considering the three UPRs and the 216-C-8 French drain, the largest area of site contamination is only 0.031 hectares (UPR-82). Accordingly, the fractional AUF for UPR-82 is 0.0002 (not 1, which was assumed in the development of the Tier 1 SSLs). Practically, this means that a badger will utilize only a small fraction of the site, assuming that the habitat is suitable for feeding and other activities that result in exposure to contaminants at UPR-82. By utilizing the AUF, unacceptable risk was identified at UPR-82 and UPR-86 for the radiological contaminants ^{137}Cs and ^{90}Sr.

It should be noted that the areas within WMA C and surrounding areas have physical features including buildings, parking lots, paved areas, and maintained landscaping that significantly reduce potential exposure to soil. In addition, WMA C has not been and is not currently managed for ecological purposes (buildings, pavement, use of herbicides to control vegetation). There have been no onsite improvements in the interim which could create a suitable habitat for ecological receptors. As a result, no ecological habitats are known to be associated with the current and future land use for WMA C. Since the soil-based exposure pathways and ecological habitats are largely absent, ecological receptors are not expected to be present and their potential risk is expected to be low. Of note, several remedial alternatives such as isolation barriers and/or infiltration barriers are being considered in support of this CMS. In summary, the analysis does not identify any ecological receptors at risk at the three UPRs and surface releases in WMA C.

1.7.4.4 Supplemental Human Health Risk Assessment for Waste Management Area C Past Tank Leaks, Surface Releases, and 216-C-8 French Drain. The "protection of groundwater pathway" assessment was performed as part of the WMA C BRA to understand the potential impacts to groundwater from past leaks originating from six SSTs (241-C-101, 241-C-104, 241-C-105, 241-C-108, 241-C-110, and 241-C-112). As mentioned earlier, those leaks were estimated to have occurred at least 20 ft bgs. Hence, no risk assessment as a part of the direct contact pathway was performed in the BRA. In addition, no risk assessment was performed in the BRA for the soil contamination associated with past discharges to the

216-C-8 French drain and the WMA C surface contamination. A supplemental human health risk assessment was performed for the WMA C past tank leaks, surface releases, and 216-C-8 French drain and the methodologies and results for those assessments are presented in RPP-CALC-61239, "Radiological Risk Assessments for Past Leaks and Surface Contamination within Waste Management Area C." The supplemental risk assessment was performed using soil contaminant concentrations that were derived using process knowledge rather than sampling and analysis results. Those are summarized below.

Human health radiological risk assessments were performed for past leaks from six tanks under baseline conditions (assuming no cover) and existing conditions (20 ft of soil cover). Under baseline conditions, a construction worker exposure scenario, which takes no credit for existing soil cover, was considered during the assessment. Under existing conditions, risks are estimated assuming a CERCLA industrial worker exposure scenario with an additional assumption of a 6.1-m (20-ft) soil cover, which represents the conceptual exposure model of the current conditions for the soil contamination associated with the past leaks.

The results of radiological risk assessment for the construction worker scenario under baseline conditions showed that the total cumulative ELCR for all past leaks are greater than EPA's acceptable target risk range of 10^{-4} to 10^{-6}. The results of radiological risk assessment for CERCLA industrial worker scenario under existing conditions showed that the total cumulative ELCR for all past leaks is less than EPA's acceptable target risk range of 10^{-4} to 10^{-6}.

Similar to the three UPRs, human health radiological risk assessments were performed for 216-C-8 French drain and WMA C surface contamination under baseline conditions (assuming no cover) and the 216-C-8 French drain was also evaluated under post-remediation conditions (4 inches of concrete cover). For both conditions, a CERCLA industrial worker exposure scenario was considered during the assessment.

The results of radiological risk assessment under baseline conditions showed that the total cumulative ELCR for the 216-C-8 French drain is greater than EPA's acceptable target risk range of 10^{-4} to 10^{-6}. However, the assessment results following placement of an isolation barrier under post-remediation conditions showed that the total cumulative ELCR is less than EPA's acceptable target risk range.

1.8 CONCEPTUAL SITE MODEL

The conceptual corrective action model establishes a framework for evaluating corrective measures within the context of the 200-BP-5 Groundwater Operable Unit cleanup activities and related facility closure actions per 78 FR 75913, "Record of Decision: Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington" (EIS ROD).

This model is based on current site conditions at WMA C, which have not changed since completion of the Phase 2 RFI, and elements described in other documents (e.g., Phase 2 RFI report, BRA, Phase 2 RFI work plan). The conceptual corrective action model is based on the

following general, conceptual understanding of soil contamination at WMA C, as shown in Figure 1-8.

- **Historical Releases:** Historical operations have led to UPRs of tank and pipeline waste to subsurface soil. The earliest documented releases may have occurred in the 1950s. Mobile portions of these releases have been migrating downward to groundwater for approximately 50 years.

- **Surface Vadose Zone Soil:** In accordance with the BRA, surface soil is defined as 0 to 1 m (0 to 3 ft) of depth.

- **Shallow Vadose Zone Soil:** In accordance with the BRA, shallow soil is defined as 0 to 4.3 m (0 to 15 ft) of depth.

- **Deep Vadose Zone Soil:** In accordance with the BRA, deep soil is defined as deeper than 4.3 m (15 ft) to groundwater.

- **Pipeline Releases:** Pressurized, buried pipeline releases originated approximately 2.4 m (8 ft) bgs and migrated vertically, becoming the UPR sites UPR-81, UPR-82, and UPR-86.

- **Unplanned Releases:** Shallow soil contamination from a variety of tank waste sources is widely distributed, but associated contaminant inventories are relatively minor, with the exception of inventories associated with UPR-81, UPR-82, and UPR-86.

- **Deeper Releases:** Releases associated with cascade lines and tank inlets originated approximately 6 m (20 ft) bgs, primarily moving vertically downward, deeper into the vadose zone.

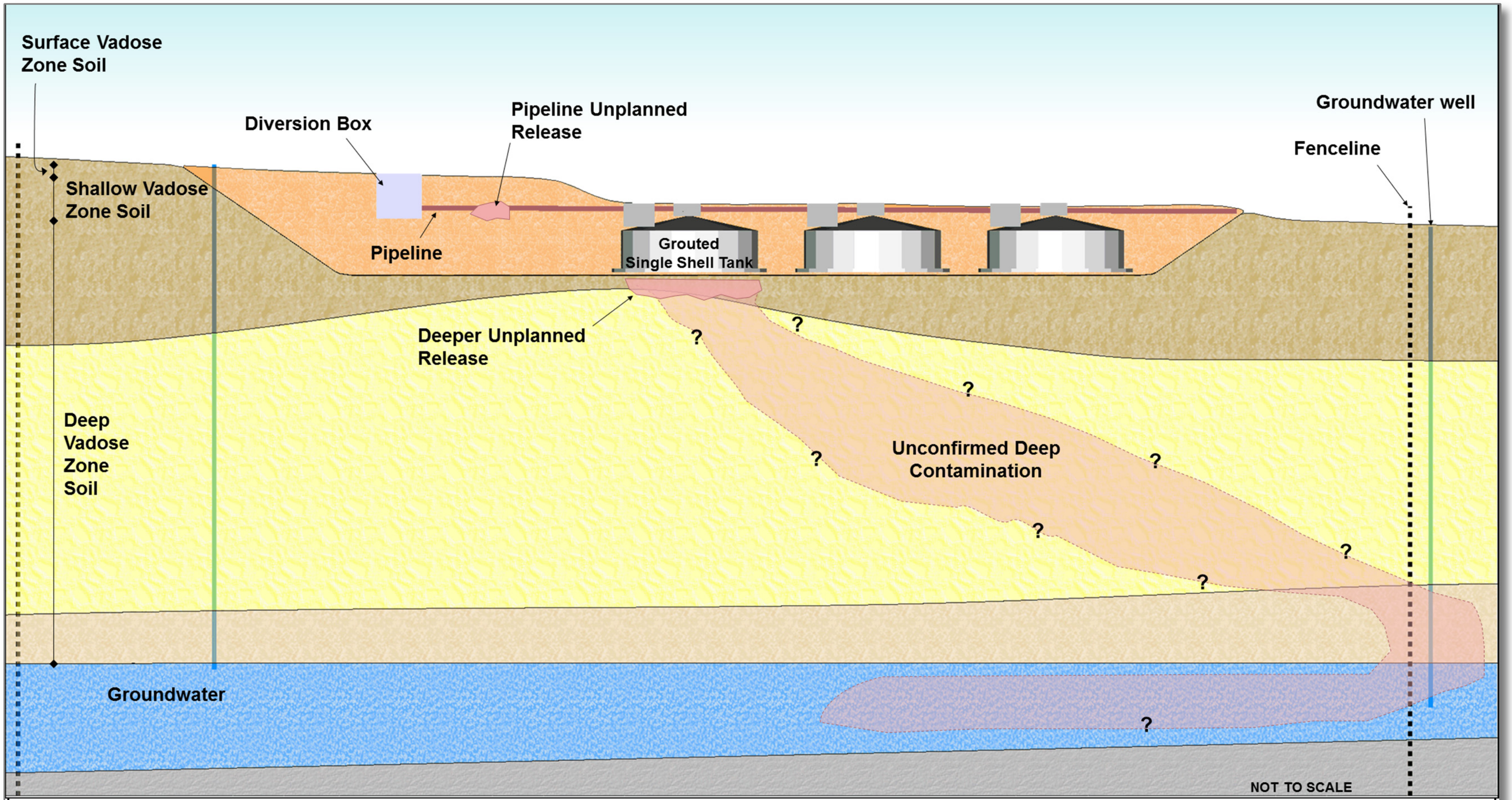
- **Contaminant Mobility:** In C Farm, contaminant mobility is generally greater vertically than laterally. Mobility varies depending on geologic material and inventories released. Mobile contaminants likely are distributed throughout the vadose zone.

- **Unconfirmed Deep Contamination:** The locations and depths of contamination inventories are not well defined in deeper portions of the vadose zone. These inventories may be discerned based on influences of different constituent mobility rates, heterogenic soil conditions and their hydraulic properties, and recharge.

- **Recharge Effects:** Contaminant mobilization deeper into the vadose zone is driven by precipitation recharge, with minimal constituent interaction with the soil. Locally, precipitation over the tanks' tops is directed laterally to the tanks' perimeters, causing enhanced recharge as a "shadow effect" around the tanks.

- **Contaminant Reactivity with Soil:** Contaminant migration has been observed for nonreactive to slightly reactive constituents.

Figure 1-8. Waste Management Area C Conceptual Site Model.



- **Contaminant Concentrations Exceed Risk Thresholds:** Concentrations of the immobile contaminants (i.e., ^{137}Cs and ^{126}Sn) in the shallow vadose zone exceed risk thresholds for industrial exposure scenarios at discreet locations (Phase 2 RFI report). Direct-contact risk values at UPR-81, UPR-82, and UPR-86 are estimated to exceed risk threshold values by 3 to 7 orders of magnitude for radiological contaminants. Based on inventory estimates for past leaks the non-radiological risks and hazards are also anticipated to exceed threshold values for these UPRs.

- **Vertical Migration Rates:** Under natural recharge conditions to the Hanford formation, ^{60}Co vertical migration rates of 0.3 to 1 m (1 to 3 ft) per year have been observed near WMA C and WMA B-BX-BY (RPP-8321, "Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area").

Unplanned release areas at WMA C are shown relative to the tanks and subsurface structures in Figure 1-2.

1.9 REPORT ORGANIZATION

This CMS report is organized into the sections listed in Table 1-2. Data and information in the appendices are pertinent to supporting the conclusions presented in this CMS report. Supporting information is included in the appendices, as listed in Table 1-3.

Table 1-2. Report Organization.

Section	Title	Description
1.0	Introduction and Background	Introduces general information that can be used to develop a basic understanding of Waste Management Area (WMA) C and the corrective measures study (CMS) report.
2.0	Technology Identification and Screening	Collects, describes, and screens remedial technologies readily available and anticipated to be suitable at WMA C.
3.0	Alternatives Development	Discusses the development of individual alternatives based on MTCA threshold, RCRA corrective action and CERCLA criteria.
4.0	Evaluation of Corrective Measures Alternatives	Evaluates the individual alternatives and compares the alternatives with each other to down-select a preferred alternative that complies with MTCA remedial and RCRA corrective action criteria.
5.0	Preferred Alternative	Identifies the preferred alternative and the rationale for the recommended alternative.
6.0	References	Lists the references cited and used to develop the CMS report.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9622, et seq.
MTCA = Model Toxics Control Act (RCW 70.105D, "Hazardous Waste Cleanup—Model Toxics Control Act," Revised Code of Washington, as amended.)
RCRA = Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

Table 1-3. Appendices Organization.

Section	Title	Description
A	HFFACO Milestone Change Number M-45-14-03	Modifies Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-045-61 into two milestones which separate generation of the Phase 2 Resource Conservation and Recovery Act of 1976 (RCRA) Facility Investigation report from the Phase 2 Corrective Measures Study report.
B	Ecological and Human Health Risk Assessment Calculations	The equations in this appendix were used to calculate the risks associated with identified radiological and non-radiological constituents of concern.
C	Technologies Identification and Screening	Provides details on the technology identification and screening process used to retain candidate technologies used to develop remedial alternatives.
D	Potential Federal and State Applicable or Relevant and Appropriate Requirements	Identifies chemical-, site-, and location-specific applicable or relevant and appropriate regulations for the remedial alternatives.
E	Detailed Cost Estimate	Cost information for the individual alternatives.

2.0 TECHNOLOGY IDENTIFICATION AND SCREENING

Corrective measures alternatives were developed using technologies that were judged effective for application at WMA C. The first step in corrective measures alternatives development was to identify the CAOs to be addressed by the corrective measures alternatives. A description of the CAOs is contained in Section 2.1.

Next, the COCs identified through the risk assessment processes described in Sections 1.6 and 1.7, which the selected corrective measures alternative will address, were reviewed. Soil concentrations for these COCs were evaluated against exposure action levels; and contaminants that have the potential to affect the groundwater were also evaluated.

The technologies were grouped into several categories called general response actions (GRAs). A description of GRAs is contained in Section 2.2.

Technologies to address the COCs were identified through a research and review process. Information was collected regarding soil remediation technologies for potential application at WMA C. Information resources included:

- CMS team direct experience;
- Result of searches for relatively new and innovative technologies;
- Information derived from websites such as the EPA's Hazardous Waste Clean-Up Information site, the Deep Vadose Zone Technologies Public Information Exchange Summary, and the Interstate Technology & Regulatory Council site;
- Regulatory guidance;
- Technical maturity reports;
- Performance reviews for analogous sites;
- Cost estimating guides;
- Case studies; and
- Interviews with other professionals.

Over 70 technologies were evaluated. Eight technologies were retained after the pre-screening. These technologies were further evaluated for effectiveness, implementability, and relative cost. The technology screening process is described in Section 2.3. Process options are the application of the retained technologies in the corrective measures alternatives. The process options are described in Section 2.4.

2.1 CORRECTIVE ACTION OBJECTIVES

RCRA guidance [OSWER Directive 9902.3-2A, "RCRA Corrective Action Plan (Final)"] for the development of CAOs suggests that corrective measures attain a degree of corrective action that protects human health and the environment; are cost effective; and use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. The CAOs for this CMS were developed to satisfy these requirements.

Corrective action objectives are site-specific, media-specific, and location-specific goals for protecting human health and the environment, including groundwater, and are based on the evaluation of relevant exposure routes and receptors aligned with current and foreseeable land-use planning. Corrective action objectives are based on the nature and extent of contamination identified at WMA C as analyzed in the Phase 2 RFI report, and as identified in documented past release reports.

Designed to protect human health and the environment, CAOs are based on occupational (site worker), public health, and environmental exposure criteria; information gathered during assessment and characterization; applicable guidance; and applicable State and Federal regulations. The CAOs are the basis for defining the alternatives in this CMS.

The current contamination distribution and migration, and the exposure risks, must be considered when developing CAOs. The CAOs developed for WMA C consist of the following.

1. Protection of human health and the environment. Included in this are the following:

    a. Protect site workers from doses greater than 2 rem/yr total effective dose equivalent (TEDE) from each exposure pathway (DOE-STD-1098-2008, DOE Standard Radiological Control)

    b. Protect the public from doses greater than 25 mrem/yr TEDE from each exposure pathway (DOE O 435.1 Change 1)

    c. Protect the public from doses greater than 10 mrem/yr TEDE, via the air exposure pathway (DOE O 435.1 Change 1)

    d. Maintain the radon emission rate to ambient air dose at less than 20 pCi/square meters/second (DOE O 458.1, Radiation Protection of the Public and the Environment, Change 3)

    e. Limit the dose to wildlife at less than 0.1 rad/day from each exposure pathway (DOE O 458.1, Change 3).

2. Minimize biological intrusion into buried waste and resulting release, and redistribution of contaminants to potential receptors.

3. Prevent or limit human intrusion into buried waste over the long term.

4. Limit migration of contaminants to groundwater such that regulatory applicable limits are not exceeded.

After establishing CAOs, ARARs are reviewed to determine which may apply to a site during corrective measures implementation. A preliminary identification of potential ARARs and to-be-considered (TBC) information in the scoping phase can assist in initially identifying alternatives and is useful for initiating communications with the support agency to facilitate ARARs identification. Furthermore, early identification of potential ARARs will support better planning of site activities. Because of the iterative nature of the RFI/CMS process, ARAR identification continues throughout the CMS, as a better understanding is gained of site conditions and remedial action alternatives. ARARs may be categorized as follows:

- Chemical-specific requirements that may define acceptable exposure levels

- Location-specific requirements that may set restrictions on activities within specific locations such as floodplains or wetlands

- Action-specific requirements that may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous wastes.

EPA/540/G-89/006, CERCLA Compliance with Other Laws Manual: Interim Final, contains detailed information on identifying and complying with ARARs. Appendix D lists and discusses ARARs and TBCs for consideration for WMA C.

2.2 GENERAL RESPONSE ACTIONS

General response actions represent broad categories of actions, which include a range of implementation strategies and technologies. The most appropriate GRAs applicable to a specific CMS are developed after CAOs have been identified. After CAOs are identified, GRAs are selected to satisfy the CAOs. Each GRA consists of technologies and process options. The GRAs for WMA C soil are listed as follows:

- No action,
- Institutional controls,
- Containment,
- Removal and disposal,
- Removal, treatment, and disposal.

Under the “no action” response, the site would be left “as is.” No further actions would be taken, including restriction of access to WMA C.

Institutional controls involve the implementation of legal, administrative, and/or informational devices, and structures such as fencing, to minimize public and environmental contact with the soil contaminants.

2.2.1 Containment Actions

Containment can involve physically restricting direct-contact exposure to soil contamination. It can also involve isolating the contaminated soil from natural processes (e.g., water infiltration) to minimize the migration of contaminants.

Soil containment technologies are used to isolate contaminated material from access and/or intrusion, or effectively reduce contaminant mobility and the potential for exposure to human and ecological receptors. Containment actions generally do not reduce contaminant volume or toxicity. Containment technologies, such as surface and subsurface barriers, are designed to prevent vertical and/or horizontal migration. Combining multiple containment technologies can prevent contaminant migration in any direction in the subsurface. Containment technologies are viable options for the WMA C vadose zone.

2.2.2 Treatment Actions

Treatment involves on-site and/or off-site measures to change the physical or chemical characteristics of the soil to render the contaminated soil less hazardous. Remedial technologies were evaluated based on their ability to treat WMA C soil contaminants to the extent that exposure risks are reduced for humans and ecological receptors. Both in situ and ex situ soil treatment technologies were considered.

In situ soil treatment technologies are used to treat soil in place and may be implemented from the surface to depth. These typically involve applying an amendment that will alter the physical or chemical properties of the soil, reducing contaminant toxicity or mobility. Delivery of an amendment often requires combining several different technologies. For example, delivery of a phosphate amendment in the deep vadose zone may require installation of a vertical injection well, and amendment sorption time be enhanced by using sheer thinning fluid as a carrier.

Ex situ soil treatment technologies are used to treat removed soil, altering the properties of soil and/or contaminants. For example, contaminants can be bound to reduce their mobility and/or toxicity, reducing the potential for exposure, and/or contaminants can be separated from soil to reduce overall waste volumes. Ex situ soil treatment technologies can be applied locally or at a receiving landfill or final disposition facility. Ex situ soil treatment technologies may also be applied to soil that can be rendered harmless through treatment and put back in place.

2.2.3 Removal (Soil) Actions

Removal actions (in this context) involve the direct physical removal of contaminated soil for subsequent treatment and disposal. Soil removal actions can include conventional and remote excavation techniques and often are followed by, or integrated as part of, a larger corrective action.

Removal reduces the volume of waste in the soil, but carries an increased risk of exposure to contamination for site workers. The removal action used as a particular corrective action would depend on factors, such as:

- Time of contaminant release,
- The type and amount of contamination released,
- The nature, volume, and extent of contaminated media,
- The physical setting in which the release occurred, and/or
- The type, number, and proximity of potentially affected human and ecological receptors.

Excavation provides the potential for reduction of toxicity, mobility and volume of COCs. Excavation effectiveness will depend on locating the COCs.

2.2.4 Disposal Actions

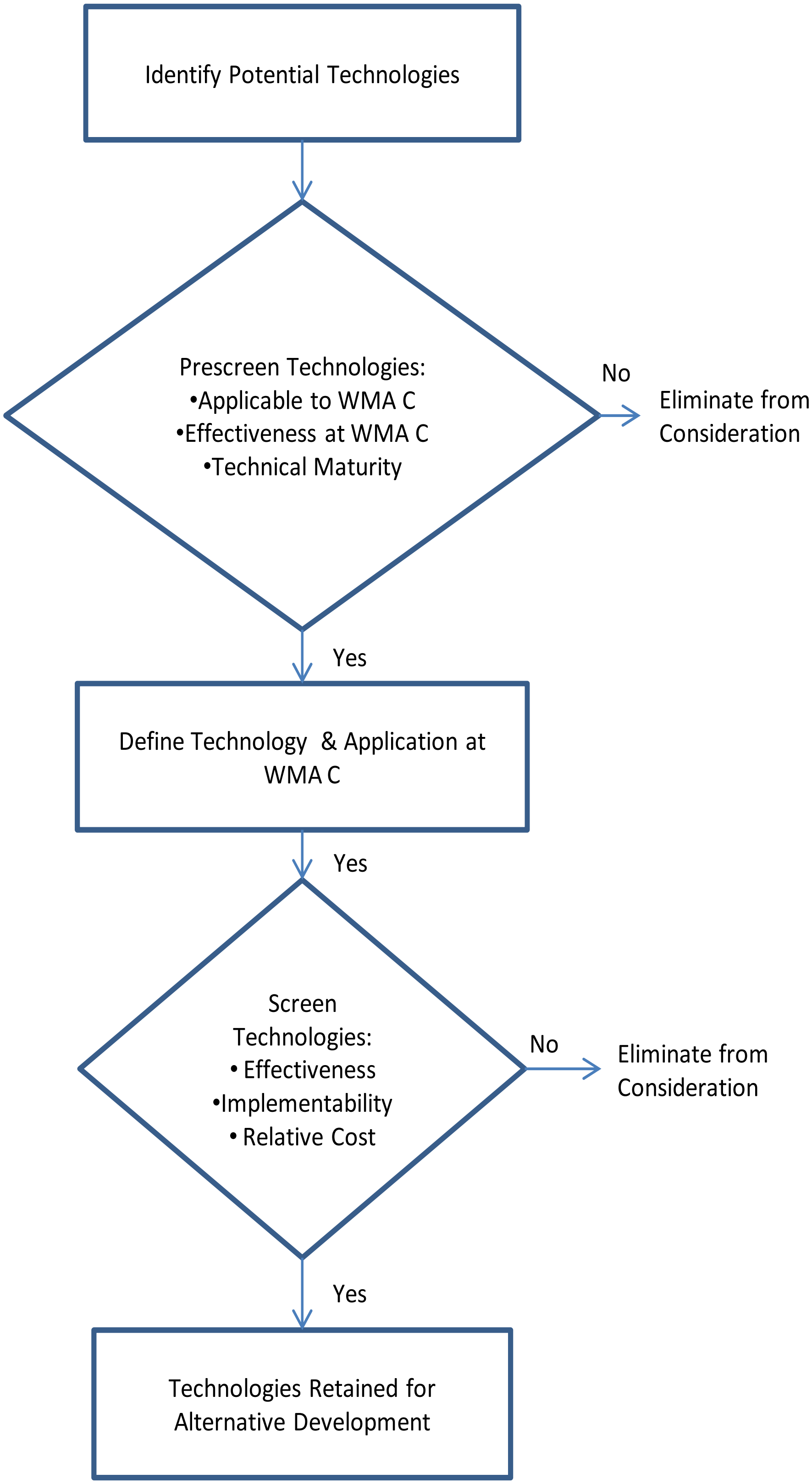
Contaminated soil removed becomes "waste," and if not treated, must be disposed appropriately. Disposal involves measures to relocate the contaminated soil to a permitted facility for permanent disposal. Disposal options include waste transport and disposal to an appropriate facility, such as a landfill. The chemical and radionuclide inventory (amount of radioactivity, activity concentration, and total activity) are the principal criteria used to determine the specific requirements for packaging and transporting soil waste. The receiving facility may not accept the soil waste without pre-treatment.

2.3 TECHNOLOGY SCREENING

The process used to identify and screen technologies is illustrated in Figure 2-1. This process consists of identifying potentially applicable technologies, and performing a prescreening followed by a more detailed screening to generate a subset of technologies to be used in developing corrective measures alternatives.

Available information for each potentially applicable technology was reviewed to develop a basis for technology screening. An understanding of the technology in terms of function, contaminant applicability, effectiveness, implementability, technical maturity, and relative cost are needed to support an evaluation relative to WMA C site-specific conditions.

Figure 2-1. Technologies Identification and Screening Process.



WMA = waste management area

Information on over 70 technologies was collected to conduct an initial screening of technologies considered for potential use in developing remedial alternatives. The prescreening approach allowed a large number of technologies to be considered as a part of the CMS development. Three criteria were identified for use in performing the prescreening (Figure 2-1). The three criteria included the following.

- Technical Maturity: This criterion considers technology maturity level, and whether performance data and implementation data are available for use in developing and evaluating alternatives.
- Applicability to WMA C Conditions: This criterion considers whether a technology would address site-specific conditions at WMA C relative to the site conceptual model.
- Effectiveness for WMA C Site Conditions: This criterion considers whether a technology would be effective, given the site conceptual model for the nature and extent of contamination and deployment considerations within WMA C.

The pre-screening evaluation was performed using WMA C physical site characteristics including geology; hydrogeology; availability of space, and resources necessary to implement technology; and geochemical considerations, including contaminated soil, types and concentrations of contaminants, and physical and chemical properties of the contaminated soil. Professional/engineering judgment was used to assess each technology against the pre-screening criteria. Technologies that met all three criteria were retained for further consideration in the technology evaluation process. The results of the prescreening are briefly discussed in Section 2.3.1.

After the prescreening process, a second level screening was conducted, the results of which are briefly discussed in Section 2.3.2. The retained technologies from the second-level screening were carried forward and used to form process options (Section 2.4) used in alternatives development (Section 3.0).

2.3.1 Prescreening

Technologies were evaluated in the initial prescreening by GRA groupings (see Appendix C, Table C-1). A number of the potentially applicable technologies identified were considered not applicable or effective for application at WMA C, as briefly discussed in Sections 2.3.1.1 through 2.3.1.4.

2.3.1.1 Containment Technologies. Both surface and subsurface barriers were evaluated in this technology screening. Surface barriers evaluated included geomembrane barriers, evapotranspiration barriers, modified-asphalt barriers, and concrete barriers. Subsurface barriers evaluated included horizontal barriers; vertical barriers such as grout walls, sheet pile walls, and slurry walls; and jet injection barriers.

Barriers are effective at limiting access and/or limiting migration of surface and subsurface contaminants. Barriers may require maintenance to remain reliable over the long-term (e.g., repair of cracks may be required to prevent deterioration).

Maintenance and performance monitoring, specified in a maintenance and operations plan, generally is required to be conducted throughout the design life of a containment structure. These actions ensure the long-term effectiveness of the containment structure.

Geomembrane barriers were not retained because unless they are covered with a soil layer, they generally would require more extensive maintenance than other barrier types such as modified-asphalt barriers. Placing a soil layer over a geomembrane barrier would complicate inspection and any necessary repair activities; and could mask a leak in the underlying barrier material. In addition, the greater thickness caused by the addition of a soil layer over the geomembrane could interfere with final closure cap placement, or could necessitate barrier removal prior to final closure cap placement.

Evapotranspiration barriers are essentially a non-permeable barrier (e.g., modified asphalt or geomembrane) with a layer of soil and vegetation over the top of it. The soil and vegetation would complicate inspections and any necessary repair activities; and could mask a leak in the underlying barrier material. In addition, the soil and vegetation could interfere with final closure cap placement, or could necessitate barrier removal prior to final closure cap placement. For these reasons, evapotranspiration barriers were not retained.

Subsurface barriers were not retained because of difficulties in placement and verification of barrier integrity. Subsurface barriers are designed to prevent downward migration of contaminants, but require precise and controlled placement to create an effective seal. It would also be extremely challenging to verify barrier integrity following placement. The existing WMA C infrastructure and the presence of soil contamination pose additional challenges for subsurface barrier construction. Subsurface barrier technologies considered in the screening process included jet grouting, high density polyethylene geomembranes, freeze barriers, molten wax injection, and vertical grout walls. Using geomembranes for subsurface barriers would require extensive excavation. Freeze barriers would require ongoing operational support to ensure continued effectiveness and incur energy costs over the time frame the barrier would be in place. Molten wax injection would require soil heating to aid in mobilizing the wax material, and this technology is not sufficiently mature to consider. Vertical grout walls are utilized to prevent the lateral spread of contamination, but do not prevent vertical contaminant migration.

Modified-asphalt and concrete barriers were retained through the initial screening as infiltration barrier systems and isolation barriers. Both infiltration and isolation barriers provide additional physical separation between the contaminated soil and potential receptors. Infiltration barrier systems also use low-permeability materials to limit surface-water infiltration, thereby controlling moisture-driven transport of underlying contaminants.

2.3.1.2 Treatment Technologies. Both in situ and ex situ treatment technologies were considered for application at WMA C. Categories of treatment technologies considered are below.

- Chemical treatment technologies, which add chemicals to react with contaminants directly or with the surrounding matrix to reduce contaminant toxicity or mobility. Technologies considered included immobilization, sequestration, oxidation/reduction, in situ mineral recovery, and hybrid delivery of treatment chemicals.

- Physical treatment technologies, including electrokinetic mobilization and recovery; soil flushing with aqueous solutions; and solidification and stabilization.

- Biological treatment technologies, which involve applying specific vegetation and/or microbial populations to degrade contaminants to less toxic forms, or concentrate contaminants into a form that can be further managed for final disposition. Biological treatment technologies considered include microbial biodegradation, biological reduction, and supported growth biological reactors.

- Thermal treatment technologies, including volatilization or vitrification, which use relatively high temperatures to volatilize, decompose, and/or melt contaminants.

Many treatment technologies were not retained beyond the initial screening due to lack of technical maturity (e.g., carbonate sequestration, carbon nanotubes), incompatibility with the WMA C vadose zone (e.g., electrokinetic mobilization and recovery is most effective in soils with a higher moisture content), incompatibility with WMA C COCs (e.g., soil vapor extraction), or implementability challenges (e.g., biological treatments). Reduction/oxidation technologies were not retained because reduction is potentially reversible and could require repeated treatments.

A number of in situ treatment technologies were initially considered to be potentially viable for addressing mobile contaminants, including phosphate/apatite sequestration, clay minerals, gas-phase delivery, and jet injection. However, none were retained for further consideration given the current level of understanding of the nature and extent of contamination at WMA C. Implementation of the in situ treatment technologies would require a well-defined contamination zone for technology deployment which is not available for WMA C, and correct placement would be difficult to achieve and ensure. Therefore, the technologies could not be deployed to address the mobile COCs in the vadose zone.

Ex situ treatment technologies were evaluated for use in stabilizing soil contamination following excavation. Vitrification was not retained due to the level of infrastructure required and implementation cost. Soil washing was not retained because the complexity of WMA C soil contamination would require multiple treatment trains and generate significant liquid waste volumes. Molecular sieves and soil sorting and screening were considered impractical based on the volume of soil to be excavated and complexity of soil contamination.

Ex situ solidification/stabilization was retained due to implementability and effectiveness. Large volumes of soil could be processed with minimal process waste resulting from treatment.

2.3.1.3 Removal Technologies. Excavation technologies were evaluated during technology screening for the purpose of removing WMA C contaminated soil. Conventional excavation, remotely controlled excavation, and soil vacuuming were considered for physical soil removal. Retaining wall technologies were evaluated for excavations to greater depth (up to 45 ft). Minimizing worker exposure was a key consideration in selecting the excavation technologies. Site conditions such as buried tanks, pipelines, and geology were also considered in evaluation of implementability.

A number of technologies were not retained beyond the initial screening due to implementability concerns. Technologies such as jet grout walls, caissons, deep mixed walls, secant/tangent pile walls, and diaphragm walls were not retained as they introduce high amounts of grout or slurry that may potentially absorb and spread contamination. Dragline excavation was not considered because it would require significant setbacks to reach required depths and would be difficult to implement around existing infrastructure (e.g., exposed ventilation pipes). Soil nail walls were not retained due to the poor cohesiveness of the soils at WMA C. Cofferdams and tunneling were not retained because both of these technologies would be difficult to implement at WMA C due to below-grade infrastructure and site-specific conditions.

2.3.1.4 Disposal Options. Disposal at ERDF (on-site) and disposal at an off-site facility in Texas were considered and both were retained through the prescreening.

2.3.2 Second-Level Screening

Based on the prescreening, eight technologies were carried forward for a second-level screening against the criteria of effectiveness (including long-term effectiveness; short-term effectiveness; reduction of toxicity, mobility, and volume; and long-term reliability), implementability, and cost. The definitions of these criteria are as follows.

- Long-term Effectiveness and Permanence – The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met. In this CMS report, the evaluation criterion of long-term effectiveness and permanence relates to the period of time between the placement of the alternative and the construction of the final closure cap over WMA C.

- Short-term Effectiveness – The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.

- Reduction of Toxicity, Mobility, and Volume – The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ.

- Implementability – This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.

- Cost – This assessment evaluates the capital and operation and maintenance costs of each alternative.

The results of this second-level screening are shown in Table 2-1 and in Appendix C, Table C-2, and briefly discussed in Sections 2.3.2.1 through 2.3.2.4.

Table 2-1. Results of Second-Level Screening. (3 sheets)

Screening Criteria	Responsiveness to Screening Criteria[1]	Performance[2]	Retained/ Not Retained
Concrete Isolation Barrier			
Effectiveness	Yes	Fair	Retained
Long-term Effectiveness	Yes	Fair	
Short-term Effectiveness	Yes	Good	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Fair	
Long-term Reliability	Yes	Fair	
Implementability	Yes	Good	
Cost	Low	Good	
Modified-Asphalt Surface Barrier			
Effectiveness	Yes	Fair	Retained
Long-term Effectiveness	No	Poor	
Short-term Effectiveness	Yes	Good	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Fair	
Long-term Reliability	No	Poor	
Implementability	Yes	Good	
Cost	Moderate	Good	
Conventional Excavation			
Effectiveness	Yes	Good	Retained
Long-term Effectiveness	Yes	Good	
Short-term Effectiveness	Yes	Fair	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	No	Poor	
Cost	Low	Good	

Table 2-1. Results of Second-Level Screening. (3 sheets)

Screening Criteria	Responsiveness to Screening Criteria[1]	Performance[2]	Retained/ Not Retained
Remotely Operated Excavation			
Effectiveness	Yes	Good	Retained
Long-term Effectiveness	Yes	Good	
Short-term Effectiveness	Yes	Fair	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	No	Poor	
Cost	High	Poor	
Vacuum Excavation			
Effectiveness	No	Poor	Not Retained
Long-term Effectiveness	Yes	Good	
Short-term Effectiveness	No[3]	Poor[3]	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	No	Poor	
Cost	High	Poor	
Standard Sloping and Benching Systems			
Effectiveness	Yes	Good	Retained
Long-term Effectiveness	No	Poor	
Short-term Effectiveness	No	Poor	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	Yes	Fair	
Cost	Low	Good	
Sheet Pile Walls			
Effectiveness	Yes	Good	Retained
Long-term Effectiveness	Yes	Fair	
Short-term Effectiveness	Yes	Fair	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	Yes	Fair	
Cost	Moderate	Fair	

Table 2-1. Results of Second-Level Screening. (3 sheets)

Screening Criteria	Responsiveness to Screening Criteria[1]	Performance[2]	Retained/ Not Retained
Remove, Treat, and Dispose: Ex Situ Solidification and Stabilization			
Effectiveness	Yes	Good	Retained
Long-term Effectiveness	Yes	Good	
Short-term Effectiveness	Yes	Good	
Reduction of Toxicity, Mobility, or Volume of Wastes	Yes	Good	
Long-term Reliability	Yes	Good	
Implementability	Yes	Good	
Cost	Low	Good	

Notes:
[1] To indicate relative **cost** of each technology, the semi-quantitative system uses a rating of low to moderate to high.
[2] To indicate relative **performance** of the technologies against the evaluation criteria, the qualitative system uses a rating of poor to fair to good.
[3] High airborne contamination.

2.3.2.1 Containment Technologies. The two containment technologies retained during this screening include a concrete isolation barrier and a modified-asphalt surface barrier system. Concrete pads have been routinely placed in the tank farms for structural purposes and a modified-asphalt barrier system was successfully constructed at the 241-TY Tank Farm as an interim surface barrier. The cost of implementation is low to moderate.

2.3.2.2 Treatment Technologies. Ex situ solidification and stabilization of contaminated soil will include the addition of clean soil and/or grout to ensure the waste container radiological dose rates are acceptable for transport and disposal. Application of water or fixative will suppress but not completely eliminate airborne contaminants during excavation and waste box loading. Administrative controls and personal protective equipment will be required to minimize the spread of contamination and exposure to radiation. Although an additional control will solve one issue, the control easily complicates the process thus adding other issues (i.e., supplied air for breathing limits worker visibility and mobility while operating equipment; increases the risk of heat related illness; and increases the time necessary to accomplish even simple tasks, thus increasing exposure to radiation). These factors make soil treatment cost intensive.

2.3.2.3 Removal Technologies. Three excavation technologies were evaluated along with two excavation support technologies. The excavation technologies include conventional excavation, remotely operated excavation equipment and vacuum excavation. Excavation has been used to remove contaminated soil on the Hanford Site. The cost of excavation is dependent on the soil contamination levels, volume of soil to be removed, and location of the excavation relative to existing infrastructure. Based on these factors, the need for confinement ventilation, methods for shoring, and selection of equipment would be addressed during design.

As a result of the second-level screening, vacuum excavation was not retained for alternative use. Although vacuum excavation has been successfully implemented in tank farms, the use of vacuum technology to target high contamination areas is unprecedented. Carrying contaminated particulates in a high volume airflow poses many hazards to site workers and the environment. These hazards would require thorough evaluation and controls. Performing a Process Hazards Analysis and formulating Technical Safety Requirements will require a thorough knowledge of contaminants and their distribution, expected dose rates, and volumes of soil to be excavated. The level of information required to perform a defensible hazard evaluation and design effective controls would not be available.

Two excavation support technologies were evaluated. These support technologies include standard sloping and benching systems and sheet pile walls. These support technologies are relatively cost effective and can be implemented on-site.

2.3.2.4 Disposal Options. Both on-site and off-site disposal technologies were evaluated. Disposal is discussed in greater detail in Section 2.4.5.4. On-site disposal will be the least expensive and most expeditious disposal path.

2.4 RETAINED TECHNOLOGIES AND PROCESS OPTIONS

Applicable technologies have been identified for the GRAs for use at WMA C. The remedial technologies retained for WMA C are described in this section. The application of the technologies at WMA C form process options.

Eight process options were developed from the seven technologies that were retained. To develop alternatives, a screening of applicable technologies was performed. CERCLA criteria guiding the development of alternatives provides for using effectiveness, implementability, and cost. The eight process options retained to support corrective measures alternatives development are:

1. Institutional controls,
2. Environmental monitoring,
3. Isolation barriers,
4. Infiltration barrier systems,
5. Conventional or remotely-operated excavation,
6. Standard excavation sloping and benching,
7. Sheet pile walls, and
8. Ex situ solidification and stabilization.

These eight process options were used to develop the corrective measures alternatives described in Section 3.0.

2.4.1 Institutional Controls

Institutional controls are applied to limit public access, control worker access and activities, and limit environmental contact with contaminated soil and groundwater contaminants at WMA C. Institutional controls involve implementing legal, administrative, and/or informational devices, and barriers such as fencing.

The DOE's site-wide institutional control plan, DOE/RL-2001-41, Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions, describes institutional controls to be used to restrict public access to the Hanford Site in general. Additional institutional controls restrict access to the Central Plateau for as long as necessary to protect human health. Other institutional controls support effectiveness over time. Additional controls are administered to limit access and control work activities within WMA C. The maintenance of such institutional controls will likely fall to each successive generation.

2.4.2 Environmental Monitoring

Groundwater and air environmental monitoring is described in Sections 1.6.4 and 1.6.5, respectively. Environmental monitoring will continue to be conducted into the foreseeable future.

Groundwater monitoring representative of groundwater conditions beneath WMA C will continue under the 200-BP-5 Groundwater Operable Unit monitoring program. Monitoring results are used to determine if residual contaminants associated with WMA C are migrating, and if contaminant concentrations greater than acceptable exposure levels could reach potential receptors. Proper use of monitoring data can alert DOE to impending exceedances of acceptable exposure levels and health and safety parameters. Current levels of environmental monitoring would be maintained under all of the alternatives. Additional monitoring requirements may be identified as a part of corrective action implementation.

Monitoring provides a method for tracking changes in contamination levels and location over time. Monitoring of areas that have impacted groundwater typically includes groundwater monitoring. However, groundwater monitoring is not addressed in this CMS. The remediation of groundwater will be done under CERCLA as part of the 200-BP-5 Groundwater Operable Unit remedial investigation/feasibility study.

An alternative that includes environmental monitoring will also include a contingency plan to identify actions taken if the monitoring results suggest the selected alternative is not protective, or is not performing as anticipated. Contingency plans can be developed during the corrective measure design phase of the project for measuring and assessing metrics that reflect the appropriateness and ongoing effectiveness of the selected alternative. Contingency plans conducted to support environmental monitoring may be triggered by observations of unacceptable conditions that may interfere with protection of human health and the environment.

2.4.3 Containment

Containment encompasses both isolation barriers and infiltration barrier systems. Concrete would be the favored material for isolation barriers, while modified asphalt would be the favored option for infiltration barrier systems.

Concrete isolation barriers could be placed over areas where isolation is needed. Basically, surface preparation would be performed as needed, removable forms and reinforcing steel would be placed, a commercial concrete mixture would be placed, and the removable forms would be removed. This technology is well understood and could be implemented using standard construction equipment and practices.

Standard commercial asphalt would likely not prevent infiltration of meteoric water over the potential timeframe needed. However, impermeability and durability can be increased by adding amendments during material preparation to generate modified asphalt, as discussed in RPP-RPT-47488, "241-SX Tank Farm Interim Surface Barrier Material Alternatives Study."

Modified-asphalt barriers are constructed using standard paving equipment, but slightly modified techniques. Basically, a storm water conveyance and disposal system would be constructed, the farm surface would be prepared, a base layer of compacted fill material would be placed over the area to be covered, and modified asphalt would be placed over the fill material. Construction of modified-asphalt barriers is well understood at the Hanford Site.

2.4.4 Treatment

Several remedial technologies were evaluated based on their ability to treat WMA C soil contaminants to the extent that exposure risks are reduced for humans and ecological receptors. Ex situ solidification and stabilization is retained as a treatment for excavated soil. This treatment would involve altering the properties of the soil; physically binding contaminants to reduce mobility; and reduce the potential for exposure.

2.4.5 Removal

The retained removal technologies are removal by conventional and remotely-controlled methods along with supporting functions. Remotely-controlled excavation is necessary when physical, chemical, and/or radiological hazards preclude worker contact with the contaminated media.

Remotely-controlled excavation activities may employ long-reach equipment (e.g., trackhoe, boom-mounted drum grappler) or computer-controlled, remotely-operated equipment to allow excavation and container management from a safe distance. Remotely-controlled excavation has been deployed at a number of sites where radiological or explosive wastes demanded remote operations.

2.4.5.1 Benching and Sloping. Both benching and sloping are used to prevent cave-ins to an excavation and thereby protect workers and maintain the integrity of the excavation. Benching

consists of cutting one or more steps into the side-walls of an excavation, usually with vertical or near-vertical surfaces between levels. Sloping consists of cutting sidewalls into relatively smooth, angled planes dipping toward the excavation. The benching and sloping designs depend, in part, on soil types, depth of excavation, anticipated weather conditions, and loads that may affect the soil in the area of the excavation. Benching and sloping may be used together or as standalone methods. Benching and sloping actions are applicable to both conventional and remote-controlled excavation methods.

2.4.5.2 Sheet Pile Walls. Sheet pile walls are used to support excavation by retaining soil using prefabricated sheet sections that are typically connected by interlocking edges. These sheet sections are sequentially installed by being vibrated or hammer driven into the ground, with each successive lateral section interlocking to the adjacent section. Additional lateral support may be achieved using bracing or anchors to tie the wall into the supporting soil behind the excavation.

2.4.5.3 Backfilling Support Function. Non-contaminated, imported soil would be used to backfill excavations. Potentially, removed and treated soil could be returned to the excavation, if action-levels are met by the ex situ treatment.

2.4.5.4 Waste Disposal Options. Disposal includes waste packaging, transport, and disposal at an appropriate facility, such as a landfill. The chemical and radionuclide inventory are principal criteria used to determine specific requirements for packaging and transporting soil waste. The receiving facility may not accept soil waste that has not been pre-treated in accordance with a facility's waste acceptance criteria. Data collected during the Phase 2 RFI would be used for initial disposal planning, while real-time analysis of the waste would be performed before transport.

The preference for WMA C soil waste is transport and disposal to the Hanford Site Environmental Restoration Disposal Facility (ERDF). ERDF accepts cleanup waste from various areas of the Hanford Site. Hanford waste is transported to the facility by a fleet of trucks traveling between the waste sites and the landfill. Using ERDF and the on-site transportation routes keeps Hanford waste on the Hanford Site and away from the Columbia River, major roads, and members of the general public. In order to dispose of waste at ERDF the waste must meet the ERDF waste acceptance criteria, and a CERCLA decision document is required.

Alternatively, if the soil waste cannot be accepted by ERDF, appropriate documentation would need to be developed to transport the waste for disposal to an off-site facility, such as the Waste Control Specialists site in Andrews County, Texas. The Waste Control Specialists site offers treatment and storage of various waste types. In order to dispose of waste at an off-site facility, the waste must meet that facility's waste acceptance criteria.

ERDF and off-site facilities would place restrictions on the waste types, specific characteristics, and volumes received by requiring that waste acceptance criteria are met and volume constraints are maintained per their operating licenses. In addition, U.S. Department of Transportation requirements would apply for off-site hazardous waste transport. Waste disposal may apply to

the waste that meets specified conditions, including treatment to land disposal restriction standards per Title 40, CFR, Part 268, “Land Disposal Restrictions” (40 CFR 268).

3.0 ALTERNATIVES DEVELOPMENT

The remedial alternatives developed in this section combine one or more of the technologies into process options for an appropriate range of alternatives that are more fully analyzed in the detailed analysis (Section 4.0). Alternatives development follows EPA guidance, and considers the nature and extent of contamination at WMA C from Section 6.0 of the Phase 2 RFI report and the BRA, final COCs (based on the BRA), and CAOs from Section 2.1 of this CMS. Additionally, the alternatives are developed within the context of a set of assumptions, constraints, and uncertainties that address site-specific conditions and integration with other planned cleanup efforts.

3.1 ALTERNATIVE CONSIDERATIONS

Factors that affect the evaluation of a technology's effectiveness, implementability, and relative cost are the site-specific assumptions, constraints, and uncertainties. Each factor is described in the following subsections.

3.1.1 Assumptions

Assumptions are factors considered in developing the process options into alternatives for WMA C. Some assumptions applicable to WMA C include the following.

- The WMA will be closed as a landfill, with no removal of sub-grade structures.

- The tanks and associated equipment and piping will remain in place.

- Sub-grade structures (100-series tanks, 200-series tanks, C-301 catch tank, CR vaults and tank, and diversion boxes) will be filled with grout, as required, to prevent potential subsidence and/or collapsing of these structures. Pipeline encasements may be filled or partially filled with grout, as necessary, to prevent possible subsidence, while stabilizing activities for the tanks and structures are performed. No special effort will be made to preclude or ensure that pipelines are grouted.

- The implementation of the preferred alternative of this CMS will be followed by future closure actions including the placement of a final closure cap. The anticipated final closure cap represents a permanent closure action for WMA C.

- Corrective actions are intended to be effective from the completion of construction/implementation, beginning in approximately 2020, through completion of final cap installation in approximately 2050.

- Before conducting tank and component closures, above-grade equipment and structures will be removed as necessary to prepare WMA C for construction of a final closure cap.

- The final closure cap to be installed at WMA C will follow most closure activities at the Tank Farms 241-A, 241-AX, 241-AN, 241-AY, 241-AZ, and 241-AW.

- Land ownership by DOE is not anticipated to change in the foreseeable future.

- Being located on the Central Plateau, WMA C will maintain an Industrial Exclusive land-use classification through approximately the year 2050. Combining land-use restrictions with institutional controls will limit the need to achieve unrestricted use levels in the short term.

3.1.2 Constraints

Constraints are considered during a remedial technology evaluation to eliminate or set limits on those technologies that may be affected by physical or administrative challenges. Examples are as follows.

- DOE limits access to the Hanford Site in general. Hanford Site access requirements may constrain access, or impede scheduled activities, for some construction personnel, equipment, and material deliveries during construction and maintenance activities for WMA C.

- Buried piping and sub-grade structures will limit the vertical extent of excavation because of layback requirements, unless engineered slope stability measures are deployed.

- For potential soil excavation activities, the space needed may exceed available WMA C space for managing excavated soil.

- WMA C security risks may increase during construction activities relative to the anticipated greater numbers of personnel (e.g., heavy equipment operators, waste transporters) that would be involved at WMA C construction activities.

- Using soil treatment away from WMA C is not anticipated, as the EIS ROD establishes that "Disposal of contaminated equipment and soil will occur on site," meaning the Hanford Site (78 FR 75913). However, disposal to the ERDF would require a CERCLA decision document.

3.1.3 Uncertainties

This section describes key uncertainties inherent in the analysis performed as part of the CMS. Uncertainties reflect limitations of knowledge (unknowns) regarding data, engineering, and technical assumptions made during the remedial technology evaluation.

Uncertainties may propagate throughout CMS evaluations in the areas of access restrictions, technology limitations, cost, performance, regulatory policy, future land use, and human health and ecological risk. Nevertheless, although some uncertainties pose challenges for WMA C,

sufficient data have been generated to support the development, evaluation, and recommendation of an appropriate corrective measures alternative in this CMS.

Example uncertainties include the following.

- Data used to interpret the depth to, and characteristics of, the capillary zone beneath WMA C are derived from the results of characterization activities conducted outside WMA C.

- In 2011 and 2012, groundwater was encountered beneath WMA C at approximately 80 m (260 ft) per PNNL-15837, "Data Package for Past and Current Groundwater Flow Contamination Beneath Single-Shell Tank Waste Management Areas." However, Phase 2 RFI characterization activities did not address soils deeper than approximately 67 m (223 ft) at WMA C. As a result, the nature and extent of soil contamination are partially defined, specific contaminant source areas are not well defined, the list of COCs may be incomplete, maximum contaminant concentrations are unconfirmed, and contaminant mass releases to the environment are not confirmed or well understood.

- Soil contamination is not homogenous throughout the vadose zone. Conducting subsurface characterization of the deep vadose zone is difficult and the difficulty increases with increased depth.

- Ten "Exposure Areas" were identified in the BRA to support objectives of the Phase 2 RFI. Exposure Area "Site X" could not be accessed to evaluate waste losses from tank 241-C-105, due to access problems during investigation activities. Site X continues to pose access difficulties. However, the results of numerical modeling may provide additional information, if needed (RPP-RPT-58329). Therefore, no further field characterization was recommended at this sampling location in the Phase 2 RFI report.

- Uncertainties may result through quantification of risks to human health and the environment, and to site workers, based on limitations of the available analytical data set generated to date.

- Estimates of corrective action performance, restoration time frames, and estimated costs in this CMS reflect uncertainties in key parameters needed for assessing corrective action performance and restoration time frames.

- To develop a recommended alternative, best-estimate values are used, based on professional judgment. Future developments can affect the chosen alternative.

- Known and unknown preferential removal areas, release mechanisms, and dynamics of the subsurface have not been comprehensively identified or characterized.

3.2 BASIS FOR ALTERNATIVE DEVELOPMENT

The retained technologies described in Section 2.4 are used to develop viable alternatives. Each remedial alternative is formulated with the purpose of operating for approximately 30 years, until approximately 2050, pending implementation of the final closure cap at WMA C. Further, each alternative considered for WMA C was designed such that it would not restrict future management or preclude future closure and corrective actions at WMA C.

Each remedial alternative is developed and evaluated for its ability to mitigate the risk of direct contact with contaminated soil and offer protection of groundwater until a permanent remedy is implemented at WMA C.

Implementation of any of the alternatives will not preclude DOE's ability to reach final closure of WMA C. This section discusses the process used to generate a range of viable alternatives for WMA C and describes each alternative's ability to eliminate and/or mitigate unacceptable risk associated with vadose zone soil contamination.

Prior to implementing any corrective measures, it is assumed that below-grade structures with the exception of pipelines would be filled with grout. Above-grade facilities and equipment would be removed from the tank farm.

A limited number of remedial alternatives were constructed using the retained technologies such that one or more remedial alternatives offer the ability to meet CAOs. Approaches that address WMA C COCs were considered as implementable and in alignment with the anticipated and reasonable future industrial land use of WMA C.

Seven technologies were retained for consideration in developing remedial alternatives. In addition, a "no action" alternative provides a baseline against which the remedial alternatives can be compared. The site conceptual model is used as a framework to identify potential technology combinations that could serve to address different areas of soil contamination within WMA C. Additionally, the volumes and associated contaminant inventories for different waste releases are taken into consideration during remedial alterative definition.

The following considerations were used to support the development of remedial alternatives.

- Contaminant inventories at UPR-81, UPR-82, and UPR-86 account for approximately 28% of the ^{137}Cs, 23% of the ^{126}Sn, 23% of the ^{99}Tc, and 58% of the nitrate attributed to leaks and releases in the soils of WMA C (RPP-RPT-42294). For comparison purposes, contaminant inventories associated with tank 241-C-105 account for approximately 69% of the ^{137}Cs, 57% of the ^{126}Sn, 56% of the ^{99}Tc, and 1% of the nitrate attributed to leaks and releases in the soils of WMA C (RPP-RPT-42294).

- Shallow releases at UPR-81, UPR-82, and UPR-86 are associated with pressurized transfer line leaks. At these release locations, tank waste was released from transfer line breaks approximately 10 ft bgs. Waste migrated to the surface of the tank farm at all

three of these release locations. Actions were taken to cover the release sites with gravel and after ~30 years a shotcrete cover was installed over UPR-82 and UPR-86.

- Releases from the tanks are generally associated with cascade line leaks that originated approximately 20 ft bgs. These releases were not pressurized transfer line leaks and are assumed to have mainly migrated vertically downward.

- The Phase 2 RFI concluded that sampling locations showed concentrations of mobile constituents exceeding background concentrations, suggesting that for the most part mobile constituents had migrated through the sample region, to greater depths.

- In at least some parts of WMA C there appears to be lateral movement of contamination.

- The results of the Phase 2 RFI sampling efforts confirmed that several immobile waste constituents remain near sources of waste releases.

- Mobile constituents are anticipated to be present at WMA C soils at varying depths and lateral locations. Due to the depth of the vadose zone and the number and location of releases, specific contaminant plume locations and geometries are not well defined.

Based on contaminant inventory estimates, release locations, and the conceptual site model, the technologies were assembled into six alternatives as shown in Table 3-1. To meet the CAO regarding protection from the direct-contact risk, the primary area of focus is associated with the three target UPRs.

Table 3-1. Corrective Measure Alternatives.

Alternative	Institutional Controls	Environmental Monitoring	Isolation Barrier	Infiltration Barrier System	Remote Excavation	Sloping & Benching	Sheet Piling	Treatment & Stabilization
1 No Action		●						
2 Institutional Controls	●	●						
3 Isolation Barriers	●	●	●					
4 Isolation Barriers + Infiltration Barrier System	●	●	●	●				
5 Excavation	●	●			●	●	●	●
6 Excavation + Infiltration Barrier System	●	●		●	●	●	●	●

3.3 ALTERNATIVES DEVELOPMENT

Alternatives considered to address soil at WMA C were those that have the potential ability to mitigate the direct-soil contact risk and provide a degree of protection of groundwater. The alternatives developed for evaluation in this CMS are as follows:

- Alternative 1 – No Action,
- Alternative 2 – Institutional Controls,
- Alternative 3 – Isolation Barriers,
- Alternative 4 – Isolation Barriers + Infiltration Barrier System,
- Alternative 5 – Excavation, and
- Alternative 6 – Excavation + Infiltration Barrier System.

All alternatives, with the exception of the "no action" alternative, include institutional controls, environmental monitoring, and future placement of a closure cap as described and implemented as part of the WMA C closure plan. These alternatives are described in the following sections.

3.3.1 Alternative 1 – No Action

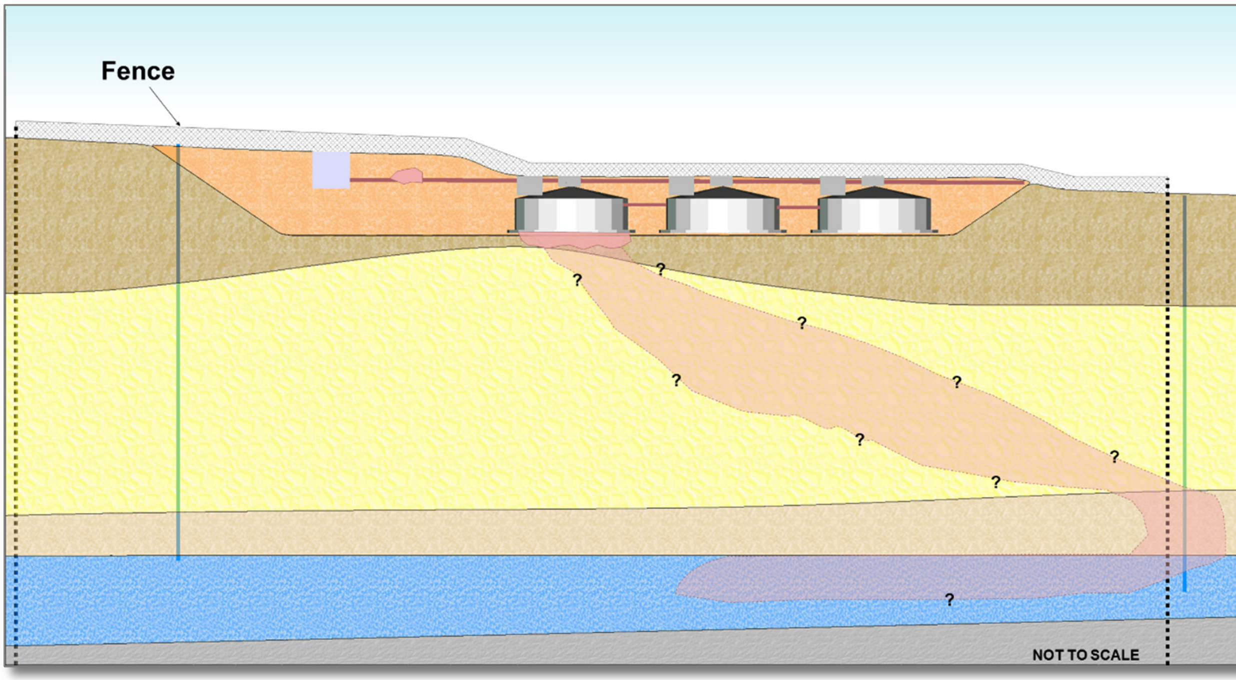
Under the "no action" alternative, the site would remain "as is." No further actions, including restriction of access to WMA C or other institutional controls, would be taken.

3.3.2 Alternative 2 – Institutional Controls

This alternative consists of a continuation of existing institutional controls for both the Hanford Site and WMA C. Hanford's Site-Wide institutional controls plan (DOE/RL-2001-41) establishes three categories of institutional controls: access controls including warning notices, entry restrictions, and fences. No actions would be taken to reduce the toxicity, mobility, or volume of contaminated soil or to mitigate the risks from exposure to soil contamination. Existing administrative control of the WMA would continue and all in-farm work would be controlled using the existing work planning processes. Existing work planning processes would document the work to be performed, identify hazards, and provide for appropriate monitoring and control for worker protection. HNF-54166, "Surveillance and Maintenance Plan for the Long-Term Stewardship Program," describes surveillance and maintenance activities to protect human health and the environment. Figure 3-1 illustrates a conceptual site model for Alternative 2.

After completing tank closure and removal of above-grade facilities and equipment at WMA C, access to WMA C will be limited to performing routine monitoring and surveillance activities pending final closure actions (e.g., placement of the final closure cap). Institutional controls will be maintained to monitor site conditions and maintain access controls.

Figure 3-1. Conceptual Site Model for Alternative 2.



3.3.3 Alternative 3 – Isolation Barriers

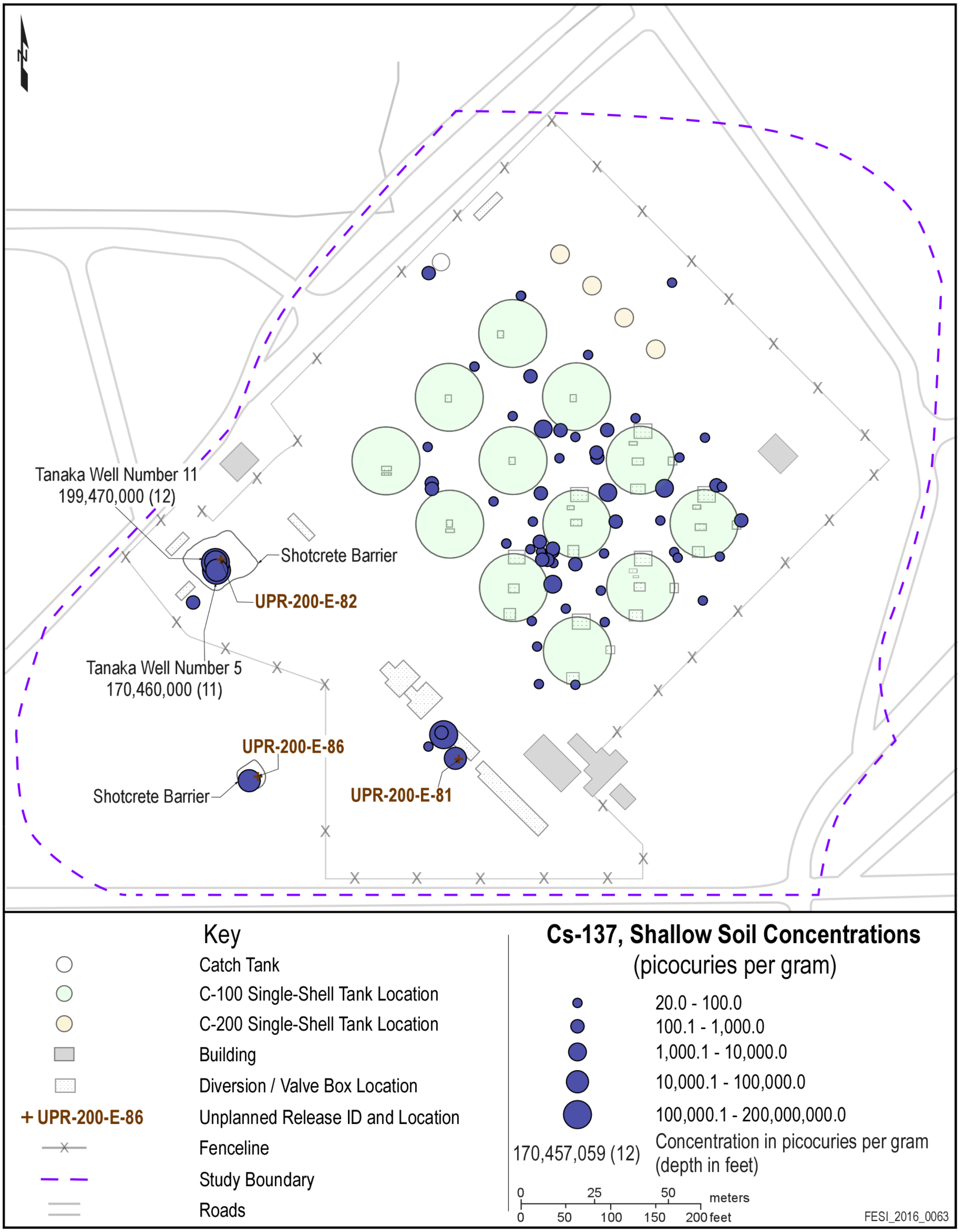
This alternative consists of constructing concrete isolation barriers as a corrective measure to mitigate risks to site workers from exposure to soil contamination. The areas selected for this action include those where contaminant concentrations in shallow soil exceed risk thresholds. Figure 3-2 shows the locations where ^{137}Cs concentrations in soil exceed threshold values in the shallow vadose zone. Figure 3-3 shows the locations where concentrations of ^{126}Sn in the soil exceed threshold values in the upper 15 ft of WMA C soils. Utilizing these maps, an assumed conceptual layout for the location and size of the isolation barriers is identified in Figure 3-4. . An isolation barrier would also be constructed over the French drain designated as 216-C-8 to prevent contact with near-surface contamination. The isolation barrier concept over the 100-series SSTs was developed to cover that portion of the WMA where high levels of ^{137}Cs were observed in the shallow soil in combination with waste release locations derived from process knowledge as described in RPP-ENV-33418.

The isolation barriers would isolate site workers from direct contact with contaminated soil and minimize the potential exposure to future site workers, pending placement of the final closure cap over WMA C. A map of the isolation barriers footprint is shown in Figure 3-4. The isolation barrier footprints do not cover the localized elevated ^{126}Sn contamination northeast of the C-200-series tanks. This location is not associated with a known UPR event and is anticipated to have limited extent and inventory.

The isolation barriers would also mitigate the potential post-closure intrusion risks by providing additional defense-in-depth to prevent intrusion into contaminated soils near the tank farm surface.

1 **Figure 3-2. Map of Shallow Soil Cesium-137 Concentrations Greater Than Action Levels.**

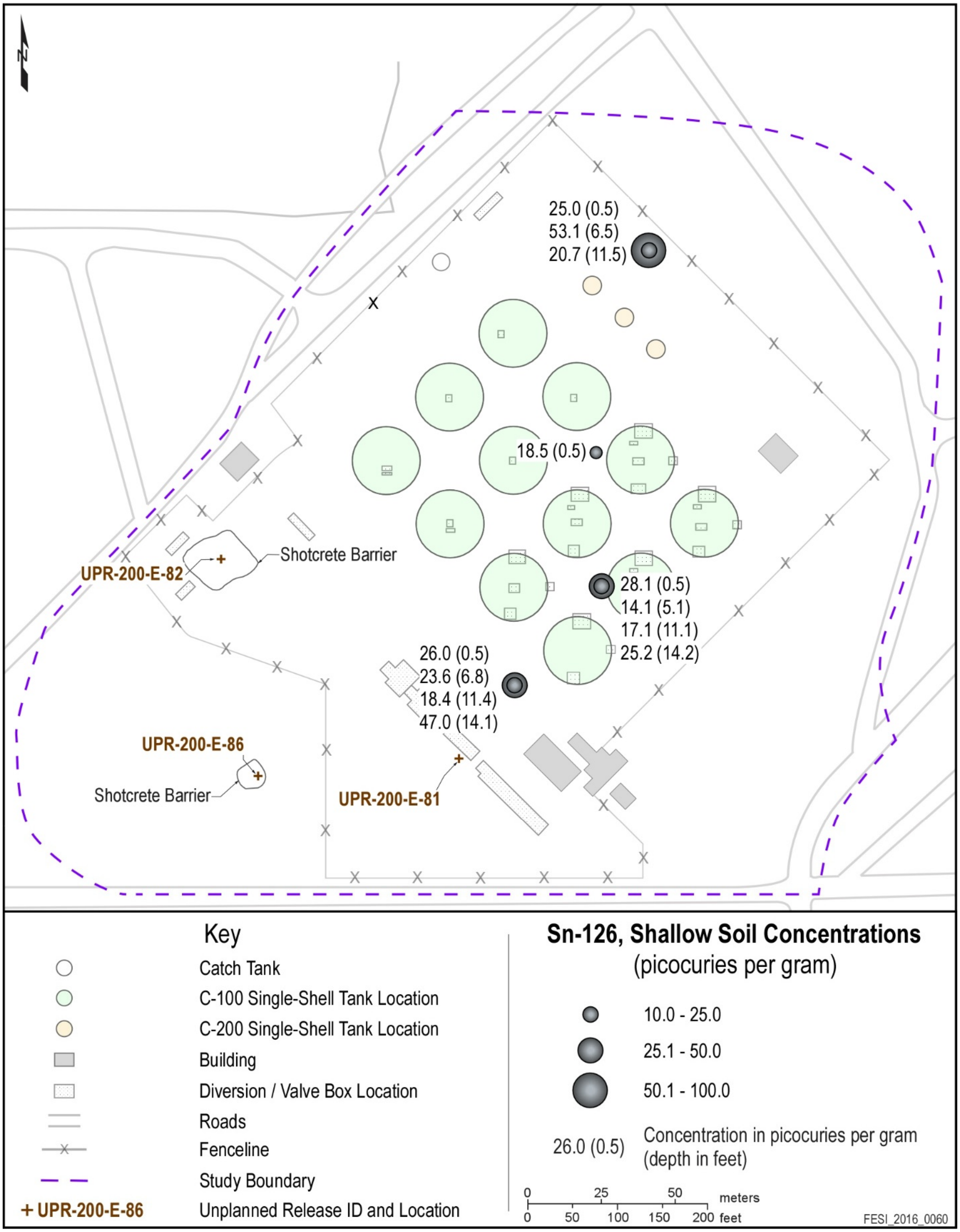
2



3

4

1 **Figure 3-3. Map of Shallow Soil Tin-126 Concentrations Greater Than Action Levels.**
2



3
4

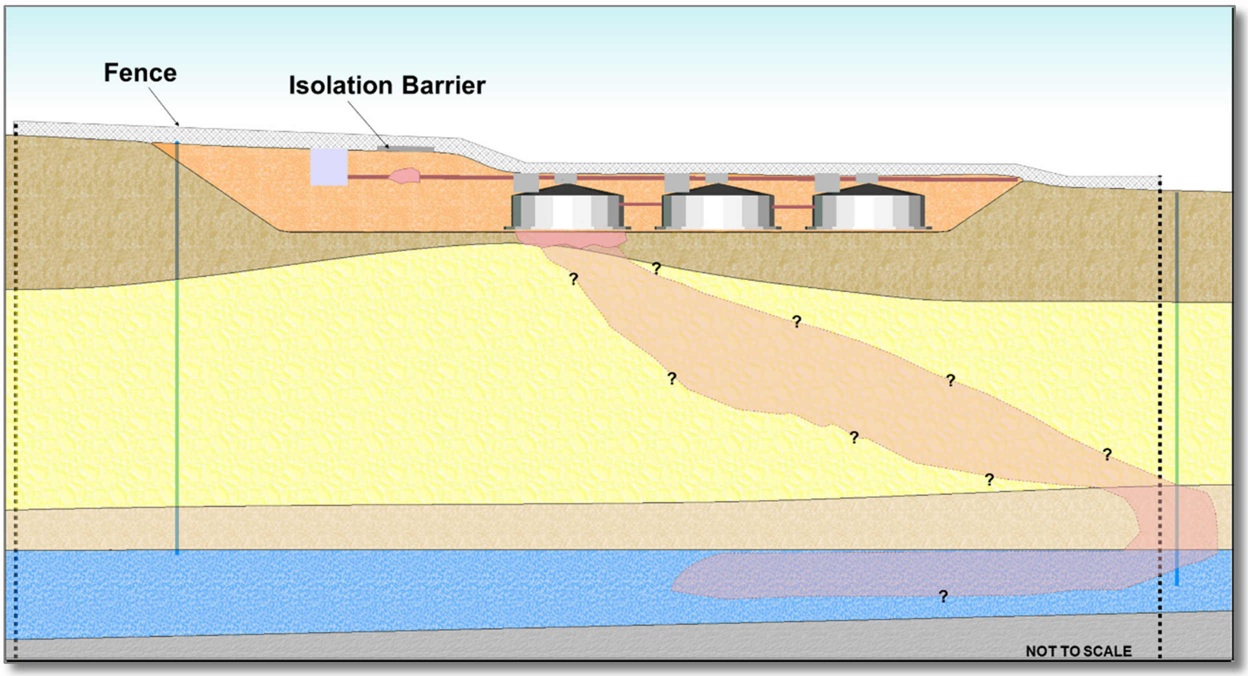
1 **Figure 3-4. Alternative 3 Conceptual Isolation Barriers Footprint.**

2

3

Although the concrete isolation barriers are not designed to prevent infiltration (e.g., they incorporate no runoff controls), they would provide some reduction in infiltration. Isolation barriers would not be anticipated to reduce the future groundwater impacts from continued migration of mobile contaminants that have migrated to below their effective depths. The conceptual site model for this Alternative 3 is shown in Figure 3-5.

Figure 3-5. Conceptual Site Model for Alternative 3.



Activities included in the construction of the isolation barriers include those listed below. Isolation barriers adjacent to or on top of the SSTs would be constructed after the tanks and below-grade structures are grouted and above-grade equipment has been removed.

- Construct isolation barriers to isolate localized areas with contamination exceeding action levels in shallow soils. In addition to isolating the exposure pathway from soil contamination, the isolation barriers would provide defense-in-depth for post-closure intrusion prevention.

- Each isolation barrier would require the placement of forms and reinforcing steel followed by filling the forms with commercial concrete mix to a thickness of approximately 15 cm (6 inches).

- At the UPR locations where the surface is covered with a shotcrete cap (Figure 3-6 and Figure 3-7), the surface is irregular. At these locations the process would be similar, but a thicker concrete isolation barrier (3 to 4 feet) would be constructed to avoid disturbing the contamination.

- The French drain (216-C-8) will be covered with an approximately 15-cm (6-inch) isolation barrier.

Figure 3-6. Shotcrete Cover over UPR-200-E-86.

3.3.4 Alternative 4 – Isolation Barriers + Infiltration Barrier System

This alternative consists of constructing modified-asphalt infiltration barriers, in conjunction with isolations barriers at UPR-82 and UPR-86. The objective of the infiltration barriers would be to reduce infiltration of meteoric water and mitigate future groundwater quality impacts from mobile contaminants. An infiltration barrier would be constructed over the 100-series SSTs and UPR-81, and around the isolation barriers constructed at UPR-82 and UPR-86. The infiltration barriers would reduce the infiltration of precipitation, while providing some degree of isolation to site workers from direct-contact exposure to contaminants in shallow soil.

At both UPR-82 and UPR-86, actions previously taken in response to the transfer line leaks included placing gravel over the exposed leak area and later covering the gravel with shotcrete. At both of these locations, the mounded surface does not lend itself to covering with modified asphalt without disturbing the UPRs. These UPRs will be covered with a concrete isolation barrier to avoid removing existing cover material. The infiltration barrier system will then be placed up to the edge of the isolation barriers to provide a larger barrier footprint and storm water collection and conveyance out of WMA C.

This alternative utilizes a low permeability modified-asphalt material over WMA C to minimize infiltration. This concept is similar to the Interim Surface Barrier constructed over the 241-TY Tank Farm (Figure 3-8). To collect and control storm water runoff, a sloped subgrade would be established by placing and compacting fill material to establish a minimum slope.

Modified-asphalt material would then be placed using commercial paving equipment for hot mix asphalt.

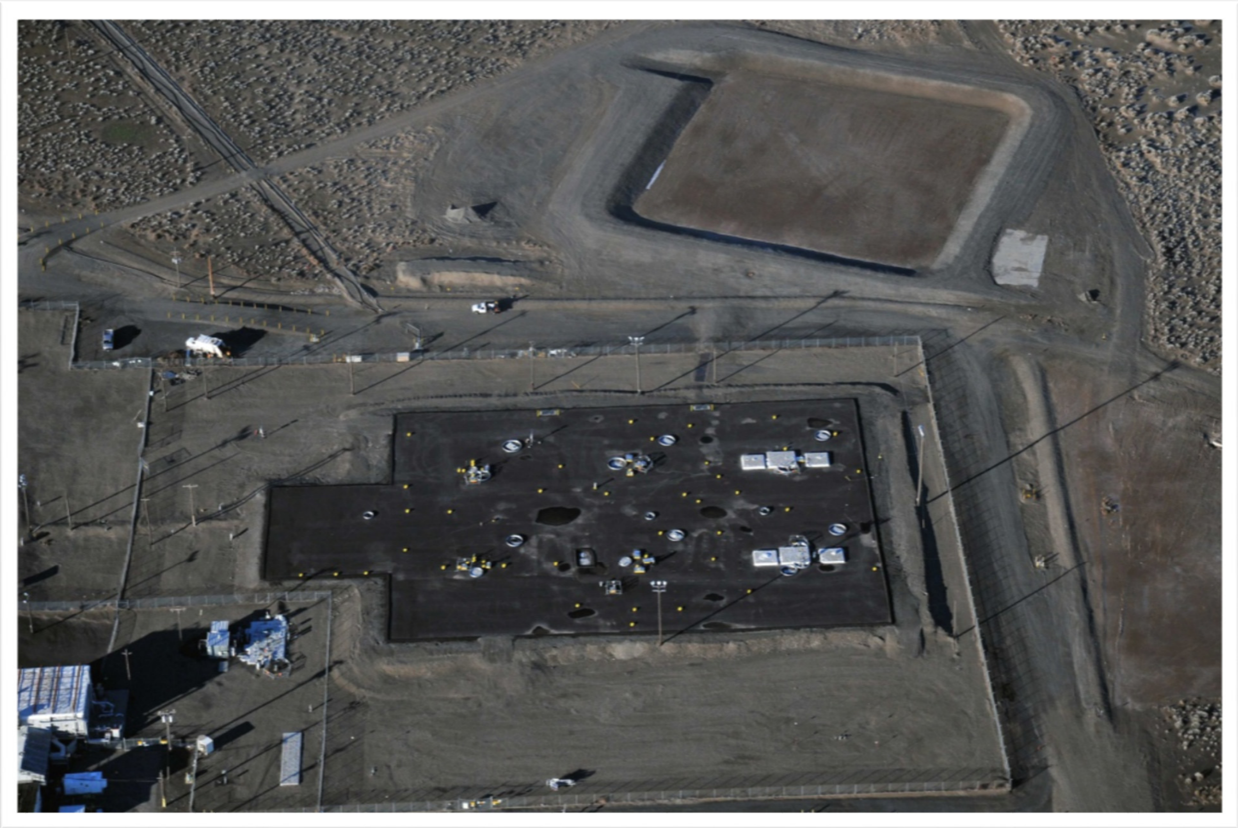
Figure 3-7. Shotcrete Cover over UPR-200-E-82.

Reduction of the infiltration over a contaminated area generally results in a delay of peak mobile contaminant concentrations reaching groundwater, thereby resulting in a reduction of future peak concentrations in the groundwater. Additionally, the isolation barrier will serve to isolate site workers from shallow soil contamination, minimizing potential exposure to future site workers pending placement of the final closure cap over WMA C.

The design of the infiltration barrier system in conjunction with isolations barriers at UPR-82 and UPR-86 would take into account a number of factors related to effectiveness, constructability, durability, and maintainability. For example, the effectiveness of an infiltration barrier system is a function of a number of factors including barrier permeability, barrier size, geologic conditions, water disposal, and the depth of the mobile contaminants. These factors would be considered in the design process.

Design of the infiltration barriers would include design of the subgrade to establish sufficient slope to direct storm water for collection and conveyance to a discharge location. The design of the subgrade could be extended to cover the tank features remaining above-grade after component closure (e.g., risers) but would require a substantial volume of fill material.

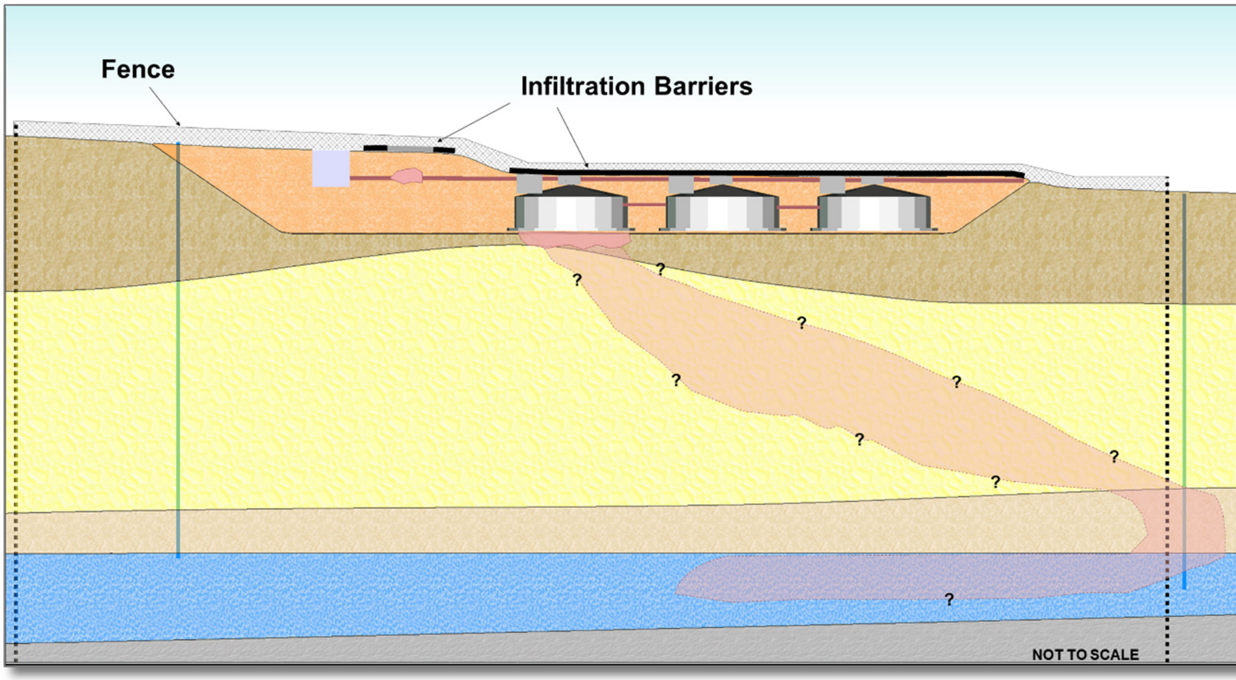
Figure 3-8. Modified-Asphalt Barrier and Evapotranspiration Basin at 241-TY Tank Farm.



The storm water from the infiltration barrier would be routed away from WMA C to limit storm water discharges near adjacent waste sites. Water disposal could occur via a number of options and those options would be evaluated as part of the design process. For purposes of this CMS, it is assumed that an evapotranspiration basin will be constructed for water disposal. The conceptual site model for this alternative is shown in Figure 3-9.

Given the uncertainties associated with the depth and lateral extent of the mobile contaminants at WMA C, the footprint for the infiltration barrier is assumed to cover the 100-series tanks and the UPRs on the upper portion of C Farm (UPR-81, UPR-82, and UPR-86). The infiltration barrier over the 100-series tanks would have a footprint of approximately 450×500 ft. The barriers over UPR-82 and UPR-86 and the French drain (216-C-8) would be a combination of an isolation barrier directly over the UPRs and a modified-asphalt barrier constructed around the isolation barrier to extend the footprint. A general concept for the infiltration barrier footprint is shown in Figure 3-10.

Figure 3-9. Conceptual Site Model for Alternative 4.



In addition to the construction steps described for isolation barriers in Section 3.3.3, construction of the infiltration barrier system portion of this alternative involves the following.

- Establishing the drainage subgrade within the footprint of the interim barrier through a combination of cut and fill. Any regrading of the existing WMA surface could disturb potentially contaminated material and would be minimized to the extent practicable. Constructing a subgrade over the 100-series tanks to establish a 1% slope would require approximately 20,000 cubic yards of fill material. Commercial earthwork equipment would be used to haul, place, and compact the fill material. Water would be used to aid in compaction and control dust but use would be controlled to avoid mobilizing contamination.

- Installing a storm water collection and conveyance system. This could disturb potentially contaminated material, and the design of the storm water collection and conveyance system would minimize this disturbance to the extent practicable.

- Constructing the interim surface barrier. The modified asphalt would be placed using commercial paving equipment.

- The final design of the infiltration barrier system would include features for disposition of storm water runoff. For the purpose of alternative development, an evapotranspiration basin northeast of WMA C was assumed. The evapotranspiration basin would be sized to accommodate the barrier runoff. The evapotranspiration basin would be located to limit excavation in contaminated areas and to allow gravity drainage to the basin if possible.

The actual method to be used to dispose of storm water would be established during the barrier design phase.

3.3.5 Alternative 5 – Excavation

This alternative consists of selective removal of contaminated soils at three target areas within WMA C. The three target areas include UPR-81, UPR-82, and UPR-86 where the highest concentrations of COCs in the shallow soil have been observed and exceed action levels by 3 to 7 orders of magnitude.

It is assumed contaminated soils would be treated if/as required to meet the ERDF waste acceptance criteria and transported to ERDF for disposal. Excavation efforts would be delimited by the assumed limit of technology for surface-based excavation of 12 m (40 ft) bgs. The 12-m (40-ft) depth was selected for the purposes of discussion as an achievable depth using commercially available means and methods (e.g., maximum depth of excavation for a commercially available CAT® 336D long-reach excavator is 12.8 m [42 ft]). The 12-m (40-ft) excavation depth provides for removal of contaminated soil from the shallow zone along with contamination that has migrated below the shallow zone. After removal, clean backfill would be placed in the excavation locations to restore the C Farm surface.

Removal of contaminated soils from WMA C was previously evaluated in RPP-RPT-49111, "Evaluation of Standard Contaminated Soil Removal Technologies at Single-Shell Tank Waste Management Area C." This report was developed to support evaluation of potential corrective measure technologies. Site-specific conditions and inventories associated with UPRs at WMA C were used to evaluate technologies and controls that would be needed for removing contaminated soil.

Two options for controlling the radiological dose to workers while excavating contaminated soil include adding shielding (steel and lead glass) to the excavation equipment or modifying the equipment so it can be remotely operated. Given the worker dose rates estimated in RPP-RPT-49111 of up to 3,300 mrem/hr and the potential to encounter higher than anticipated contamination levels, it is assumed that remotely-operated excavation equipment would be used.

Preliminary estimates of potential air emissions and air dispersion modeling performed in RPP-RPT-49111 identified the TEDE to the hypothetically maximally exposed off-site individual as 3.69 mrem/yr. The TEDE for unabated emissions resulting from excavation of contaminated soil is based on a number of assumptions documented in RPP-RPT-49111. Based on the TEDE, it is assumed that design features would be required to reduce exposure to radioactive air emissions from excavation of contaminated soil. Air emissions would conceptually be controlled by using a containment enclosure with a high-efficiency particulate air filtration system to provide ventilation and minimize potential air emissions.

Remotely-operated equipment would require an operator control station and additional cameras and lighting in and around the excavation area. Remotely-operated excavation equipment is commercially available in a variety of sizes and with different attachments available to support both excavation of soils and demolition of piping and utilities, as required. However,

commercially-available equipment would likely need to be modified to address tank farm-specific requirements. For example, additional skid plates and provisions to prevent any fluid losses would likely be needed, and radiation sensors would likely be installed to provide real-time dose and contamination levels during excavation.

It is assumed that extensive operator training would be required prior to using remotely-operated excavation equipment, somewhat similar to the training needed for the operation of remotely-operated tank waste retrieval equipment, and that production rates would be lower than using conventional manned equipment. The use of remotely-operated excavation equipment would likely not preclude the need for remediation personnel to enter the site to support management of the waste containers, and confirmatory sampling. Also, equipment repair and maintenance activities would need to be adequately planned to limit worker exposures.

Excavation design would be performed on a location-specific basis with consideration of infrastructure in the excavation area. For alternative development, the excavation design for the first 4.6 m (15 ft) would use standard layback of 1.5:1, and that from 4.6 m (15 ft) to 12.2 m (40 ft) sheet piling would be used to support the excavation. This combination limits the overall footprint of the excavation and the size of the confinement structure. It is assumed that excavation activities would work around underground infrastructure to the extent practicable and would not remove any major infrastructure (e.g., pipe trenches, tanks, diversion boxes) stabilized with grout during component closure.

This alternative would result in removing shallow soil contamination from the three UPRs that pose the highest direct-contact risk. The conceptual site model for this alternative is shown in Figure 3-11.

The Phase 2 RFI report notes that the extent of contamination found around UPR-82 indicates that ^{137}Cs was fairly constrained laterally and limited to relatively shallow depths. Additionally, ^{99}Tc was detected in shallow, intermediate, and deep vadose zone. Conversely, ^{99}Tc concentrations were at approximately 24 m (80 ft) bgs, suggesting that the mobile contaminants have migrated at least 24 m (80 ft) bgs and possibly deeper.

Based on the available characterization data, an excavation footprint of 19.8×24.4 m (65×80 ft) would be sufficient to remove the majority of the shallow contaminated soils associated with each of the target excavation areas: UPR-81, UPR-82, and UPR-86. With a standard layback of 1.5:1, this would provide for an excavation footprint of 6.1×6.1 m (20×20 ft) at a depth of 4. m (15 ft) with an allowance for an equipment access ramp. After reaching the 4 m (15 ft) excavation depth, a sheet pile retention wall would be installed to support continued excavation to a depth of 12.2 m (40 ft) bgs. This would allow for confirmatory sampling to be conducted and continued excavation below the 4 m (15 ft) depth if necessary based on contamination levels.

Given the subsurface pipelines, the potential for high dose rates, and proximity to below-grade structures (vaults and diversion boxes), a combination of methods is anticipated for removing contaminated soil. Segments of the transfer lines within the excavation area would require removal to facilitate equipment operation. These lines would be crimped and sheared at the face of the excavation and placed into disposal boxes. A site-specific design would be developed for

each location that would establish the necessary footprint for the temporary confinement structure, provide ingress/egress routes for personnel and equipment, and detail waste container handling areas and methods.

As described in the technology screening, excavation activities are intrusive and would require a Process Hazards Analysis (PrHA) to identify and evaluate hazards. Additional Technical Safety Requirements may be required to maintain safe operations of the facility. Any of the systems, structures, or components that are defined as important to safety (safety class or safety significant) identified in the PrHA will result in increased costs associated with the additional rigor for design, procurement, construction, and startup.

Unanticipated conditions (e.g., higher than anticipated contamination levels) and equipment failures will need to be considered during the design phase in order to provide the necessary flexibility to complete planned removal actions. Real-time monitoring along with contamination control practices would be needed to manage work activities.

Field implementation would include the following actions.

- Construct a temporary enclosure over each excavation area with airlocks for personnel and equipment entry and exit. The enclosure will be sized to accommodate the anticipated footprint of the excavation with some contingency allowing for an increase of the footprint based on field conditions. Figure 3-12 shows an example of a fabric-covered enclosure by RUBB Building Systems of Sanford, Maine.

- Install a ventilation system with high-efficiency particulate air filtration to maintain the interior of the enclosure at a slight negative pressure and control potential air emissions.

- Install electrical power distribution for lighting ventilation and monitoring systems from existing site utilities or from the use of a temporary generator. Electrical power could be obtained by tying into existing nearby electrical service or by utilizing temporary portable generators.

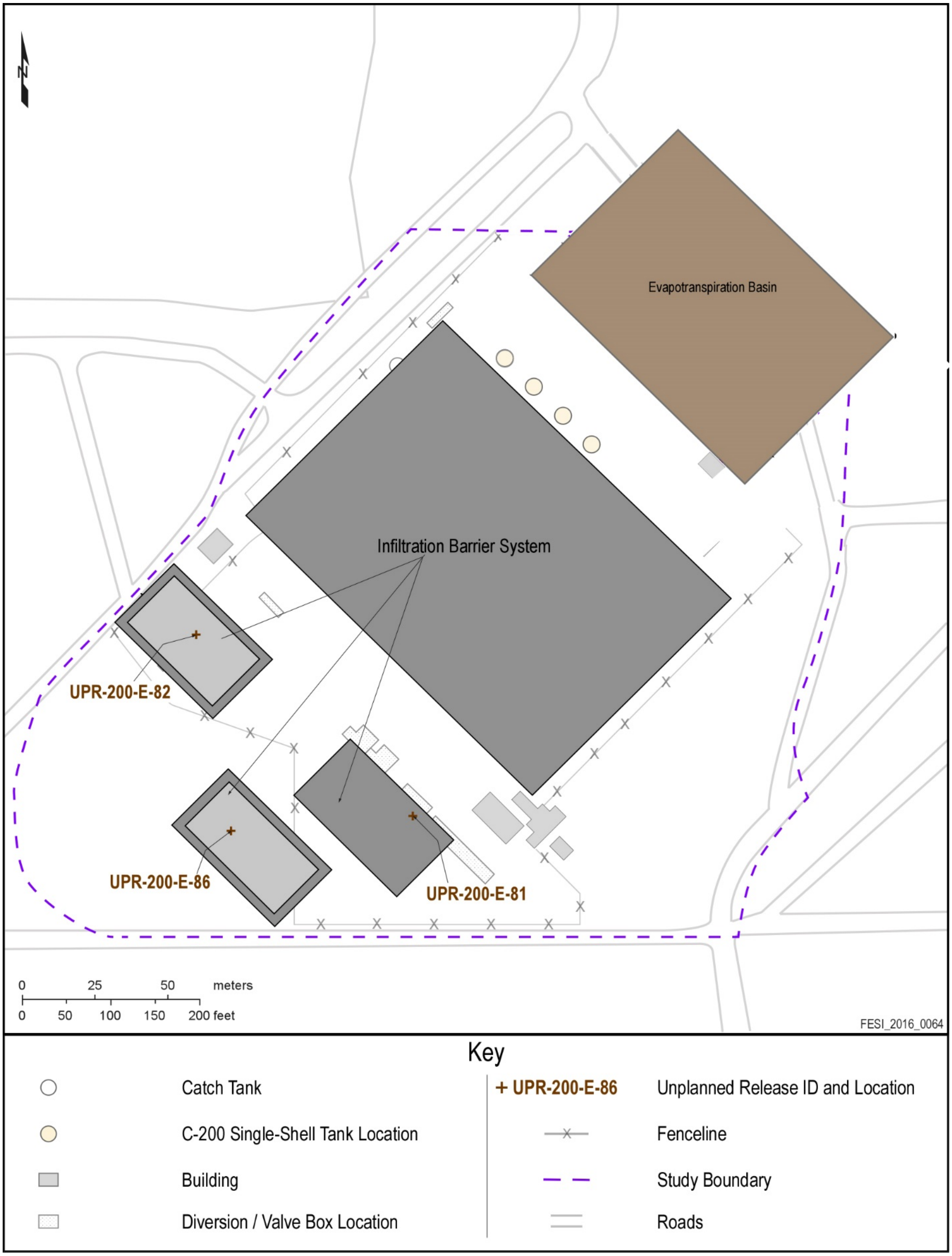
- Establish a container transfer area (CTA) for managing transfer of containers with contaminated materials out of C Farm. Once the containers inside of the confinement tent are filled, they would be transferred into the CTA for survey, decontamination of the exterior surfaces if/as required, sampling and analysis, and staging while shipping documentation is completed.

- Install a control trailer for remote equipment operations.

- Implement a safety program and environmental monitoring program to support excavation activities, before initiating operations.

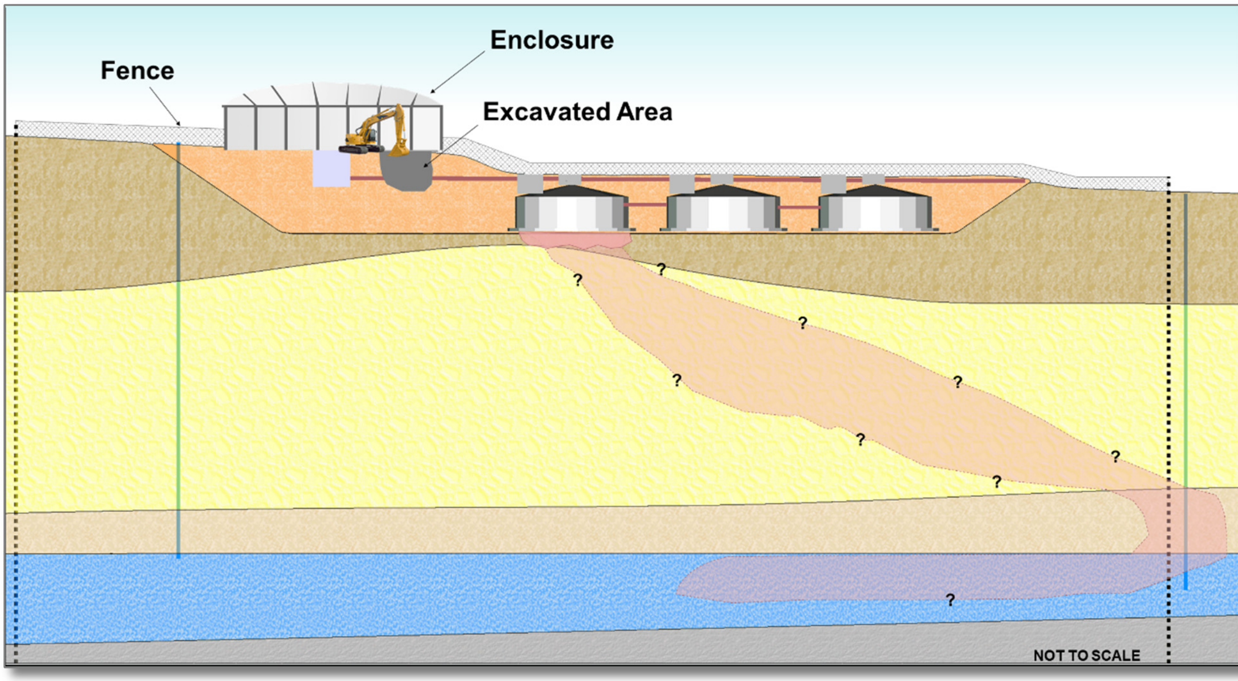
- Remove soil using remotely-operated excavation equipment, and place it into roll on/roll off containers. A variety of methods are anticipated to minimize contamination spread during excavation including water fogging and spray-on fixatives for dust suppression (e.g., dust bond from D&D Emulsions, Inc. of Mansfield, Ohio).

1 **Figure 3-10. Alternative 4 Conceptual Infiltration Barrier System Footprint.**
2



3

Figure 3-11. Conceptual Site Model for Alternative 5.



- Treat where required to meet ERDF waste acceptance criteria, contaminated soils and debris with macro-encapsulation prior to transfer to the CTA.
- Transfer waste containers from the confinement enclosure to the CTA for staging.
- Crimp and shear direct-buried pipe encountered in the excavation and place into a dedicated disposal box using readily-available demolition attachments for excavators. To meet void-fill requirements, the disposal box will be filled with self-consolidating grout before shipment to ERDF.
- Establish the extent of the excavation with confirmatory surveys.
- Place and compact clean fill to reestablish the grade at the completion of excavation activities.
- Dismantle the enclosures, which will be contaminated after soil removal activities and transport them to ERDF for disposal.

Based on available data, it is difficult to quantify how much of the leak inventory would be removed through shallow excavation at the three UPRs. At each of the three target UPRs the releases originated at a transfer line and the peak concentrations of non-mobile gamma contamination (i.e., ^{137}Cs) are expected to remain in the upper 4.3 m (15 ft) (RPP-ENV-33418).

Figure 3-12. Example RUBB Building Systems Fabric-Covered Enclosure.

For purposes of this evaluation, it is assumed that most of the non-mobile inventory would be recovered through shallow excavation. At UPR-81 the peak gamma concentration was observed at a depth of approximately 3.4 m (11 ft). At UPR-82 most of the non-mobile inventory is anticipated to range from 0.6 to 6 m (2 to 20 ft) below grade. Little of the mobile inventory (COCs for groundwater protection) would be recovered though shallow excavation. Based on available data and the time that has elapsed since the leak events occurred, most of the mobile inventory has migrated below the shallow excavation zone.

3.3.6 Alternative 6 – Excavation + Infiltration Barrier System

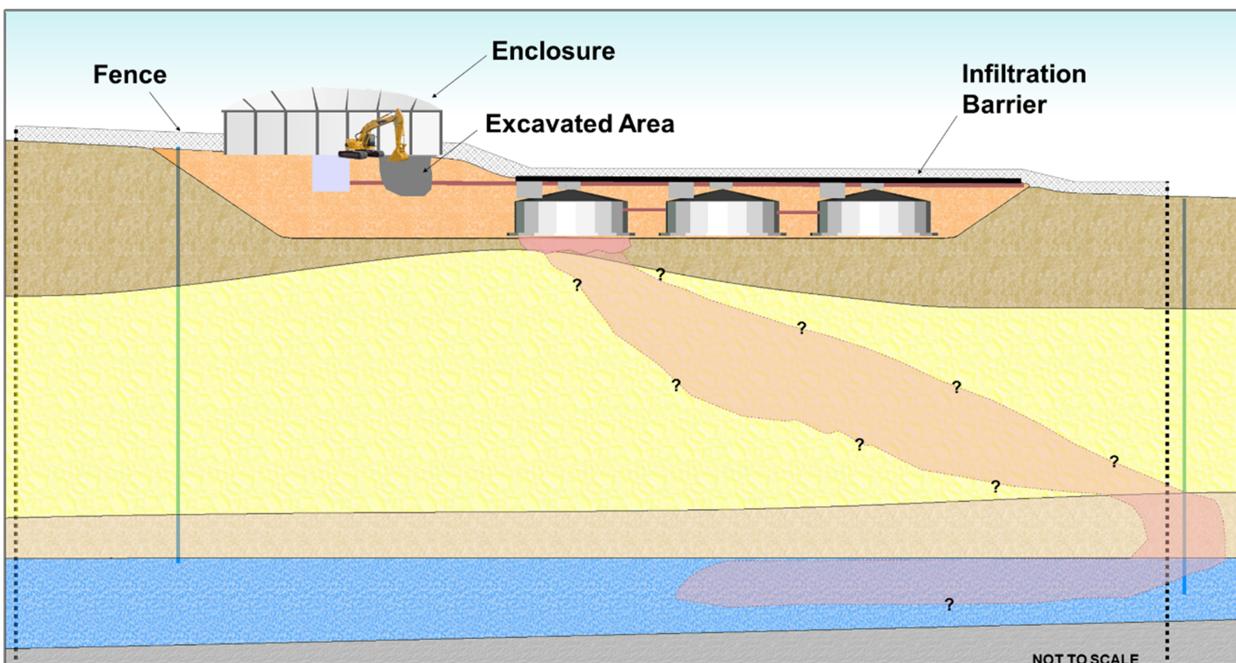
This alternative consists of a combination of the actions taken for Alternatives 3 and 4. Shallow contaminated soils will be removed at three target areas within WMA C. The three target areas include UPR-81, UPR-82, and UPR-86 where the highest concentrations of COCs in the shallow soil have been observed and the maximum concentrations exceed action levels by 3 to 7 orders of magnitude.

Contaminated soils would be treated if/as required to meet the ERDF waste acceptance criteria and transported to ERDF for disposal. Excavation efforts would be limited to the assumed limit of technology for surface-based excavation of 12 m (40 ft) bgs. After completing removal activities, clean backfill would be placed in the excavation locations to restore the C Farm surface.

After backfill and removal of the containment structures, a modified-asphalt interim surface barrier would be constructed over the UPR locations and over the 100-series tanks. The footprint of the modified-asphalt barrier would be the same as shown in Figure 3-10 for Alternative 4. After the removal action at the UPRs there would no longer be a need to install an isolation barrier, so the infiltration barrier system would cover the entire UPR areas.

This alternative would result in removing shallow soil contamination from the three UPRs that pose the highest direct-contact risk and construct an infiltration barrier to reduce infiltration in an effort to limit groundwater impacts. The conceptual site model for Alternative 6 is illustrated in Figure 3-13.

Figure 3-13. Conceptual Site Model for Alternative 6.



4.0 EVALUATION OF CORRECTIVE MEASURES ALTERNATIVES

This section describes the evaluation criteria and provides a detailed analysis of the performance or acceptability of each alternative. The alternatives were evaluated against a set of evaluation criteria followed by a comparative analysis, so relative strengths and weaknesses may be identified. Alternatives were developed from technologies that were screened against three criteria, effectiveness, implementability, and cost. However, no alternatives were identified that would meet all of the corrective action objectives fully.

4.1 EVALUATION CRITERIA

The evaluation criteria described in this section were used to analyze the corrective measures alternatives. The evaluation criteria identified in Table 4-1 are consistent with RPP-PLAN-39114, and derived from guidance provided by EPA in OSWER Directive 9902.3-2A, CERCLA guidance, and MTCA. Section 4.2 compares the performance of each alternative against the others, relative to the criteria, so that a recommendation for the preferred alternative for corrective measures implementation can be made (Section 5.0).

Table 4-1. Summary of Evaluation Criteria.

Effectiveness	
Overall Protection of Human Health and the Environment	The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment.
Compliance with Applicable or Relevant and Appropriate Requirements	The assessment against this criterion describes how the alternative complies with applicable or relevant and appropriate requirements, or if a waiver is required and how it is justified. The assessment also addresses other information from advisories and guidance that the lead and support agencies have agreed is “to be considered.”
Long-Term Effectiveness	The assessment of alternatives against this criterion evaluates the effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met.
Reduction of Toxicity, Mobility, or Volume	The assessment against this criterion evaluates the anticipated performance of the specific technologies an alternative may employ.
Short-Term Effectiveness	The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.
Implementability	
Implementability	This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.
Cost	
Cost	This assessment evaluates the capital and operations and maintenance costs of each alternative.

4.1.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment is the primary requirement that corrective actions must meet under RCRA. This evaluation criterion is an assessment of whether each alternative achieves and maintains short-term and long-term protection from unacceptable risks posed by contaminants. Alternatives are protective by eliminating, reducing, or controlling exposure through applicable exposure pathways. Overall protection of human health and the environment draws on the assessments of the other evaluation criteria, especially long-term effectiveness, short-term effectiveness, and compliance with ARARs (Appendix D). The alternative's ability to reduce overall risk to human health and the environment is the measure of this standard; risk is further discussed in Section 4.2.

4.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Evaluation with respect to this criterion addresses whether an alternative will meet identified ARARs (as defined in CERCLA, Section 121 and Appendix D of this CMS). The detailed analysis summarizes the requirements that are applicable or relevant and appropriate for each alternative and describes how the alternative meets those requirements. If an alternative is not anticipated to achieve compliance with a given ARAR, the basis for justifying the noncompliance can be based on the following:

- The alternative is an interim measure that would become part of a total corrective action that would attain the applicable or relevant and appropriate Federal or State requirement

- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives

- Compliance with the requirement is technically impracticable from an engineering perspective

- The alternative would attain a standard of performance that is equivalent to that required under the otherwise applicable standard or requirement.

4.1.3 Long-Term Effectiveness

Once the CAOs are met, long-term effectiveness is a criterion used to evaluate the ability of the alternatives to maintain reliable protection of human health and the environment. Alternatives will be assessed for the long-term effectiveness they afford, along with the degree of certainty that the alternative will prove successful. The following factors are considered in this assessment.

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial activities, including their volume, toxicity, and mobility.

- The adequacy, reliability, and durability of controls, such as containment systems and institutional controls, necessary to manage treatment residuals and untreated waste. For

example, this factor addresses uncertainties associated with land disposal for providing long-term protection from residuals, the assessment of the potential need to replace technical components of the alternative, such as a treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

4.1.4 Reduction of Toxicity, Mobility, or Volume

This criterion focuses on the degree to which the alternatives employ techniques, such as treatment technologies, that are capable of eliminating or substantially reducing the inherent potential for the waste to cause future environmental releases or other risks to human health and the environment. This evaluation relates to the statutory preference for selecting an alternative that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. This evaluation includes a comparison of initial site conditions to anticipated post-corrective measure conditions.

4.1.5 Short-Term Effectiveness

This criterion focuses on short-term effects of the alternatives by examining the effectiveness in protecting human health and the environment during the construction and implementation phase. The following analysis factors are considered:

- Short-term risks that might be posed to the community;
- Potential risks or hazards to workers, and the effectiveness and reliability of protective measures; and
- Potential adverse environmental impacts and the effectiveness and reliability of mitigation measures.

4.1.6 Implementability

Implementability relates to the technical and administrative feasibility of executing an alternative, and the availability of various services and materials required during its implementation. The ease or difficulty of implementing the alternative is assessed by considering the following:

- Technical feasibility, including technical difficulties and unknowns associated with constructing and operating the technology, reliability of the technology, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy;
- Administrative feasibility, including activities required to coordinate with other offices and agencies and the ability and time needed to obtain any necessary approvals and permits for off-site actions from other agencies; and

- Availability of required materials and services, personnel, resources, and technologies necessary to construct and operate the alternative.

4.1.7 Cost

The cost estimates presented in this CMS are based on a conceptual level of alternatives development and support a relative comparison of costs between alternatives. The cost estimates are based on a variety of information, including cost quotes from vendors and service providers, generic unit costs, conventional cost-estimating guides, and actual cost data from Hanford projects. The cost estimates included in this CMS have been prepared for guidance in project evaluation and implementation from information available at the time of the estimate.

The base year for alternative costs is 2016. Additional detail on the cost estimates is provided in Appendix E.

The cost estimate for each corrective measure alternative typically includes the following items:

- Annual costs for maintaining institutional controls;
- Design costs including preparation of design drawings and specifications, construction bid documents, work planning, safety evaluations;
- Regulatory and permitting costs associated with implementing an alternative;
- Construction costs including construction management, capital equipment, general and administrative costs, and construction subcontract costs and fees;
- Estimated operating, maintenance, and performance monitoring and reporting costs for the duration of the corrective measures;
- Equipment replacement costs;
- Project management; and
- Alternative oversight costs.

Rough order of magnitude (ROM) estimated costs for implementing Alternatives 3 through 6 are described in Appendix E and summarized in Section 4.3. These ROM costs were calculated to include markups, taxes, and contingencies, and are further calculated for accuracy in a range of -30% to +50%, per EPA guidance in EPA 540-R-00-002, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. The estimated costs of the corrective measures alternatives are compared with each other in Section 4.3. For cost estimate details, refer to Appendix E.

4.2 ALTERNATIVES EVALUATION

This section analyzes each alternative defined in Section 3.0 against the evaluation criteria described in Section 4.1. Evaluation results provide semi-quantitative ratings for how well each alternative performs against each criterion. Those results are summarized for each alternative in in the following sections.

The rating process used for the individual analyses follows a semi-quantitative system that ranks the performance of each alternative against the evaluation criteria. The semi-quantitative system uses a rating scale of 0 to 5 in which a rating of "0" indicates the alternative does not satisfy the standard in any way, a rating of "1" indicates the lowest performance, and a rating of "5" indicates the highest performance. The estimated costs are presented for each alternative but are not rated, since no standard has been established for cost performance.

Cost estimate summaries are also presented for each alternative. Detailed cost estimate information is presented in Appendix E.

4.2.1 Alternative 1 – No Action

Alternative 1 provides a baseline against which other alternatives can be compared. This alternative is retained throughout the alternative selection process. Preliminary design details and cost estimates are not prepared for Alternative 1. Alternative 1 would provide no overall protection of human health and the environment for the following reasonable maximum exposure (RME) receptor scenarios considered for WMA C:

- Industrial,
- Maintenance,
- Trespasser Youth,
- Resident, and
- Native American.

Plants and animals would be exposed to contaminants. This alternative would do nothing to mitigate the migration of contaminants to groundwater. Given that "no action" does not meet the requirements of the criteria, information is not included regarding the performance of this alternative with respect to the criteria.

This alternative assumes no institutional controls for WMA C (i.e., institutional controls currently in place would not be maintained, and no corrective measures would be performed). Because corrective measures would not be implemented with the "no action" alternative, long-term human health and environment risks for the site essentially would be the same as those identified in the BRA.

Table 4-2 provides a summary of evaluation results for the "no action" alternative. A detailed cost estimate is presented in Appendix E. That estimate presents a summary of the remedial components, areas, and volumes that were assumed for each UPR in development of cost estimates. Based on the Alternative 1 "no action" work scope, no direct costs are associated with this alternative.

Table 4-2. Individual Analysis of Alternative 1 – No Action.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	0	Not anticipated to be protective of human health and the environment. Corrective action objectives will not be achieved. Has a potential for exposure to human and ecological receptors.
Compliance with Applicable or Relevant and Appropriate Requirements	0	Is not compliant. Since no action would occur, applicable or relevant and appropriate requirements for contaminated soil will not be met.
Long-Term Effectiveness	0	Alternative 1 does not meet the requirements of this criterion. Since no remedial action is performed, the alternative provides no additional protection of human health or environment.
Reduce Toxicity, Mobility, or Volume	0	Alternative 1 does not meet the requirements of this criterion. Since no remedial action would occur, no change in the toxicity, mobility, or volume of contaminated soil would result.
Implementability	5	This alternative could easily be implemented.
Short-term Effectiveness	5	No field work would be required to implement this alternative, and no associated risks to human health and the environment.

4.2.2 Alternative 2 – Institutional Controls

This alternative provides for ongoing institutional controls and maintenance activities (i.e., housekeeping activities). No remedial action would be performed to reduce the existing risks to human health or environment.

4.2.2.1 Overall Protection of Human Health and the Environment. Alternative 2 would provide control of site access and access to WMA C, limiting the potential receptor scenarios to the industrial and maintenance workers. Alternative 2 would fail to provide overall protection of human health and the environment for the industrial worker and maintenance worker RME receptor scenarios evaluated for WMA C. Soil concentrations in five of the ten exposure areas addressed in the BRA would have human health risks above the upper risk threshold of 1.0×10^{-4}. Institutional controls would be relied on to prevent direct contact exposures to elevated shallow soil contamination present in UPR-81, UPR-82, and UPR-86.

Ongoing practices (i.e., herbicide application and fencing) to control vegetation and maintain the tank farm would support limiting plant and animal exposure to contaminants. These practices would manage the potential ecological risks and spread of contaminants.

Alternative 2 is not anticipated to reduce future impacts to groundwater from past releases. Based on the results of the BRA groundwater protection evaluation, the maximum concentration of ^{99}Tc in groundwater from past releases is predicted in approximately 2019 and will exceed DWSs, as defined in Title 40, CFR, Part 141, "National Primary Drinking Water Regulations" (40 CFR 141), by a factor of 10.

4.2.2.2 Compliance with Applicable or Relevant and Appropriate Requirements. The ARARs and TBCs identified for applicability to this alternative are presented in Table D-1 in Appendix D Activities conducted under this alternative would be designed to meet ARARs, with the exception of those ARARs that are protective of groundwater.

4.2.2.3 Long-Term Effectiveness. This alternative includes institutional controls for exposure and "long-term" management measures. It is assumed that implementation of this alternative would result in continued institutional controls though completion of the final closure cap over WMA C. Since no actions are taken under this alternative, the existing soil contamination would remain in place. Institutional controls are relied on to provide worker protection.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume. This alternative provides no features or actions to reduce the toxicity, mobility, or volume of contaminated soil.

4.2.2.5 Short-Term Effectiveness. No physical actions are necessary to implement this alternative, so no impact would be incurred by site workers or the public.

4.2.2.6 Implementability. This alternative can be readily implemented by continuing to maintain existing institutional controls.

4.2.2.7 Cost. Costs estimated for this alternative are related to the continuation of "minimum safe operations." The estimated costs for Alternative 2 are based on an estimated fraction of the overall tank farm contract for base operations. Detailed estimated costs are presented in Appendix E. Table 4-3 lists the ROM costs estimated for Alternative 2. Table 4-3 also includes accuracy calculations that range from -30% to +50%.

Table 4-3. Summary of Alternative 2 Estimated Costs.

Costs	Estimated Costs
Total + Markups & Contingencies	$1,370,000
+50% Accuracy Range Total	$2,060,000
-0.30% Accuracy Range Total	$959,000

4.2.2.8 Alternative 2 – Evaluation Summary. Table 4-4 summarizes the evaluation results for Alternative 2.

4.2.3 Alternative 3 – Isolation Barriers

This alternative provides for isolation of areas where shallow soil contamination exceeds threshold concentrations for protection of human health. Isolation barriers placed at the surface of the WMA provide an engineered feature to make the contaminated soils inaccessible to site workers, thereby reducing the direct-contact exposure pathway. However, this alternative will not prevent direct-contact exposure protection to ecological receptors.

4.2.3.1 Overall Protection of Human Health and the Environment. This alternative provides a physical barrier to isolate locations within WMA C where the shallow contaminant concentrations in soil are greater than action levels. Implementation of the alternative would not require intrusion into the shallow contaminated soils. Isolation barriers will minimize the risk associated with external gamma radiation such that Alternative 3 would meet the requirements for the overall protection of human health and the environment associated with shallow vadose zone contamination. Based on a minimum of a 4-inch-thick concrete cover, the maximum risk for the 10 exposure areas under the industrial worker scenario is 2.0×10^{-14}, which is well below the acceptable risk range of 1.0×10^{-4} to 1.0×10^{-6}. In addition, based on field measurements for ^{137}Cs of 470 million picoCuries per gram (pCi/g) at UPR-82, the isolation barrier would reduce the risk to the industrial worker to approximately 1.0×10^{-6}, which equals the lower range of the acceptable risk limit. These risks were assessed in RPP-CALC-61238.

Table 4-4. Individual Analysis of Alternative 2 – Institutional Controls.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	3	Not anticipated to be protective of human health and the environment. Institutional controls would be used to control site access, and support planning that includes using workers to perform task-specific work procedures and personnel monitoring to manage potential worker exposure to contamination. Has a potential for human and ecological receptor exposure to contamination.
Compliance with Applicable or Relevant and Appropriate Requirements	2	Is not compliant. Since no corrective action would occur, applicable or relevant and appropriate requirements for contaminated soil would not be met.
Long-Term Effectiveness	1	Alternative 2 fails this criterion. Existing institutional controls would be maintained pending placement of the final closure cap over Waste Management Area (WMA) C.
Reduce Toxicity, Mobility, or Volume	0	Alternative 2 fails this criterion. No actions would be taken to reduce the toxicity, mobility, or volume of contaminated soil.
Implementability	5	Alternative 2 would be easily implemented and consists of a continuation of existing processes and procedures at WMA C.
Short-term Effectiveness	5	Alternative 2 would require limited worker activities to provide minimum safe conditions.

Isolation barriers over UPR-81, UPR-82, and UPR-86 would provide greater reduction in risk to the RME worker than the isolation barrier over the tank area.

Isolation barriers would not prevent access by ecological receptors to the three UPRs or other areas not scoped within this alternative. Continuation of institutional controls would maintain current practices for vegetation and animal control, limiting the potential exposure to contaminants. Ecological receptors could potentially transfer contaminants to the surface.

Alternative 3 would not reduce future impacts to groundwater from past releases. Based on the results of the groundwater protection evaluation, the maximum concentration of ^{99}Tc in

groundwater from past releases is predicted around 2019, and will exceed DWSs (40 CFR 141) by a factor of 10.

4.2.3.2 Compliance with Applicable or Relevant and Appropriate Requirements. Implementation of this alternative would be non-intrusive and would limit exposures to shallow soil contamination. The ARARs and TBCs identified for applicability to this alternative are presented in Table D-1 in Appendix D. Activities conducted under this alternative would be designed to meet ARARs, with the exception of those ARARs that are protective of groundwater.

4.2.3.3 Long-Term Effectiveness. This alternative includes permanent features to control direct-contact exposures to site workers. While corrective measures applied under this alternative are intended to be able to remain effective until the final closure cap is installed, the isolation barriers would not need to be removed and would remain in place under the closure cap. It is assumed that implementing this alternative would be effective from the beginning of installation (approximately 2020) to installation of the final closure cap (approximately 2050). The final closure cap will provide the long-term effectiveness required. The isolation barriers would provide additional defense-in-depth for mitigating the risks from inadvertent intrusion after placing the final closure cap.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume. This alternative would reduce the potential for site workers to be exposed to contaminated soils at WMA C.

4.2.3.5 Short-Term Effectiveness. Actions taken under this alternative are all above the existing grade and do not require disturbing contaminated media. This alternative can be implemented in a manner that is protective of human health and the environment. Implementation of this alternative would require approximately one year to complete, if selected, after publishing the decision document.

4.2.3.6 Implementability. This alternative can be readily implemented using standard construction materials and practices.

4.2.3.7 Cost. The estimated costs for implementing Alternative 3 include markups, taxes, and contingencies. These ROM costs were calculated per EPA guidance in EPA 540-R-00-002, with an accuracy ranging from -30% to +50%, as shown in Table 4-5. These estimated costs are compared with those of the other alternatives in Section 4.3. For cost estimate details, refer to Appendix E.

Table 4-5. Summary of Alternative 3 Estimated Costs.

Costs	Estimated Costs
Total + Markups & Contingencies	$4,640,000
+50% Accuracy Range Total	$6,960,000
-0.30% Accuracy Range Total	$3,250,000

4.2.3.8 Alternative 3 – Evaluation Summary. Table 4-6 summarizes the evaluation results for Alternative 3.

Table 4-6. Individual Analysis of Alternative 3 – Isolation Barriers.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	4	Partially protective of human health and the environment. Eliminating soil direct-contact risk associated with unplanned release contaminated areas will be achieved. Effective for long-term protection from direct-contact exposures in shallow soil.
Compliance with Applicable or Relevant and Appropriate Requirements	3	Implementation would be non-intrusive and would limit exposures to shallow contamination.
Long-Term Effectiveness	3	Isolation barriers would provide long-term deterrence to intrusion after Waste Management Area (WMA) C closure.
Reduce Toxicity, Mobility, or Volume	1	Alternative 3 would isolate contaminated soils at WMA C and reduce the potential for inadvertent direct contact by site workers.
Implementability	5	Anticipated to be very effective in the short term. Although little exposure risk is posed to site workers, this alternative will provide immediate reduction in exposure risk from direct contact with shallow soils.
Short-term Effectiveness	5	Anticipated to be very implementable. Conventional equipment is used to construct the isolation barriers.

4.2.4 Alternative 4 – Isolation Barriers + Infiltration Barrier System

Alternative 4 includes placement of isolation barriers over select UPRs and an infiltration barrier over areas with soil contamination levels that exceed thresholds for protection of human health or environment. The infiltration barriers would reduce infiltration into the contaminated soils after placement. Storm water would be collected and routed away from WMA C for disposal. This alternative includes continuation of institutional controls.

4.2.4.1 Overall Protection of Human Health and the Environment. This alternative provides a physical barrier to isolate locations within WMA C where the shallow contaminant concentrations are greater than action levels. Implementation of the alternative would not require intrusion into the shallow contaminated soils. Isolation barriers will minimize the risk associated with external gamma radiation such that Alternative 3 would meet the requirements for the overall protection of human health and the environment associated with shallow vadose zone contamination.

Based on a minimum of a 4-inch-thick cover, the maximum risk for the ten exposure areas under the industrial worker scenario is 2.0×10^{-14}, which is well below the acceptable risk range of 10^{-4} to 10^{-6}. In addition, based on field measurements for ^{137}Cs of 470 million pCi/g at UPR-82, the barriers would reduce the industrial worker risk to approximately 1.0×10^{-6}, which equals the lower range of the acceptable risk limit. These risks were assessed in calculation RPP-CALC-61238.

Isolation barriers over UPR-81, UPR-82, and UPR-86 would provide greater reduction in risk to the RME worker than the isolation barrier over the tank area.

Isolation barriers would not prevent access by ecological receptors to areas that were not covered by an isolation barrier. Continuation of existing institutional controls would include vegetation and animal control to limit potential exposures to ecological receptors. A potential exists for ecological receptors to bring contaminants to the surface.

Alternative 4 would not reduce future peak impacts to groundwater from past releases. The infiltration barrier system would reduce the infiltration rate after placement, and therefore reduce the movement of mobile contaminants within the effective depth of the barrier. However, there would be little to no effect on mobile contaminants from past leaks that have migrated to below the barrier's effective depth. The results of groundwater protection evaluation showed that the maximum concentration for ^{99}Tc in groundwater will occur in approximately 2019 (RPP-RPT-58329). The results also show that the maximum ^{129}I concentration will exceed its corresponding DWS (40 CFR 141) in approximately 6,000 years.

During this evaluation, the infiltration barrier system is assumed to be installed in approximately 2020. That means the maximum concentrations for the mobile contaminants in the groundwater will have occurred before placement of the infiltration barrier system. With the planned placement of the final closure cap over WMA C in approximately 2050, implementation of this alternative would provide for reduced infiltration conditions for a period of 30 years before placement of the final closure cap. However, given the uncertainty in when a final closure cap would actually be installed, the infiltration barrier system could provide for reduced infiltration conditions for a longer time period.

4.2.4.2 Compliance with Applicable or Relevant and Appropriate Requirements. Implementation of this alternative would be non-intrusive and would limit exposures to shallow soil contamination. The ARARs and TBCs identified for applicability to this alternative are presented in Table D-1 in Appendix D. Activities conducted under this alternative would be designed to meet ARARs, with the exception of those ARARs that are protective of groundwater.

4.2.4.3 Long-Term Effectiveness. This alternative includes physical features to control direct-contact exposure to site workers. Corrective measures applied under this alternative would be maintained to limit direct-contact exposures and infiltration rates until the final cap is installed. Corrective measures offered by this alternative are assumed to be effective from the beginning of installation (approximately 2020) to the installation (approximately 2050) of the final closure cap. The final closure cap will satisfy the level of long-term effectiveness required.

4.2.4.4 Reduction of Toxicity, Mobility, or Volume. This alternative reduces the potential for exposing site workers to contaminated soils and reduces the mobility of mobile and lower-mobility contaminants by limiting the infiltration rate in the vadose zone beneath the barrier.

4.2.4.5 Short-Term Effectiveness. Actions taken under this alternative are mainly above the existing grade and may not require disturbing contaminated media. Limited excavation would be

required to install the storm water collection system and drain lines from the infiltration to the evapotranspiration basin. Excavations may encounter contaminated soil. Implementation of this alternative would require approximately 2 to 3 years to complete, if selected, after publishing the decision document.

4.2.4.6 Implementability. This alternative can be readily implemented using standard construction materials and practices.

4.2.4.7 Cost. The estimated costs for implementing Alternative 4 include markups, taxes, and contingencies. These ROM costs were calculated per EPA guidance in EPA 540-R-00-002, with an accuracy ranging from -30% to +50%, as shown in Table 4-7. These estimated costs are compared with those of the other alternatives in Section 4.3. For cost estimate details, refer to Appendix E.

Table 4-7. Summary of Alternative 4 Estimated Costs.

Costs	Estimated Costs
Total + Markups & Contingencies	$27,400,000
+50% Accuracy Range Total	$41,100,000
-0.30% Accuracy Range Total	$19,200,000

4.2.4.8 Alternative 4 – Evaluation Summary. Table 4-8 summarizes the evaluation results for Alternative 4.

4.2.5 Alternative 5 – Excavation

Alternative 5 includes removal of contaminated soils from UPR-81, UPR-82, and UPR-86. Excavation activities would be performed using remotely operated equipment inside of an enclosure designed to control airborne contamination. This alternative includes continuation of institutional controls.

4.2.5.1 Overall Protection of Human Health and the Environment. Over the long term, this alternative provides a long-term reduction in the risk to human health posed through direct contact with shallow soil contamination at the three target UPR locations. However, during excavation activities using remotely controlled excavation equipment, the risk of exposure to contamination increases significantly.

The risk to the on-site worker involved in implementing this alternative includes operation of the remote equipment, handling and managing containerized waste and maintenance of the equipment. These activities would involve exposing workers to radiological contamination. A radiological dose rate survey of the excavated soil will be recorded. The contaminated soil will be loaded into a waste container if dose rate limits are not exceeded. If the dose rate limits are reached, the contaminated soil will be loaded into multiple waste containers.

Table 4-8. Individual Analysis of Alternative 4 – Isolation Barriers + Infiltration Barrier System.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	4	Partially protective of human health and the environment. Eliminating soil direct-contact risk associated with unplanned releases will be achieved. Provides infiltration barrier to reduce infiltration and provide some reduction in contaminant migration.
Compliance with Applicable or Relevant and Appropriate Requirements	3	Not effective in meeting media cleanup objectives or standards for groundwater protection. Implementation of the barriers is non-intrusive and would limit exposures to near-surface contamination. Implementation of the evapotranspiration system would require excavation of potentially contaminated soils to install the evapotranspiration basin and the drain lines from the infiltration barrier to the basin.
Long-Term Effectiveness	3	Effective for long-term protection from direct-contact exposures from shallow soil contamination. Not effective for limiting groundwater impacts from contaminants that have migrated to depth.
Reduce Toxicity, Mobility, or Volume	2	Alternative 4 would isolate contaminated soils at Waste Management Area C and reduce the potential for inadvertent direct contact by site workers. The infiltration barriers would reduce infiltration and movement of mobile contaminants; however, there would be little to no effect on mobile contaminants from past leaks that have migrated to below the barrier effective depth.
Short-term Effectiveness	4	Effective in the short term. Construction activities are well understood. Provides near-term isolation of direct-contact exposure pathway.
Implementability	4	Alternative can be implemented using commercially-available materials and equipment.

Based on the conceptual site model for WMA C, most of the mobile contaminants from past leaks have migrated to a depth at which they would not be removed during soil excavation. Implementation of this alternative would provide little to no benefit in reducing infiltration and associated contaminant migration.

4.2.5.2 Compliance with Applicable or Relevant and Appropriate Requirements. Any corrective action implemented under this alternative would be designed to meet ARARs, with the exception of those protective of groundwater. The ARARs and TBCs identified for applicability to this alternative are presented in Table D-1 in Appendix D.

4.2.5.3 Long-Term Effectiveness. This alternative provides for long-term effectiveness in reducing direct-contact exposure risks from shallow contamination. Contaminated soil associated with the three UPR contaminated areas would be removed, packaged, and transported to an on-site disposal facility. Corrective measures applied under this alternative would remain effective until the final closure cap is installed. This alternative would mitigate the potential exposures from select UPR locations with elevated shallow surface contamination levels for the period between implementation and placement of the final closure cap. Corrective measures offered by this alternative would be effective from the time the excavation activities were completed (approximately 2020) to the time the final closure cap would be installed

(approximately 2050). The final closure cap will satisfy the long-term effectiveness level required.

4.2.5.4 Reduction of Toxicity, Mobility, or Volume. This alternative would excavate, package and dispose of contaminated soils from three UPRs having shallow soil contamination that is significantly higher than other contaminated soil locations within WMA C. These soils would be disposed of in an engineered landfill and the excavations within WMA C would be backfilled with clean fill.

4.2.5.5 Short-Term Effectiveness. Several hazards are posed by excavating highly contaminated soils at WMA C. A number of engineered features (e.g., remotely-operated equipment, highly-shielded waste boxes, positive ventilation controls), administrative controls, and protective measures would be required to implement this alternative in a manner that was protective of workers, the public, and the environment. Implementation of this alternative would require approximately 8 to 10 years to complete, if selected, after publishing the decision document.

4.2.5.6 Implementability. This alternative would be difficult to implement. While remote excavation is technically feasible using combinations of existing technology, deployment of this technology is unprecedented in a tank farm environment and would require a PrHA prior to implementation in accordance with DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.

4.2.5.7 Cost. The estimated costs for implementing Alternative 5 include markups, taxes, and contingencies. These ROM costs were calculated per EPA guidance in EPA 540-R-00-002, with an accuracy ranging from -30% to +50%, as shown in Table 4-9. These estimated costs are compared with those of the other alternatives in Section 4.3. For cost estimate details, refer to Appendix E.

Table 4-9. Summary of Alternative 5 Estimated Costs.

Costs	Estimated Costs (on-site disposal)	Estimated Costs (off-site disposal)
Total + Markups & Contingencies	$311,000,000	$478,000,000
+50% Accuracy Range Total	$467,000,000	$717,000,000
-0.30% Accuracy Range Total	$218,000,000	$335,000,000

4.2.5.8 Alternative 5 – Evaluation Summary. Table 4-10 summarizes the evaluation results for Alternative 5.

4.2.6 Alternative 6 – Excavation + Infiltration Barriers System

Alternative 6 includes removing contaminated soils from UPR-81, UPR-82, and UPR-86; placing infiltration barriers; and continuing institutional controls. Alternative 6 includes the

same removal action as described for Alternative 5 combined with the infiltration barriers described for Alternative 4.

Table 4-10. Individual Criteria Analysis of Alternative 5 – Excavation.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	3	Partially protective of human health and the environment. Shallow soils with contamination concentrations greater than action levels would be removed and dispositioned in an engineered landfill. No action would be taken to mitigate groundwater impacts.
Compliance with Applicable or Relevant and Appropriate Requirements	1	Not effective in meeting media cleanup objectives, or standards for soil contamination or groundwater protection. Implementation is intrusive and would generate high airborne contamination that would require air permitting and engineering controls.
Long-Term Effectiveness	1	Effective for long-term protection from direct contact exposures from shallow soil contamination. Not effective for limiting groundwater impacts. Effective in meeting performance goals, alternative would remove shallow soil contamination.
Reduction of Toxicity, Mobility, or Volume	3	Treatment limited to stabilization necessary to meet waste acceptance criteria. Ex situ stabilization (in disposal containers) would be performed as necessary to meet disposal facility waste acceptance criteria.
Short-term Effectiveness	1	Not effective in short-term. Design and operation of remotely-operated excavation system is complex and requires administrative and engineered controls.
Implementability	1	Difficult to implement. Cutting-edge technology deployment in a tank farm environment would require extensive technical evaluation to define requirements, design systems and equipment, test, and operate.

Excavation activities would be performed using remotely-operated equipment inside of an enclosure designed to control airborne contamination. Excavated material would be packaged and treated as necessary to meet waste acceptance criteria and transported to a disposal facility.

After removal actions are completed, infiltration barriers would be constructed over the UPRs and over areas in the tank farm where shallow soil contamination levels exceed thresholds for protection of human health and the environment. The infiltration barriers would reduce infiltration into the contaminated soils after placement. Storm water would be collected and routed away from WMA C for disposal.

4.2.6.1 Overall Protection of Human Health and the Environment. Over the long term, this alternative provides a reduction in the risk to human health posed through direct contact with UPR soil contamination and reduces future groundwater impacts. However, during excavation activities using remotely-controlled excavation equipment, the risk of exposure to contamination increases significantly.

The increased risk to the on-site worker includes excavation, obtaining radiological dose rates on the excavated soil and treatment. A radiological dose rate survey of the excavated soil will be

recorded. The contaminated soil will be loaded into a waste container if dose rate limits are allowable. If dose rate limits are reached, the contaminated soil will be loaded into multiple waste containers.

Alternative 6 would not reduce future impacts to groundwater from past releases. The infiltration barriers would reduce the infiltration rate after placement. However, little to no effect would be apparent on mobile contaminants from past leaks that have migrated to depth. The results of groundwater protection evaluation showed that the maximum concentration for ^{99}Tc in groundwater will occur in approximately 2019 (RPP-RPT-58329). The results also showed that the maximum concentration for ^{129}I will exceed its corresponding DWS (40 CFR 141) in approximately 6,000 years. During this evaluation, the barrier is assumed to be installed in approximately 2020. That means the maximum concentrations for the mobile contaminants in the groundwater will have occurred before placement of the barrier. With the planned placement of the final closure cap over WMA C in approximately 2050, implementation of this alternative would provide for reduced infiltration conditions for a period of 30 years before placement of the final closure cap.

4.2.6.2 Compliance with Applicable or Relevant and Appropriate Requirements. Any corrective action implemented under this alternative would be designed to meet ARARs, with the exception of those protective of groundwater. The ARARs and TBCs identified for applicability to this alternative are presented in Table D-1 in Appendix D.

4.2.6.3 Long-Term Effectiveness. This alternative provides for long-term effectiveness in reducing direct-contact exposure risks from shallow contamination. Contaminated soil associated with the three UPRs would be removed, packaged, and transported to an on-site disposal facility. Corrective measures applied under this alternative would remain effective until the final cap is installed. Corrective measures offered by this alternative are assumed to be effective from the completion of alternative implementation (approximately 2020) to the beginning installation of the final closure cap (approximately 2050). The final cap will provide the long-term effectiveness requirements. This alternative provides for long-term effectiveness in reducing groundwater impacts by placing an infiltration barrier at the WMA surface.

4.2.6.4 Reduction of Toxicity, Mobility, or Volume. This alternative would excavate, package, and dispose of contaminated soils from three UPRs with shallow soil contamination that is locally higher than other contaminated soil locations within WMA C. These soils would be disposed of in an engineered landfill and the excavations within WMA C would be backfilled with clean fill.

The infiltration barrier installed over areas of WMA C reduces the potential for exposing site workers to contaminated soils and reduces the mobility of mobile and lower-mobility contaminants by limiting the infiltration rate in the vadose zone beneath the barrier.

4.2.6.5 Short-Term Effectiveness. Several hazards are posed by excavating highly contaminated soils at WMA C. A number of engineered features (e.g., remotely operated equipment, highly shielded waste boxes, positive ventilation controls), administrative controls, and protective measures would be required to implement this alternative in a manner that was protective of workers, the public, and the environment. Implementation of this alternative would

require approximately 8 to 10 years to complete, if selected, after publishing the decision document.

4.2.6.6 Implementability. The shallow soil removal portion of this alternative would be difficult to implement. While technically feasible using combinations of existing technology, deployment of this technology is unprecedented in a tank farm environment. This would require a PrHA prior to implementation in accordance with DOE-STD-1027-92.

The infiltration portion of this alternative can be readily implemented using standard construction materials and practices.

4.2.6.7 Cost. The estimated costs for implementing Alternative 6 include markups, taxes, and contingencies. These ROM costs were calculated per EPA guidance in EPA 540-R-00-002, with an accuracy ranging from -30% to +50%, as shown in Table 4-11. These estimated costs are compared with those of the other alternatives in Section 4.3. For cost estimate details, refer to Appendix E.

Table 4-11. Summary of Alternative 6 Estimated Costs.

Costs	Estimated Costs (on-site disposal)	Estimated Costs (off-site disposal)
Total + Markups & Contingencies	$336,000,000	$505,000,000
+50% Accuracy Range Total	$504,000,000	$758,000,000
-0.30% Accuracy Range Total	$235,000,000	$354,000,000

4.2.6.8 Alternative 6 – Evaluation Summary. Table 4-12 summarizes the evaluation results for Alternative 6.

4.3 COST ESTIMATING SUMMARY

Table 4-13 summarizes estimated cost totals with markups, taxes, and contingencies, with accuracy ranges of -30% to +50%, per EPA 540-R-00-002. In addition, costs for Alternatives 5 and 6 indicate estimated costs for both on-site (ERDF) and off-site (Waste Control Specialists) disposal. These costs are used to evaluate each of the corrective measures alternatives. Cost estimate details are presented in Appendix E.

4.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the results of a comparative analysis used to compare the corrective measures alternatives using the results of the Section 4.2 alternatives evaluation. Table 4-14 summarizes those results and provides a comparative performance rating for each corrective measures alternative. The numerical values assigned to each alternative reflect how well the alternatives would be anticipated to perform against each criterion. The alternatives are

comparatively ranked based on the degree of how well each criterion is met, especially with respect to protectiveness.

Table 4-12. Individual Criteria Analysis of Alternative 6 – Excavation + Infiltration Barrier System.

Criterion	Rating	Analysis Summary
Overall Protection of Human Health and the Environment	4	Partially protective of human health and the environment. Shallow soils associated with three unplanned releases (UPRs) with highly elevated levels of contamination would be removed and disposed of in an engineered landfill. Infiltration barrier would be installed to reduce infiltration and reduce contaminant migration.
Compliance with Applicable or Relevant and Appropriate Requirements	1	Not effective in meeting media cleanup objectives, or standards for soil contamination or groundwater protection. Implementation is intrusive and would generate high airborne contamination and require air permitting and engineering controls.
Long-Term Effectiveness	3	Effective for long-term protection from direct contact exposures from shallow soils. Not effective for limiting groundwater impacts. Effective in meeting performance goals; alternative would remove shallow soil contamination.
Reduction of Toxicity, Mobility, or Volume	4	Highly contaminated soils associated with target UPR locations would be excavated and replaced with clean fill. The shallow soil inventory associated with the three UPRs would be removed from Waste Management Area C. Mobility is reduced by limiting water infiltration and mobile contaminants; however, the infiltration barrier will have little to no effect on reducing migration of mobile contaminants that have migrated below the barrier effective depth.
Short-term Effectiveness	1	Not effective in short-term. Design and operation of remotely-operated excavation system is complex and requires administrative and engineered controls. The infiltration barrier can be implemented in a manner that is effective in the short term; construction activities are well understood.
Implementability	1	Difficult to implement. Emerging technology deployment in a tank farm environment would require a Process Hazards Analysis, potential development of technical safety requirements, design of equipment and systems, and testing before operation.

The composite scores in Table 4-14 indicate that the two barrier alternatives, Alternatives 3 and 4, provide the highest overall score for performance across the comparative analysis. After the barrier alternatives, Alternative 2 receives the next highest score, which reflects the ability of the existing work planning practices to control potential worker exposures to contaminated soils at WMA C.

As a result of the comparative analysis, minor variations of the anticipated performance are apparent between Alternatives 3 and 4. Both are anticipated to perform well in isolating workers from direct-contact exposure from shallow soil contamination. An estimated 30 years is anticipated over which corrective measures would be in effect, pending placement of the final closure cap. During this time, routine monitoring and maintenance of tank farm conditions

would occur, but no substantial field activities (e.g., waste retrieval, equipment replacement) are planned as part of implementing Alternatives 3 and 4.

Table 4-13. Summary of Rough Order of Magnitude Estimated Costs.

Analysis Criteria	Alternatives							
	1	2	3	4	5		6	
	No Action	Institutional Controls	Isolation Barriers	Isolation + Infiltration Barriers	Excavation (on-site disposal)	Excavation (off-site disposal)	Excavation + Infiltration Barriers System (on-site disposal)	Excavation + Infiltration Barriers System (off-site disposal)
Total with Markups	$0	$1.37	$4.64	$27.4	$311	$478	$336	$505
-30% Accuracy Range	$0	$0.96	$3.25	$19.2	$218	$335	$235	$354
+50% Accuracy Range	$0	$2.06	$6.96	$41.1	$467	$717	$504	$758

Alternative 4 scored slightly higher than Alternative 3 for the reduction of toxicity, mobility, or volume criterion, as the infiltration barrier is anticipated to provide some level of mitigation to future groundwater impacts from mobile and lower mobility contaminants. Infiltration barrier placement would provide infiltration control for an estimated 30 years, until final closure cap placement. Based on the results of the BRA's past leak assessment, the groundwater impacts from past leaks at WMA C are anticipated to peak in approximately 2019. An infiltration barrier constructed as a corrective measure would not reduce peak groundwater impacts from past leaks but may reduce future impacts associated with lower-mobility contaminants such as ^{129}I and U.

Alternative 3 scored slightly higher than Alternative 4 for the short-term effectiveness and implementability criteria. Although both alternatives are constructed above grade and do not require disturbing the subsurface contaminated soils, the isolation barrier is simpler to implement than the infiltration barrier. The infiltration barrier requires grading fill to establish a slope and excavation for the evapotranspiration basin and drain lines between the infiltration barrier and the evapotranspiration basin.

The scores define how well each corrective measures alternative would perform against the evaluation criteria in Table 4-1. The criteria are given equal weight in determining the total score for each alternative. A sensitivity analysis was performed to assess whether an alternative ranking would change, if the evaluation criteria were weighted, based on relative importance. The sensitivity analysis involved assigning a value of 1, 2, or 3 (low, medium, or high, respectively) to each criterion using a value-based weighting factor to reflect the importance of

the analysis criterion to the evaluator. An example case is provided in Table 4-15 to illustrate the application of the weighting factors.

The weighting values were then normalized, multiplied by the values in Table 4-14 to obtain weighted scores, and then summed to compare the alternative ranking. Several cases were evaluated applying different weighting values. The two barrier alternatives (Alternatives 3 and 4) consistently ranked the highest regardless of how the evaluation criteria were weighted. The results of the sensitivity analysis demonstrate that the alternative ranking is not sensitive to differences in the relative importance of the analysis criteria.

Table 4-14. Comparative Analysis Summary.

Analysis Criteria		Alternatives							
		1	2	3	4	5		6	
		No Action	Institutional Controls	Isolation Barriers	Isolation + Infiltration Barriers	Excavation (on-site disposal)	Excavation (off-site disposal)	Excavation + Infiltration Barriers System (on-site disposal)	Excavation + Infiltration Barriers System (off-site disposal)
Protection of Human Health & Environment		0	3	4	4	3		4	
Applicable or Relevant and Appropriate Requirements Compliance		0	2	3	3	1		1	
Long-Term Effectiveness		0	1	3	3	1		3	
Reduce Contaminant Toxicity, Mobility, & Volume		0	0	1	2	3		4	
Short-Term Effectiveness		5	5	5	4	1		1	
Implementability		5	5	5	4	1		1	
Scores		**10**	**16**	**21**	**20**	**10**		**14**	
Cost	Total with Markups	$0	$1.37	$4.64	$27.4	$311	$478	$336	$505
	-30% / +50% Accuracy Range	$0 / $0	$0.96 / $2.06	$3.25 / $6.96	$19.2 / $41.1	$218 / $467	$335 / $717	$235 / $504	$354 / $758

Table 4-15. Summary of Alternatives Sensitivity Analysis.

Criteria	Non-Weighted Rankings of Alternatives						*Weighting Factors*	*Normalized*	Criteria	Weighted Rankings of Alternatives					
	1	2	3	4	5	6				1	2	3	4	5	6
	No Action	Institutional Controls	Isolation Barriers	Isolation + Infiltration Barriers	Excavation	Excavation + Infiltration Barrier System				No Action	Institutional Controls	Isolation Barriers	Isolation + Infiltration Barriers	Excavation	Excavation + Infiltration Barrier System
Protection of Human Health & Environment	0	3	4	4	3	4	3	0.231	Protection of Human Health & Environment	0.00	0.69	0.92	0.92	0.69	0.92
ARARs Compliance	0	2	3	3	1	1	3	0.231	ARARs Compliance	0.00	0.46	0.69	0.69	0.23	0.23
Long-Term Effectiveness	0	1	3	3	1	3	1	0.077	Long-Term Effectiveness	0.00	0.08	0.23	0.23	0.08	0.08
Reduce Toxicity, Mobility, & Volume of Contaminants	0	0	1	2	3	4	2	0.154	Reduce Toxicity, Mobility, & Volume of Contaminants	0.00	0.00	0.15	0.31	0.46	0.61
Short-Term Effectiveness	5	5	5	4	1	1	1	0.077	Short-Term Effectiveness	0.38	0.38	0.38	0.31	0.08	0.08
Implementability	5	5	5	4	1	1	3	0.231	Implementability	1.15	1.15	1.15	0.92	0.23	0.23
Scores	10	16	21	20	10	14	2	1	Scores	1.54	2.77	3.54	3.38	1.77	2.30

ARAR = applicable or relevant and appropriate requirement

5.0 PREFERRED ALTERNATIVE

The CMS alternative recommendation for WMA C is Alternative 4 - Isolation Barriers + Infiltration Barrier System. Alternative 4 would mitigate identified, unacceptable risks to human health and the environment. The combination of isolation barriers over near-surface contamination along with infiltration barrier system over the widely distributed contamination in WMA C will protect the workers and will also provide for long-term groundwater protection. The combination will also mitigate the risk at the exposure areas that exceeded the acceptable risk range, but were not a direct contact risk so not covered with an isolation barrier. The infiltration barrier system has a larger footprint than the isolation barrier to control infiltration and manage runoff.

Based on application of a 15-cm (6-inch) thick concrete isolation barrier, the maximum risk is 2.0×10^{-14} for the 10 BRA exposure areas under the industrial worker scenario, which is considerably less than the acceptable risk range from 10^{-4} to 10^{-6}. In addition, based on ^{137}Cs measurements of 470 million pCi/g at UPR-82, applying an isolation barrier would reduce the risk to approximately 10^{-6} for the industrial worker. These calculations indicate the risk of exposure to ^{137}Cs at the lower range of the acceptable risk limit.

The placement of an infiltration barrier system would provide additional isolation and infiltration mitigation in areas of WMA C identified as potentially having widespread and near-surface contamination. Although the placement of an infiltration barrier system will not mitigate peak groundwater impacts, it will provide additional groundwater protection from the migration of contaminants within the effective depth of the barrier. Given the additional uncertainty of when a final closure cap would be installed at WMA C, the length of time over which the infiltration barrier system provides additional protection could be greater than the 30 years discussed in this CMS.

As noted above, Alternative 4 does not mitigate peak impacts to groundwater but will reduce flux of contaminants beneath the barrier to the groundwater that are within the effective depth of the barrier.

- Peak concentrations of ^{99}Tc in groundwater are anticipated to occur in approximately 2019, based on past leaks inventory predictions. These peak concentrations potentially would exceed DWSs (40 CFR 141) by tenfold.

- Over the next few decades, nitrate would potentially continue to threaten and reach groundwater beneath WMA C.

- Groundwater impacts from ^{129}I as predicted to occur in approximately 6,000 years are calculated to be slightly greater than DWSs as defined in 40 CFR 141.

- Analysis of past leaks has assumed that chromium contamination in groundwater is represented by the mobile hexavalent form. However, hexavalent chromium has not been confirmed in groundwater at WMA C. Therefore, chromium in past leak inventories likely is the reduced, less mobile trivalent chromium.

- Based on their affinity to adsorb to Hanford formation sediments, lead and uranium are not anticipated to reach groundwater in concentrations that would exceed DWSs as defined in 40 CFR 141.

Alternative 4 was selected from among the six alternatives developed for this CMS, listed as follows:

- Alternative 1 – No Action,
- Alternative 2 – Institutional Controls,
- Alternative 3 – Isolation Barriers,
- Alternative 4 – Isolation Barrier + Infiltration Barrier System,
- Alternative 5 – Excavation, and
- Alternative 6 – Excavation + Infiltration Barrier System.

These alternatives were developed as a result of a technology screening process, which identified technologies to be used to develop corrective measures alternatives that would address soil contamination in the shallow vadose zone. No technologies were identified that would be effective for practicably reducing peak groundwater impacts from mobile contaminants associated with WMA C past leaks. Given the depth and distribution of mobile contaminants in the vadose zone, no remediation technologies were identified that would be effective at reducing peak groundwater impacts. The groundwater protection evaluation presented in the BRA indicates that mobile contaminants associated with past leaks have already reached the groundwater, and contaminant concentrations in groundwater are anticipated to peak in approximately 2019.

The performance of the six corrective measures alternatives defined in Section 3.0 was evaluated and compared in Section 4.0. This information along with the cost estimate summaries for each of the alternatives provides a basis for selection of the preferred alternative and recommendation of a path forward.

The two barrier alternatives, Alternative 3 and 4, both resulted in overall performance scores that were nearly identical. The cost for implementing Alternative 4 is higher than Alternative 3 due to the additional cost associated with establishing a sloped subgrade under the barrier and installing the storm water collection and disposal features. The additional costs associated with Alternative 4 would provide features to limit water infiltration above contaminated soils. In general, this would serve to slow the migration of mobile contaminants. Given the site-specific conditions at WMA C, near-term infiltration barrier placement would occur after the anticipated peak impact and would not be effective for mobile contaminants below the effective depth of the barrier. However, given the uncertainty with contaminant distributions within the vadose zone and uncertainties in timing of the final closure cap, placement of an infiltration barrier would reduce the overall flux of contaminants to groundwater that are within the effective depth of the barrier.

Based on the outcome of the comparative analysis presented in Section 4.4, and the estimated cost for implementation, Alternative 4 provides the greatest overall protection of human health and the environment and short-term effectiveness. Alternative 4 balances applicable corrective

measures selection criteria in a way that meets CAOs and best complies with the identified ARARs.

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6.0 REFERENCES

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40 CFR 268, "Land Disposal Restrictions," Code of Federal Regulations, as amended.

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Code of Federal Regulations, as amended.

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APPENDIX A

HFFACO MILESTONE CHANGE NUMBER M-45-14-03

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Figure A-1. HFFACO Milestone Change Number M-45-13-03 (page 1 of 2).

Change Number M-45-14-03	**Federal Facility Agreement and Consent Order** **Change Control Form** Do not use blue ink. Type or print using black ink.	**Date** 09/29/2014

Originator
Thomas W. Fletcher, DOE-ORP

Phone
(509) 376-3434

Class of Change
[ ] I - Signatories [X] II - Executive Manager [ ] III - Project Manager

Change Title

Modification of TPA milestone M-045-61 into two separate milestones

Description/Justification of Change

The existing milestone is for a combined RFI/CMS Report. This change separates the single report into a stand-alone draft Phase 2 RCRA Facility Investigation (RFI) Report, and a later Phase 2 Corrective Measures Study (CMS) and an update to the RFI Report for WMA C to be submitted at a later date.

Impact of Change

Change clarifies that this draft RFI Report will be Draft A. The submittal of a Draft A RFI Report on the original milestone date allows incorporation of Ecology comments on Draft A, while waiting for the completion of the WMA C Performance Assessment.

In accordance with HFFACO Action Plan Section 9.2.1, a revised draft RFI Report (Rev 0) will be prepared based on Ecology review comments on Draft A. Rev 0 will also address: (a) data gaps identified in Draft A and (b) the WMA C Performance Assessment prepared in accordance with HFFACO Action Plan Appendix I. The Rev 0 RFI Report will be updated to include:

- A summary of all sources of contamination remaining in WMA-C, including but not limited to soil, surface structures and all ancillary equipment,
- Impacts from existing soil contamination and structures in the WMA C area of interest,
- Reference to other documents that provide the details on those sources of contamination (e.g. Retrieval Data Reports, Leak Loss reports).

Affected Documents

The HFFACO as amended and Hanford Site internal planning, management, and budget documents (e.g., River Protection Project System Plan, Baseline Control documents, and related work authorizations and directives).

Approvals

DOE [signature]	Date 9/30/14	X Approved	___ Disapproved
EPA N/A	Date ___	___ Approved	___ Disapproved
Ecology [signature]	Date 10/1/2014	✓ Approved	___ Disapproved

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Figure A-1. HFFACO Milestone Change Number M-45-13-03 (page 2 of 2).

Change Control Form M-45-14-XX
Page 2 of 2

Specific changes to Tri-Party Agreement Appendix D are displayed with double underline to indicate addition of text and by ~~strikeout~~ to indicate deletion of text.

Number	Milestone	Due Date
M-045-61	Submit to Ecology ~~for review and approval as an Agreement~~ in accordance with HFFACO secondary document review process, a Phase 2 RCRA Facility Investigation~~/Corrective Measures Study~~ Report Draft A for WMA C.	12/31/2014
M-045-61A	Submit to Ecology for review and approval as an Agreement primary document, a Phase 2 Corrective Measures Study, and revision 0 update to the RFI Report for WMA C.	12/31/2016

APPENDIX B

ECOLOGICAL AND HUMAN HEALTH RISK ASSESSMENT CALCULATIONS

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LIST OF ENVIRONMENTAL MODEL CALCULATIONS

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ENVIRONMENTAL MODEL CALCULATION COVER PAGE

Section 1: Completed by Responsible Manager

0
RELEASE/ISSUE

Project: Waste Management Area C(WMA C)

Date: 11/17/2016

Calculation Title & Description: Radiological Risk Assessments for Exposure Areas Covered with Isolation Barrier and Nonradiological Risk Assessments for Three Unplanned Releases Under Industrial Worker Scenario

Section 2: Completed by Preparer

Calculation No.: RPP-CALC-61057 Revision No.: 0

Revision History

Revision No.	Description	Date	Affected Pages
0		11/17/2017	All

Section 3: Completed by Responsible Manager

Document Control

1. Is document intended to be controlled within SmartPlant? ☒ Yes ☐ No
2. Does document contain scientific and technical information intended for public use? ☒ Yes ☐ No
3. Does document contain controlled-use information? ☐ Yes ☒ No

Section 4: Training and Software Installation Approval (Completed Prior to Performing Calculation)

Modeler-Required Training Completed:

WE Nichols/Principal Engineer	[signature]	17 NOV 2016
Training Coordinator (Name/Position)	Signature	Date

Software Installation and Checkout Certified:

W E Nichols /Principal Engineer	[signature]	17 NOV 2016
Integration Lead (Name/Position)	Signature	Date

Section 5: Document Review & Approval

Md Mahmudur Rahman/Sr. Risk Assessor	M. Rahman	11/17/2016
Preparer (Name/Position)	Signature	Date
S. Lindberg/Sr. Risk Assessor	[signature]	11/17/2016
Checker (Name/Position)	Signature	Date
Doug Evans/Sr. Risk Assessor	Doug Evans	11/28/2016
Senior Reviewer (Name/Position)	Signature	Date
Andrea Hopkins/Env. Compliance/WRPS	[signature]	11/28/2016
Responsible Manager (Name/Position)	Signature	Date

A-6006-716 (REV 0)

Contents

Appendices

Tables

Terms

BRA	baseline risk assessment
COPC	contaminant of potential concern
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
EA	Exposure Area
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ELCR	Excess lifetime cancer risk
EMCF	Environmental model calculation file
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic model
IRIS	Integrated Risk Information System
µg/dl	micrograms per deciliter
K_d	distribution coefficient factor
MTCA	Model Toxics Control Act
ORNL	Oak Ridge National Laboratory
NJDEP	New Jersey Department of Environment Protection
OSWER	Office of Solid Waste and Emergency Response
pCi	pico-Curies
PEF	Particulate Emission Factor
RCRA	*Resource Conservation and Recovery Act of 1976*
RFI	RCRA Facility Investigation
RESRAD	RESidual RADioactivity computer code
RfC	reference concentration
RfD	reference dose
RSR	risk to source ratio
SF	Slope Factor
UPR	unplanned release

VF	volatilization factor
WAC	*Washington Administrative Code*
WMA	Waste Management Area

1 Purpose

This environmental model calculation file (EMCF) presents the results of a human health risk assessment that evaluates the risk associated with the exposure of soil radiological and nonradiological contaminants of potential concern (COPCs) under an industrial worker exposure scenario at Waste Management Area (WMA) C. The baseline risk assessment (BRA) report (RPP-RPT-58329, *Baseline Risk Assessment for Waste Management Area C*) indicates that the radiological total excess lifetime cancer risks (ELCRs) for an industrial worker are greater than the U.S. Environmental Protection Agency (EPA) upper risk threshold of 1×10^{-4} at five exposure areas (EAs) (A plus B, C, E, L1 plus L2 and P). It is noted that no type of cover was considered during the BRA. The results also showed that the external gamma pathway is the predominant exposure pathway for contaminated soils at WMA C. Therefore, several remedial alternatives such as isolation barriers and/or infiltration barriers are being considered to minimize the risk associated with the external gamma pathway in support of *RCRA Corrective Measure Study Report for Waste Management Area C*. Based on the design of the remedial alternatives, a 4-in. isolation barrier is being considered at each EA. Therefore, a radiological risk assessment was performed for the CERCLA industrial worker scenario to determine the impacts of a 4-in. barrier with respect to the total risk for each EA within WMA C.

High levels of radiological contamination are present at three unplanned release (UPR) locations within WMA C - 200-E-81 (UPR-81), 200-E-82 (UPR-82), and 200-E-86 (UPR-86). Due to safety concerns, no samples were collected and risk assessments were not performed at these UPR locations as part of the BRA. As part of this EMCF, nonradiological risk assessments of the three UPRs are presented for two receptor scenarios – (1) CERCLA industrial worker scenario; and (2) an adult industrial worker receptor scenario, defined in the Model Toxics Control Act (MTCA) Method C of the Cleanup Regulation Chapter 173-340 Washington Administrative Code (WAC). Radiological risk assessments of the three UPRs are presented in RPP-CALC-61238, *Radiological Risk Assessments for Three Unplanned Releases within Waste Management Area C*.

2 Background

The industrial worker exposure scenario is one of six CERCLA scenarios considered during the BRA to represent the range of receptors that could be exposed to COPCs in soil from WMA C. All exposure scenarios identified for evaluation at WMA C are described in RPP-RPT-47479, *Exposure Scenarios for the Waste Management Area C Performance Assessment*. It is noted that subsequent to the BRA the assigned exposure parameters for all exposure scenarios were updated in the following data package, RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*. However, to be consistent with the BRA, the updated values in RPP-ENV-58813 are not used in this risk assessment.

2.1 Exposure Areas (EAs) within WMA C Tank Farm

Consistent with the risk assessment approach of the BRA, site characterization data collected from 14 sampling locations within WMA C are grouped into 10 primary exposure areas (EAs). The EAs, their general locations within WMA C, and their Phase 2 characterization objectives are identified in Table 2-1.

3 Methodology

The section summarizes the risk assessment methodologies for both radiological and nonradiological contaminants.

3.1 Radiological Risk Assessment Methodologies

This section summarizes the methodology used to calculate cumulative ELCRs for radiological contaminants under the CERCLA industrial worker scenario. The ELCR is the incremental increase in the probability of developing cancer during an individual's lifetime in addition to the background probability of developing cancer.

During the BRA, the RESidual RADioactivity computer code (RESRAD) Version 6.5 (ANL, 2009) was utilized in part to determine the risk to an industrial worker at each EA. However, RESRAD version 7.0 (ANL, 2014) was used during this radiological risk assessment for each EA. The following describes each step of the radiological risk assessment process:

1. Enter RESRAD Input Parameters listed in Table 4-3 and Table 4-4 into the RESRAD model. For the source terms, input a unit concentration of 1 pCi/g for each COPC identified for each EA. It should be noted that the 4-in. concrete isolation barrier is used as the cover thickness during the calculation of radiological risk for each EA.
2. Run RESRAD and review the results to identify the year at which peak risk occurs.
3. Rerun RESRAD with time periods corresponding to years of peak risk (as necessary).
4. Open the Health Risk Report and obtain the pathway-specific and cumulative risk to source ratio (RSR) for each radiological COPC for year of peak risk within a time period of year 0, 41.3 (4-in. cover only), and year 1,000, and copy the results into a Microsoft Excel® workbook.
5. Multiply RSR results for all radiological COPCs by their corresponding EA-specific exposure point concentration (EPC) (Table 4-1) to calculate COPC-specific risks and add the results for each COPC-specific risk together to calculate the cumulative ELCR at year 0, year 41.3 (4-in. cover only), and year 1,000 for each EA.
6. For each EA, compare the maximum results of the cumulative ELCR with the acceptable risk criteria to identify whether unacceptable risks are present and if so, identify the primary risk contributors.

3.2 Nonradiological Risk Assessment Methodologies

Nonradiological risk assessment for each UPR was performed for the CERCLA industrial worker and MTCA Method C industrial worker scenarios. Methodologies performed for both receptors are summarized below.

3.2.1 Risk Assessment Methodologies for CERCLA Industrial Worker Exposure Scenario

An adult industrial worker is selected as a receptor to represent potential exposures for industrial land use, which is consistent with the current and anticipated future land use in the Inner Area of the Central Plateau at the Hanford Site. The direct contact and inhalation exposure pathways are considered potentially complete for the industrial worker exposure scenario. The receptor could potentially be exposed to shallow vadose zone material at depths ranging between 0 and 15 ft below ground surface (bgs). The magnitude of human exposure to chemicals in environmental media is usually described in terms of the chronic daily intake (CDI), which is the amount of chemical in contact with exchange surfaces of the body (e.g., skin, lungs, gastrointestinal tract). The specific formulas used to calculate exposure route-specific chronic daily intake for nonradiological COPCs are presented below. Parameter values are provided in Table 4-5.

® Microsoft Excel is a registered product of the Microsoft Corporation.

3.2.1.1 Intake, Cancer Risk, and Noncancer Hazard Equations for Incidental Ingestion of Soil

The following equation was used to calculate intake of chemicals from incidental soil ingestion and as documented in EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*, Exhibit 6-14:

$$\mathrm{CDI}\left(\frac{mg}{kg-day}\right)=\frac{\mathrm{C_s{\times}IR_s{\times}EF{\times}ED{\times}CF1{\times}FI}}{\mathrm{BW{\times}AT}}$$

Where:

CDI	=	chronic daily intake of chemical (mg/kg-day)
C_s	=	concentration of COPC in soil (mg/kg)
IR_s	=	ingestion rate for soil (mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF1	=	conversion factor (10^{-6} kg/mg)
FI	=	fraction of intake (unitless)
BW	=	body weight (kg)
AT	=	averaging time (days)

Cancer risk is calculated using the following equation as documented in EPA/540/1-89/002:

$$Risk = CDI{\times}CSF_o$$

Where:

Risk	=	excess lifetime cancer risk (unitless)
CDI	=	daily intake of chemical (mg/kg-day)
CSF_o	=	oral cancer slope factor $(\text{mg/kg-day})^{-1}$

Noncancer hazard is calculated using the following equation as documented in EPA/540/1-89/002:

$$HQ=\frac{CDI}{RfD_o}$$

Where:

HQ	=	hazard quotient (unitless)
CDI	=	daily chemical intake (mg/kg-day)
RfD_o	=	oral reference dose (mg/kg-day)

3.2.1.2 Intake, Cancer Risk, and Noncancer Hazard Equations for Inhalation of Dust and Vapors in Ambient Air

The equations used to calculate the exposure concentration (EC) of each COPC from the inhalation pathway are provided in EPA-540-R-070-002, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*, Equation 6. The equation used to estimate the exposure concentration for inhalation is as follows:

$$EC=\frac{CA{\times}ET{\times}EF{\times}ED}{AT{\times}CF2}$$

Where:

EC = exposure concentration (micrograms per cubic meter [ug/m^3])
CA = concentration of COPC in air (ug/m^3)
ET = exposure time (hours/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
AT = averaging time (days)
CF2 = conversion factor (24 hours/day)

Cancer risk is calculated using the following equation as documented in EPA-540-R-070-002 (Equation 11):

$$Risk = EC \times IUR$$

Where:

Risk = excess lifetime cancer risk (unitless)
EC = exposure concentration (μg/m^3)
IUR = inhalation unit risk (μg/m^3)$^{-1}$

Noncancer hazard is calculated using the following equation as documented in EPA-540-R-070-002 (Equation 12):

$$HQ = \frac{EC}{RfC \times 1000 \frac{\mu g}{mg}}$$

Where:

HQ = hazard quotient (unitless)
EC = exposure concentration (μg/m^3)
RfC = reference concentration (mg/m^3)

3.2.1.3 *Intake, Cancer Risk, and Noncancer Hazard Equations for Dermal Contact with Soil*

The equations used to calculate average daily chemical intake for the dermal absorption of COPCs in soil are provided in EPA/540/R/99/005, *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final*, Equation 3.11 and Equation 3.12. The equations used to estimate the dermal absorbed dose per event are as follows:

$$DAD = \frac{DA_{event} \times EF \times ED \times EV \times SA}{BW \times AT}$$

Where:

$$DA_{event} = C_s \times CF1 \times AF \times ABS_d$$

Where:

DAD = dermal absorbed chemical dose (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (yr)
EV = event frequency (events/day)
SA = skin surface area available for contact (cm^2)
BW = body weight (kg)
AT = averaging time (days)

C_S = concentration of COPC in soil (mg/kg)
CF1 = conversion factor (10^{-6} kg/mg)
AF = soil to skin adherence factor (mg/cm^2-event)
ABS_d = dermal absorption fraction (unitless)

Cancer risk is calculated using the following equation as documented in EPA/540/R/99/005 (Equation 5.1):

$$Risk = DAD \times SF_{ABS}$$

Where:

Risk = excess lifetime cancer risk (unitless)
DAD = dermal absorbed chemical dose (mg/kg-day)
SF_{ABS} = absorbed cancer slope factor (mg/kg-day)$^{-1}$

Absorbed cancer slope factor is calculated using the following equation as documented in EPA/540/R/99/005 (Equation 4.2):

$$SF_{ABS} = \frac{CSF_o}{ABS_{GI}}$$

Where:

SF_{ABS} = absorbed cancer slope factor (mg/kg-day)$^{-1}$
CSF_o = oral cancer slope factor (mg/kg-day)$^{-1}$
ABS_{GI} = fraction of contaminant absorbed in GI tract (unitless)

Noncancer hazard is calculated using the following equation as derived in EPA/540/R/99/005 (Equation 5.2):

$$HQ = \frac{DAD}{RfD_{ABS}}$$

Where:

HQ = hazard quotient (unitless)
DAD = dermal absorbed chemical dose (mg/kg-day)
RFD_{ABS} = Absorbed reference dose (mg/kg-day)

Absorbed reference dose is calculated using the following equation as documented in EPA/540/R/99/005 (Equation 4.3):

$$RfD_{ABS} = RfD_o \times ABS_{GI}$$

RFD_{ABS} = Absorbed reference dose (mg/kg-day)
RfD_o = oral reference dose (mg/kg-day)
ABS_{GI} = fraction of contaminant absorbed in GI tract (unitless)

3.2.2 Risk Assessment Methodologies for WAC Industrial Worker Exposure Scenario

The 2007 Standard Method C soil cleanup levels are based on exposure to an adult receptor and include incidental soil ingestion, using industrial exposure frequency and duration assumptions. The MTCA Standard Method C air cleanup levels are based on exposure to an adult receptor and include inhalation of

vapors and dust in ambient air, using industrial exposure frequency and duration assumptions. The specific formulas used to calculate exposure route-specific chronic daily intake for nonradiological COPCs are presented below. Parameter values are provided in Table 4-6.

3.2.2.1 Intake, Cancer Risk, and Noncancer Hazard Equations for Direct Contact

The equation used to calculate a CDI for direct contact was derived from Equations 745-1 and 745-2 for direct contact under an industrial land use scenario (2007 MTCA WAC 173-340-745). The exposure assumptions used to calculate CDI for direct contact under an industrial land use scenario are consistent with the values documented in WAC 173-340-745(5)(b)(iii)(B)(I) and WAC 173-340-745(5)(b)(iii)(B)(II).

The following equation was used to calculate intake of chemicals from direct contact***:***

$$\text{CDI}\left(\frac{mg}{kg - day}\right) = \frac{\text{C}_\text{S}\times\text{SIR}\times\text{EF}\times\text{ED}\times\text{UCF1}\times\text{AB1}}{\text{ABW}\times\text{AT}}$$

Where:

CDI	=	daily intake of chemical (mg/kg-day)
C_s	=	concentration of COPC in soil (mg/kg)
SIR	=	soil ingestion rate (mg/day)
EF	=	exposure frequency (unitless)
ED	=	exposure duration (years)
UCF1	=	unit conversion factor (10^{-6} kg/mg)
AB1	=	gastrointestinal absorption fraction (unitless)
ABW	=	average body weight (kg)
AT	=	averaging time (years)

Cancer risk is calculated using the following equation as documented in EPA/540/1-89/002:

$$Risk = CDI \times CSF_o$$

Where:

Risk	=	excess lifetime cancer risk (unitless)
CDI	=	daily intake of chemical (mg/kg-day)
CSF_o	=	oral cancer potency factor $(\text{mg/kg-day})^{-1}$

Noncancer hazard is calculated using the following equation as documented in EPA/540/1-89/002:

$$HQ = \frac{CDI}{RfD_o}$$

Where:

HQ	=	hazard quotient (unitless)
CDI	=	daily chemical intake (mg/kg-day)
RfD_o	=	oral reference dose (mg/kg-day)

3.2.2.2 Intake, Cancer Risk, and Noncancer Hazard Equations for Inhalation of Dust and Vapors in Ambient Air

Similar to direct contact, the equation used to calculate a CDI for the inhalation pathway was derived from Equations 750-1 and 750-2 for the inhalation pathway under an industrial land use scenario (WAC

173-340-750). The exposure assumptions used to calculate CDI for inhalation under an industrial land use scenario are consistent with the values documented for the equations and in WAC 173-340-750(4)(b)(ii)(A) and WAC 173-340-750(4)(b)(ii)(B).

Intake due to inhalation of vapors and dust in ambient air was estimated under MTCA Method C by using the following equation:

$$\mathrm{CDI}\left(\frac{mg}{kg-day}\right)=\frac{\mathrm{C_A \times BR \times ABS \times EF \times ED}}{\mathrm{ABW \times AT \times UCF}}$$

Where:

CDI	=	chronic daily intake (mg/kg-day)
C_A	=	constituent concentration in air (μg/m^3)
BR	=	breathing rate (m^3/day)
ABS	=	inhalation absorption fraction (1.0) (unitless)
EF	=	exposure frequency (unitless)
ED	=	exposure duration (years)
ABW	=	average body weight (kg)
AT	=	averaging time (years)
UCF	=	unit conversion factor (10^3 μg/mg)

Cancer risk is calculated using the following equation as documented in EPA/540/1-89/002:

$$Risk = CDI \times CPFi$$

Where:

Risk	=	excess lifetime cancer risk (unitless)
CDI	=	chronic daily intake (mg/kg-day)
CPFi	=	inhalation carcinogenic potency factor (mg/kg-day)$^{-1}$

The inhalation cancer potency factors are calculated as shown in the following equation taken from EPA/540/1-89/002:

$$\text{IUR (ug/m}^3)^{-1} \text{ x 70 kg x (20 m}^3\text{/day)}^{-1} \text{ x 1000 ug/mg = CPFi (mg/kg-day)}^{-1}$$

Where:

IUR	=	unit risk ((ug/m^3)$^{-1}$)
CPFi	=	inhalation carcinogenic potency factor (mg/kg-day)$^{-1}$

Noncancer hazard is calculated using the following equation as presented in EPA/540/1-89/002:

$$HQ = \frac{CDI}{RfDi}$$

Where:

HQ	=	hazard quotient (unitless)
CDI	=	chronic daily intake (mg/kg-day)
RfDi	=	inhalation reference dose (mg/kg-day)

The RfDs are calculated as shown in the following equation (EPA/540/1-89/002):

$$[RfC\ (mg/m^3) \times 20\ m^3/day] / 70\ kg = RfDi\ (mg/kg\text{-}day)$$

Where:

RfC = inhalation reference concentration (mg/m^3)
RfDi = inhalation reference dose (mg/kg-day)

3.2.3 Cumulative Risk for Nonradiological Contaminants— Cancer

For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used. The basis for the equation is provided in EPA/540/1-89/002.

$$Risk_T = \sum_1^N Risk_i$$

where:

$Risk_T$ = Total cancer risk from route of exposure
$Risk_i$ = Cancer risk for the i^{th} chemical
N = Number of chemicals

3.2.4 Hazard Index for Nonradiological Contaminants—Noncancer

The HI is calculated using the following equation. The basis for the equation is provided in EPA/540/1-89/002.

$$HI = \sum_1^N CDI_i / RfD_i$$

where:

HI = hazard index
CDI_i = chronic daily intake of the i^{th} chemical (mg/kg-day)
RfD_i = reference dose of the i^{th} chemical (mg/kg-day)
N = number of chemicals

4 Assumptions and Inputs

This section provides key assumptions and inputs used in calculating cancer risk for the CERCLA industrial worker exposure scenario.

4.1 Contaminants of Potential Concern and Exposure Point Concentrations

The COPCs and associated exposure point concentrations (EPCs) for each EA at WMA C are presented in the following section.

4.1.1 Radiological COPCs and EPCs for Each EA

The BRA report (RPP-RPT-58329) documents the COPCs and associated EPCs for each EA at WMA C. The COPCs were identified by application of data reduction and weight of evidence screens to the WMA C soil analytical data sets.

Table 4-1 identifies the list of radiological COPCs and their corresponding EPCs for each EA. The EPCs in this table were calculated using analytical data for shallow zone (0 to 15 ft bgs) soil samples.

4.1.2 Nonradiological COPCs and EPCs for three UPRs

Due to the elevated concentrations of the radiological COPCs, samples for nonradiological analyses were not collected from the three UPRs. Therefore, the concentrations of the nonradiological contaminants in soils affected by unplanned releases associated with UPR-81, UPR-82, and UPR-86 were estimated to support an assessment of potential human health risks and hazards.

Source concentrations for nonradiological COPCs were developed based on the inventories information for various types of releases presented in RPP-ENV-33418, *Hanford C-Farm Leak Inventory Assessments Report*. The volume of leaks/releases were assessed by using the Cs-137 distributions in the soil and release volume information included in RPP-ENV-33418.

The release inventories are assumed to be uniformly distributed throughout volume of impacted soil. Therefore, the estimated leak volume was divided by the soil porosity of 0.258, based on the site-wide value for Hanford formation sandy gravel (Table 6.3 of PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*) to determine the volume of the impacted soil.

During the final step, the nonmobile chemical constituents are assumed to then remain in the soil at a uniform concentration calculated by the following equation:

$$Estimated\ Soil\ Concentration\ \left(\frac{mg}{kg}\right) = \frac{Inventory\ (kg) \times 10^6\ \frac{mg}{kg}}{\left[Volume\ of\ Impacted\ Soil\ (ft^3) \times Density\ \frac{g}{cm^3} \times 28{,}316\ \left(\frac{cm^3}{ft^3}\right)\right] \times \frac{kg}{1000\ g}}$$

A soil density of 2.13 kg/L was assumed to be consistent with the effective bulk density value assumed for backfill (gravelly) in the WMA C Performance Assessment (Table 3-5 of RPP-RPT-58949, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA C Performance Assessment and RCRA Closure Analysis*).

Among non-mobile nonradiological contaminants, aluminum, chromium, iron, lead, mercury, nickel and total uranium were identified as the nonradiological COPCs for three UPRs. Calcium and potassium are considered to be human nutrients essential to a well-balanced diet, and as such are often added to foods as supplements. For this reason, they typically are not considered hazardous to humans. Therefore, calcium and potassium are not considered as COPCs. In addition, contaminants (manganese and strontium) with no reported inventory are also excluded as COPCs. Table 4-2 presents the estimated EPCs for non-mobile nonradiological contaminants.

4.1.3 Calculation of EPCs for Nonradiological COPCs in Air

The concentration of a COPC in air was calculated based on its concentration in soil as recommended in EPA's RAGS Part B (EPA/540/R-92/002). The air concentration was calculated using the following equation

$$CA = C_s \times CF3 \times [\frac{1}{VF} + \frac{1}{PEF}]$$

Where:

CA	=	Concentration of contaminant in air (µg/m^3)
C_s	=	EPC for COPC in soils (mg/kg)
CF3	=	conversion factor (10^3 micrograms per milligram [µg/mg])
VF	=	volatilization factor (constituent-specific cubic meter [m^3]/kg)
PEF	=	particulate emission factor (m^3/kg)

No VOCs were identified as COPCs for the three UPRs. The equations to calculate the particulate emission factor (PEF) used for the adult industrial worker scenario are presented in ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 area Remedial Investigation/ Feasibility Study Reports*.

4.2 Exposure Assumptions

The CERCLA industrial worker scenario is considered for both radiological and nonradiological risk assessment. In addition, the WAC industrial worker under MTCA Method C industrial land use scenario was considered during nonradiological risk assessment. Both exposure scenarios are summarized below.

4.2.1 CERCLA Industrial Worker Scenario

An adult industrial worker is selected as the receptor to represent potential exposures from industrial land use similar to that experienced in the Inner Area of the Central Plateau. The direct contact exposure pathway is considered potentially complete for the industrial worker exposure scenario. The receptor could potentially be exposed to shallow vadose zone material (0 to 15 ft bgs) and will be at the site for 250 days per year for 25 years. The industrial worker is assumed to spend two hours per day outdoors and six hours per day indoors. An incidental soil ingestion rate of 50 milligrams of soil per day (mg/day) is assumed. The inhalation rate for the receptor is 20 m^3 per day. The gamma shielding factor for the CERCLA industrial worker scenario is assumed to be 0.4.

Exposure pathways evaluated for the radiological COPCs for the CERCLA industrial worker scenario include:

- External gamma radiation from radionuclides in the shallow soil;
- Incidental ingestion of shallow soil; and
- Inhalation of airborne contaminated dust or volatile emissions from soil.

Table 4-3 includes the assigned values and source references for the intake parameters associated with each exposure pathway for the radiological risk assessment under the CERCLA industrial worker scenario. Table 4-3 also presents the assigned values for all other RESRAD input parameters. Table 4-4 includes the distribution coefficient factors for each radiological COPC. Three key assumptions associated with these parameter values are discussed below.

Area of Contaminated (AOC) Zone: During the BRA, the AOC for each EA is assumed to be 2,000 m^2. Consistent with the BRA, the AOC for each EA was also assumed to be 2,000 m^2 for this risk assessment.

Thickness of the Contaminated Zone: Under the 2007 Washington State Model Toxics Control Act (MTCA) (Revised Code of Washington 70.105D, “Hazardous Waste Cleanup — Model Toxics Control Act”) cleanup regulations (Washington Administrative Code [WAC] 173-340-740, “Unrestricted Land Use Soil Cleanup Standards”), the point of compliance for soil cleanup levels based on the direct contact pathway is defined as the zone extending from the ground surface to 15 ft bgs. Therefore, the thickness of the contaminated zone for the BRA and this risk assessment was assumed to be 15 ft or 4.6 m.

Cover Thickness – As mentioned earlier, four (4) inches of concrete isolation barrier is used as cover thickness during the calculation of radiological risk for each EA.

During nonradiological risk assessment, exposure routes evaluated for the nonradiological COPCs for the CERCLA industrial worker scenario include:

- Incidental ingestion of soil;
- Inhalation of airborne contaminated dust or volatile emissions from soil; and
- Dermal contact with soil.

Table 4-5 presents the assigned values for exposure parameters associated with CERCLA industrial worker exposure for the nonradiological risk assessments.

4.2.2 WAC Industrial Worker Scenario

The 2007 MTCA Standard Method C soil cleanup levels are based on exposure to an adult receptor through incidental soil ingestion, and through inhalation of vapors and dust in ambient air, and include industrial exposure frequency and duration assumptions. Therefore, exposure routes evaluated for the WAC industrial worker exposure scenario are incidental ingestion of soil and inhalation of airborne contaminated dust or volatile emissions from soil. Table 4-6 presents the assigned values for the exposure parameters associated with WAC industrial worker exposure.

4.3 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at WMA C and the likelihood of adverse health effects to potentially exposed populations. Toxicity assessments for both radiological and nonradiological COPCs are summarized below.

4.3.1 Radiological COPCs

RESRAD version 6.5, used during the BRA, utilizes Federal Guidance Report (FGR) No. 13 and includes the risk coefficient values for all radionuclides (EPA 402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*). Default DCFPAK 3.02 Morbidity risk factors within RESRAD version 7.0 were utilized during this risk assessment. These risk coefficient slope factors are presented in units of pCi^{-1} (internal pathways) or (risk/year)/(pCi/g) (external pathways).

4.3.2 Nonradiological COPCs

For non-radionuclides, the analyte-specific toxicity values were determined using the recommended reference hierarchy as described in OSWER Directive 9285.7-53, *Human Health Toxicity Values in Superfund Risk Assessments* (Cook 2003). The hierarchy is the same as used in the baseline risk assessments for the River Corridor OUs. A summary follows.

- Tier 1 – The EPA Integrated Risk Information System (IRIS)

- Tier 2 – The EPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3 – Other Toxicity Values

The toxicity values were obtained from the EPA web site "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, May 2014) (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm).

The toxicity value for chromium is based on hexavalent chromium (Cr(VI). For Cr(VI), the current assessment considers cancer effects only for inhalation exposures. Note that an oral RfD and a reference concentration are available for assessment of noncancer effects. An oral cancer slope factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral cancer slope factor derived by NJDEP is 0.5 (mg/kg-day)$^{-1}$ (NJDEP, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for* Cr^{+6} *Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*). Risk due to the ingestion pathway was not considered as its oral toxicity value, developed by NJDEP, is still being evaluated by IRIS. Assessing only inhalation cancer effects from Cr(VI) has the potential to under-estimate cancer risk.

4.4 Risk Characterization

In Title 40, *Code of Federal Regulations*, Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan," the EPA considers remedial action at a site when cumulative ELCR to any current or future population exceeds a risk range of 10^{-4} to 10^{-6} (i.e., one case of cancer in ten thousand to one case of cancer in one million). Excess lifetime cancer risks below 10^{-6} are considered acceptable whereas ELCRs above 10^{-4} are considered unacceptable. Risks between 10^{-4} to 10^{-6} are generally referred to as the "acceptable risk range." Therefore, for radiological COPCs, the ELCRs were compared to the EPA acceptable target risk range of 10^{-4} to 10^{-6}. When the total cumulative ELCR exceeds 10^{-4}, those individual COPCs with a risk greater than 10^{-6} (those analytes that contribute greater than 1% of total cumulative ELCR) are identified as major risk contributors for the EA.

For the CERCLA receptor scenario, the total ELCRs for nonradiological COPCs were compared with respect to the EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}. However, for MTCA receptor scenarios, the total ELCRs for nonradiological COPCs were compared with respect to the WAC 173-340 standard. WAC 173-340 states that ELCR resulting from multiple hazardous substances should not exceed 1×10^{-5} for unrestricted and industrial land use. For noncancer hazard, both the EPA and the 2007 MTCA HHRA procedures [WAC 173-340-708, "Human Health Risk Assessment Procedures," subsection (5) "Multiple hazardous substances"] specify an acceptable target HI of 1. An HI above 1 is considered unacceptable risk. The HI may exceed 1 even if all of the individual HQs are less than 1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect.

Lead, a non-carcinogen, is considered a special case for risk characterization. The traditional RfD approach to the evaluation of chemicals is not applied to lead because most human health effects data are based on blood lead concentrations, rather than external dose. Blood lead concentration is an integrated measure of internal dose, reflecting total exposure from site-related and background sources. A clear No-Observed-Adverse-Effects-Level has not been established for such lead-related endpoints as birth weight, gestation period, heme synthesis and neurobehavioral development in children and fetuses, and blood pressure in middle-aged men. Dose-response curves for these endpoints appear to extend down to 10 micrograms per deciliter (µg/dl) or lower [*Toxicological Profile for Lead (Update)* (ATSDR 2007)]. The EPA guidance suggests that non-cancer effects from human exposure to lead contaminated media be evaluated by using the Integrated Exposure Uptake Biokinetic Model (IEUBK Model), for children's

exposure (EPA 9285.7-42, *User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows®*, 540-K-01-005), and the Adult Lead Model for adult exposure (more specifically, for estimating fetal blood lead levels in women exposed to lead containing soil under non-residential scenarios) (EPA-540-R-03-001, *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*).

For the three UPRs, the maximum estimated concentration for lead was 72 mg/kg at UPR-81. The MTCA Method A cleanup standard for lead under unrestricted land use is 250 mg/kg. As the maximum detected concentration for lead is less than MTCA Method A soil cleanup standard, no risk characterization was performed for lead in this EMCF.

5 Software Applications

RESRAD version 7.0 was used for determining risk per unit concentration for the CERCLA industrial worker scenario. All risk calculations were performed on electronic spreadsheets using Microsoft Excel. Electronic versions of all spreadsheets are provided with calculations included to facilitate comparison with hand calculations and checking of logical functions. This approach meets the requirements for "Single Use Software" as described in PRC-PRO-EP-40205, *CHPRC Environmental Calculation Preparation and Issue*. These spreadsheets are listed below in Section 6.

5.1 Approved Software

RESRAD Version 7.0 is approved for use at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309, *Controlled Software Management*. The installed RESRAD software was tested in accordance with the procedure per CHPRC-00209, *RESRAD Software Management Plan*. RESRAD was registered on the Hanford Information System Inventory (HISI) and identified as approved for use.

5.1.1 Description

The following represent the description of RESRAD software package used in the calculation:

- RESRAD for Windows
- Version 7.0, Created February 24, 2014
- HISI Identification Number: 2102
- Workstation type and property number: Intera Property-00740 and Intera Property-00474 (subcontractor supplied unique property IDs).

5.1.2 Software Installation and Checkout

The software installation and checkout forms for RESRAD are provided in Appendix A to this Environmental Calculation.

5.1.3 Statement of Valid Software Application

The following presents the statement that RESRAD is a valid software application.

- RESRAD was developed for DOE to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material. RESRAD has been used for this purpose in support of previous decision documents developed at the Hanford Site.

- RESRAD as it has been used in this Environmental Calculation has been implemented within the range of its limitations. The parameters used in the modeling (shown in Tables 4-3 and 4-4) are

included in the modeling input files accompanying this Environmental Calculation, and also in the modeling output files where they are shown alongside the default parameters provided with the model. The modeling input and output files for RESRAD are listed in Section 6.

6 Calculation

This section presents information about the input and output files and parameter sets associated with the radiological and nonradiological risk assessment calculation. The risk assessment calculations were verified independently by utilizing the methodology, assumptions and inputs described in Sections 3 and 4.

6.1 Original Radiological Risk Assessment Calculation

The ELCR results were calculated with RESRAD and Microsoft Excel® using the methodology described in Section 3 and the inputs presented in Section 4. The RESRAD input file is listed below.

- Input RESRAD file (Risk Assessment for each EA) - (INDUSTRIAL_WORKER_Cover_4Inches.RAD).

ELCR calculations are a set of Excel worksheets contained in the Excel workbook "Rad_Risk_EA_Cover-4inches.xls". Results of the calculations are presented in Section 7.

All RESRAD input and output files (*.RAD, *.SUM, and *.INT) and Excel calculations are archived under this EMCF number (RPP-CALC-61057) in the CH2M HILL Plateau Remediation Company's Environmental Risk Management Archive database to maintain and preserve configuration managed models.

6.2 Original Nonradiological Risk Assessment Calculation

The ELCR and HI results were calculated with Microsoft Excel® using the methodology described in Section 3 and the inputs presented in Section 4. ELCR and HI calculations for the CERCLA industrial worker and WAC industrial worker scenarios are a set of Excel worksheets contained in Appendices B and C, respectively. Results of the calculations are presented in Section 7.

All Excel calculations are archived under this EMCF number (RPP-CALC-61057) in the CH2M HILL Plateau Remediation Company's Environmental Risk Management Archive database to maintain and preserve configuration managed models.

6.3 QC Review of Original Risk Assessment Calculation

A QC review was performed independently for all EAs within WMA C to verify the results of the original radiological and nonradiological risk assessment.

6.3.1 QC Review of Original Radiological Risk Assessment Calculation

Two types of QC reviews were performed and are described below.

6.3.1.1 Verification of RESRAD Input Values

All RESRAD input values entered into the "INDUSTRIAL_WORKER_Cover_4Inches.RAD" file were compared to the values presented in Table 4-3 and Table 4-4 to verify that the RESRAD file and input parameters were consistent. When inconsistencies were identified, the reviewer documented the findings

and provided them to the originator of the ECF. Inconsistencies were corrected by the originator and followed up with a second review. The following parameters were checked:

- Set Pathways- verify all of the active pathways are turned on. For the Industrial Worker, the active pathways are external gamma, inhalation (without radon), and soil ingestion.
- Contaminated zone
- Cover and contaminated zone hydrological data
- Occupancy, inhalation, and external gamma data
- Ingestion (non-dietary)
- Soil radionuclide concentrations based on a unit concentration of 1 pCi/g, followed by verification of exposure point concentrations for all EAs
- Calculation times- confirm that all of the relevant years are in the table, including the year of maximum risk if it is not at year 0 or 1,000.

6.3.1.2 Verification of Risk Calculations

Verification of radiological risk calculations was performed independently by using the methodologies presented in Section 3.0. The results of the radiological risk calculations were compared to the original risk calculations to verify accurate transposition of data from the RESRAD health risk report file into the Microsoft Excel® worksheet and to verify the formulas used for each radionuclide-specific risk result for all pathways were not corrupted and correct formulas were used. Below is a step-by-step description of the review process:

- Verify calculation times of year 0, year 1,000 and the year of maximum risk.
- Obtain a copy of the RSR data for all EAs that was generated by originator (this will be in Microsoft Excel® format).
- Obtain the RSR data that was generated by the QC reviewer (note this is found in the Health Risk report).
- Copy and paste the RSR data from the Health Risk Report generated by the QC reviewer into the same Microsoft Excel® workbook with the RSR data generated by the originator. Perform this step for years 0, 41.3 (4-in. cover only) and 1,000.
- Insert a column and enter the EPCs for each radiological COPC for each EA.
- Insert another column to calculate the total risk for each radiological COPC by entering the formula provided below:

$$\text{Risk} = \text{EPC (pCi/g)} \times \text{RSR (Risk/(pCi/g))}$$

- Compare the originator results to the QC review results and verify the two sets of results are the same.

The results of the first review step did not identify any transposition errors. The results of the second review step did not identify errors associated with formulas used to calculate risk or transcription errors.

6.3.2 QC Review of Original Nonradiological Risk Assessment Calculation

A QC review was performed independently for UPR-81, UPR-82, and UPR-86 within WMA C to verify the results of the original calculation. During this process, the following evaluations were performed.

- Verification of EPCs for each COPC - The EPCs for all COPCs presented in Table 4-2 were verified to ensure actual values were used during the intake calculations. The results of this review did not identify any errors.
- Verification of the Assigned values for Intake Parameters – The assigned value for each intake parameter included in Table 4-5 and Table 4-6 was checked against its corresponding reference to ensure the correct assigned value was selected. The results of this evaluation did not identify any errors.
- Verification of Toxicity values and Physical Properties for each COPC - All physical properties and toxicity values presented in Appendix B Table B-2 and Appendix C Table C-2 were verified to ensure actual values were used during the risk calculations. The results of this evaluation identified that the IUR values and the RfC_i values need to be converted to CPF_i values and RfD_i values to be consistent with the MTCA C calculation methodology. The errors were corrected.
- Verification of Risk Calculations –Nonradiological risk calculations were performed by using the methodologies presented in Section 3 for all UPRs. The results of the risk calculations were compared to the original risk calculations to ensure the formulas used during the calculations of COPC-specific risk for each UPR and all pathways were not corrupted and correct formulas were used.

The results of the review did not identify any errors associated with the formulas used during the calculation of cancer risks or noncancer hazards. There were no references to incorrect cells on the intake or risk sheets identified. It should be noted that EPA/540/1-89/002 recommends that the resulting cancer risk estimates be expressed using one significant figure. Therefore, the results presented in Tables 7-12 and 7-13 are expressed using one significant figure.

7 Results/Conclusions

The CERCLA industrial worker exposure scenario was considered for both radiological and nonradiological risk assessment for each EA and the UPRs. The WAC industrial worker exposure scenario was considered only during nonradiological risk assessment for each UPR. The following sections summarize the results of both the radiological and nonradiological risk assessments.

7.1 Results/Conclusions for Radiological Risk Assessment

The RESRAD code calculates the ELCR for COPCs over a period of 1,000 years. The results of the maximum ELCR calculation over a period of 1,000 years under the CERCLA industrial worker exposure scenario for the ten EAs within WMA C are presented in Tables 7-1 through 7-10. Table 7-11 provides an ELCR calculation summary.

The total cumulative ELCR for each EA is compared with respect to EPA's acceptable target risk range of 10^{-4} to 10^{-6}. The results presented in Table 7-11 showed that except for EA R, the total cumulative ELCR for any EA are within EPA's acceptable target risk range of 10^{-4} to 10^{-6}. For EA R, the total ELCR is less than EPA's acceptable target risk range of 10^{-4} to 10^{-6}.

7.2 Results/Conclusions for Nonradiological Risk Assessment

Appendices B and C include the intake and risk calculations for nonradiological COPCs for the three WMA C UPRs under the CERCLA industrial worker scenario and WAC Industrial worker scenario, respectively. Tables 7-12 and 7-13 provide a summary of the cancer risks and noncancer hazards for the CERCLA industrial worker and WAC industrial worker, respectively. For carcinogenic COPCs, the total ELCRs for the three UPRs were less than the EPA's acceptable target risk range of 10^{-4} to 10^{-6} and 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. Therefore, nonradiological risk contributors were not identified. For noncarcinogenic COPCs, the HIs for the three UPRs were less than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. Therefore, nonradiological noncancer hazard contributors were not identified.

8 References

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Tables

Table 2-1. Identification of Exposure Areas

Exposure Areas[a]	General Location Within Waste Management Area C	Phase 2 Characterization Objective
A + B	Area near tank 241-C-101	Characterize releases from tank 241-C-101
C	Area near 241-C-200 series tanks	Determine if C-200 tanks actually leaked, and determine if any C-200 tank leaked during retrieval
E	Area between tanks 241-C-106 and 241-C-109	Assess ^{60}Co
F + G	Area near tank 241-C-103 and Bldg. C-801, and Bldg. C-801 chemical drain	Assess release of Plutonium Uranium Extraction plant waste, ^{137}Cs and ^{99}Tc,and ^{60}Co
H + I	Area northeast of UPR-200E-91 and UPR-200E-115	Assess surface exposures, and assess ^{60}Co and surface release conceptual models
J	Area near tank 241-C-104	Assess suspected release
L1 + L2	Area between tanks 241-C-103 and 241-C-106	Updated logging data for ^{60}Co, ^{137}Cs, Uranium, and moisture and assess potential release
P	Area near UPR-81	Characterize release
R	Area near 241-C-301 catch tank	Assess potential catch tank release
U	Area near tank 241-C-110	Characterize tank 241-C-110 release

Notes:

a. RPP-RPT-57218, *Computation of Exposure Point Concentrations for Waste Management Area C Phase 2 Soil Characterization Data*.

Table 4-1. Exposure Point Concentrations (EPCs) for Each EA in WMA C

Radiological COPCs	EA A plus B	EA C	EA E	EA F plus G	EA H+I	EA J	EA L1 plus L2	EA P	EA R	EA U
	(Unit of EPC is pCi/g)									
Americium-241	0.18	--	--	--	--	--	--	2.2	--	--
Carbon-14	3.4	--	--	12.5	3.5	13.7	53.8	--	--	1.7
Cesium-137	27.7	7.1	5.1	3.2	--	5.7	3.5	32.1	--	2.1
Cobalt-60	--	--	--	--	--	--	--	0.83	--	--
Iodine-129	--	--	--	--	--	--	--	0.81	--	--
Neptunium-237	--	--	--	--	--	--	--	1.5	--	0.60
Nickel-63	--	4.5	--	--	--	--	390	85	--	--
Plutonium-238	--	--	--	--	--	0.067	--	--	--	--
Plutonium-239/240	0.31	--	--	--	--	0.038	--	10.7	--	--
Plutonium-241	1.2	--	--	--	--	0.14	--	39.9	--	--
Selenium-79	2.4	--	3.8	2.4	2.7	11.3	1.6	4.6	--	2.8
Strontium-90	17.1	3	2.5	0.30		4.0	2.0	82.2	0.37	4.2
Technetium-99	--	--	--	--	--	--	--	24	--	--
Tin-126	31.7	53.1	18.5	2.6	7.7	--	8.9	--	--	6.3
Tritium	--	--	--	--	75.8	--	4.7	308	2.5	--
Uranium-233	--	--	2.0	1.5	1.6	--	1.5	1.9	2.4	2.1
Uranium-234	0.26	--	0.45	0.30	0.35	--	0.25	0.72	0.22	0.31
Uranium-235	0.0089	0.013	0.012	0.010	0.0078	0.010	0.010	0.025	0.010	0.0089
Uranium-238	0.19	0.28	0.28	0.24	0.18	0.22	0.23	0.52	0.22	0.21

RPP-RPT-57218, 2014, *Computation of Exposure Point Concentrations for Waste Management Area C Phase 2 Soil Characterization Data*, Rev. 0

Table 4-2: Determination of Nonradiological Soil Concentrations for the Three WMA C UPRs

	Units	UPR-81	UPR-82	UPR-86					
		release	release	release					
Waste Type	N/A	CWP2	P2	P2					
sample yr		1969	1969	1971					
^{137}Cs Conc (Ci/L)		1.63E-03	0.35	0.12					
Cs ratio		4.00	0.75	0.25					
Volume	L	136260	9841	64345					
Impacted Soil Volume[a]	gal	36000	2600	17000		ft^3	18654	1347	8809
Constituents	Units	UPR-81	UPR-82	UPR-86	Mobile?	Units	UPR-81	UPR-82	UPR-86
	Inventory					Soil Concentration[b]			
Al[c]	kg	9.25E+03	--	--	No	mg/kg	8220	NA	NA
Bi	kg	--	--	--	No	mg/kg	NA	NA	NA
butanol	kg	--	--	--	Yes	mg/kg	NA	NA	NA
Ca	kg	8.20E+01	1.11E+00	2.38E+00	No	mg/kg	NA	NA	NA
Cl-	kg	2.23E+02	6.89E+00	1.48E+01	Yes	mg/kg	NA	NA	NA
CO3--	kg	1.23E+02	1.66E+00	3.56E+00	Yes	mg/kg	NA	NA	NA
Cr	kg	8.68E+01	3.12E+00	6.70E+00	No	mg/kg	77	38	13
DBP	kg	--	--	--	Yes	mg/kg	NA	NA	NA
F-	kg	--	--	--	Yes	mg/kg	NA	NA	NA
Fe	kg	5.71E+01	7.71E-01	1.66E+00	No	mg/kg	51	9	3
Hg	kg	--	2.39E-03	5.13E-03	No	mg/kg	NA	0.03	0.01
K	kg	5.36E+01	1.65E+00	3.55E+00	No	mg/kg	NA	NA	NA
La	kg	--	--	--	No	mg/kg	NA	NA	NA
Mn	kg	--	--	--	No	mg/kg	NA	NA	NA
Na	kg	2.03E+04	1.99E+02	4.27E+02	Yes	mg/kg	NA	NA	NA
NH3	kg	1.72E-01	3.85E+00	8.27E+00	Yes	mg/kg	NA	NA	NA
Ni	kg	4.90E+01	7.88E-01	1.69E+00	No	mg/kg	44	10	3
NO2-	kg	7.12E+03	2.08E+02	4.47E+02	Yes	mg/kg	NA	NA	NA
NO3-	kg	2.32E+04	5.48E+01	1.18E+02	Yes	mg/kg	NA	NA	NA
OH-	kg	1.74E+02	2.31E+01	4.97E+01	Yes	mg/kg	NA	NA	NA
Pb	kg	8.13E+01	1.10E+00	2.36E+00	No	mg/kg	72	14	4
PO4---	kg	--	--	--	Yes	mg/kg	NA	NA	NA
SiO3--	kg	--	5.90E+00	1.27E+01	Yes	mg/kg	NA	NA	NA
SO4--	kg	3.53E+02	8.76E+01	1.88E+02	Yes	mg/kg	NA	NA	NA
Sr	kg	5.39E-03	3.35E-04	7.20E-04	No	mg/kg	NA	NA	NA
TOC (total C)	kg	--	--	--	Yes	mg/kg	NA	NA	NA
U total	kg	1.69E+01	2.28E-01	4.90E-01	No	mg/kg	15	3	1
Zr	kg	--	--	--	No	mg/kg	NA	NA	NA

a. Impacted Soil Volume (ft^3) = Volume (gallon)/ Soil Porosity (0.258)/ 7.48 gallon/ft^3
b. Soil Concentration = [Inventory (kg) x 1E+06 mg/kg] /[Impacted soil volume (ft^3) x 28316 cm^3/ft^3 x Soil density (2.13 gm/cm^3)/ 1000 gm/kg]
c. Aluminum concentration calculated using reported inventory for $Al(OH)_4^-$ and the mass ratio of Al/ $Al(OH)_4^-$ (0.2839)
-- = Inventory not reported
NA = source term concentration not applicable (either not a COPC or no inventory reported)

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
PATHWAY SELECTIONS						
External Gamma	NA	Active	Active	NA	Active pathway	NA
Inhalation (without radon)	NA	Active	Active	NA	Active pathway	NA
Plant Ingestion	NA	Active	Inactive	NA	Inactive pathway	NA
Meat Ingestion	NA	Active	Inactive	NA	Inactive pathway	NA
Milk Ingestion	NA	Active	Inactive	NA	Inactive pathway	NA
Aquatic Foods	NA	Active	Inactive	NA	Inactive pathway	NA
Drinking Water	NA	Active	Inactive	NA	Inactive pathway	NA
Soil Ingestion	NA	Active	Active	NA	Active pathway	NA
Radon	NA	Inactive	Inactive	NA	NA per Federal Register, 1994, p. 43210	NRC 1994
CONTAMINATED ZONE PARAMETERS						
Area of contaminated zone	AREA	10,000	2,000	m^2	Site-Specific Value for each EA	
Thickness of contaminated zone	THICK0	2	4.6	m	Site-specific Value	
Length parallel to the aquifer	LCZPAQ	100	NA	m	Inactive pathway	NA
Times for calculations	TI	1, 3, 10, 30, 100, 300, 1,000	1, 3, 10, 30, 100, 300, 1,000	yr	RESRAD default	ANL 2009
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	COVER	0	0.1	M	4 inches of Concrete Isolation Barrier (Each EA)	Assumption
Density of cover material	DENSCV	1.5	2.4	g/cm^3	Average Density (Minimum =2.2 and Maximum = 2.6)	Figure 8.1-1, NUREG/CR 6697 Attachment C
Cover erosion rate	VCV	0.001	2.045E-06	m/yr	Based on maximum erosion rate of 5.6 E-7 cm/day for concrete.	Figure 8.2-1 NUREG/CR 6697 Attachment C
Density of contaminated zone	DENSCZ	1.5	1.6	g/cm^3	Hanford 100 Area specific data	DOE/RL-90-07
Contaminated zone erosion rate	VCZ	0.001	0.001	m/yr	RESRAD Default	ANL 2009
Contaminated zone total porosity	TPCZ	0.4	0.4	unitless	WDOH guidance	WDOH/320-015
Contaminated zone field capacity	FCCZ	0.2	0.15	unitless	WDOH guidance	WDOH/320-015
Contaminated zone hydraulic conductivity	HCCZ	10	250	m/yr	Hanford 100 Area-specific data	DOE/RL-96-11 DOE/RL-90-07

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Contaminated zone b parameter	BCZ	5.3	4.05	unitless	WDOH guidance	WDOH/320-015
Humidity in air	HUMID	8	8	g/m^3	RESRAD Default	ANL 2009
Evapotranspiration coefficient	EVAPTR	0.5	0.91	unitless		Letter from EPA
Wind speed	WIND	2	3.4	m/sec	Hanford Site average	PNNL-12087
Precipitation	PRECIP	1	0.16	m/yr	Based on 16 cm (6.3 in.) average annual rainfall	DOE/RL-90-07
Irrigation	RI	0.2	0.76	m/yr	EPA, Region X guidance	Letter from EPA
Irrigation mode	IDITCH	Overhead	Overhead	unitless	RESRAD default	ANL 2009
Runoff coefficient	RUNOFF	0.2	0.2	unitless	RESRAD default	ANL 2009
Watershed area for nearby stream or pond	WAREA	1.00E6	1.00E6	m^2	RESRAD default	ANL 2009
Accuracy for water/soil computations	EPS	0.001	0.001	Unitless	RESRAD default	ANL 2009
SATURATED ZONE HYDROLOGICAL DATA						
Density of saturated zone	DENSAQ	1.5	NA	g/cm^3	Inactive pathway	NA
Saturated zone total porosity	TPSZ	0.4	NA	unitless	Inactive pathway	NA
Saturated zone effective porosity	EPSZ	0.2	NA	unitless	Inactive pathway	NA
Saturated zone field capacity	FCSZ	0.2	NA	unitless	Inactive pathway	NA
Saturated zone hydraulic conductivity	HCSZ	100	NA	m/yr	Inactive pathway	NA
Saturated zone hydraulic gradient	HGWT	0.02	NA	unitless	Inactive pathway	NA
Saturated zone b parameter	BSZ	5.3	NA	unitless	Inactive pathway	NA
Water table drop rate	VWT	0.001	NA	m/yr	Inactive pathway	NA

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Well pump intake depth (meters below water table)	DWIBWT	10	NA	m	Inactive pathway	NA
Model for Water Transport Parameters [Non-dispersion (ND) or Mass-Balance (MB)]	MODEL	ND	ND	unitless	RESRAD default	ANL 2009
Well pumping rate	UW	250	NA	m^3/yr	Inactive pathway	NA
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zone strata	NS	1	NA	unitless	Inactive pathway	NA
Unsaturated zone thickness	H(1)	4	NA	m	Inactive pathway	NA
Unsaturated zone soil density	DENSUZ(1)	1.5	NA	g/cm^3	Inactive pathway	NA
Unsaturated zone total porosity	TPUZ(1)	0.4	NA	unitless	Inactive pathway	NA
Unsaturated zone effective porosity	EPSZ(1)	0.2	NA	unitless	Inactive pathway	NA
Unsaturated zone field capacity	FCSZ(1)	0.2	NA	unitless	Inactive pathway	NA
Unsaturated zone hydraulic conductivity	HCSZ(1)	10	NA	m/yr	Inactive pathway	NA
Unsaturated zone b parameter	BSZ	5.3	NA	unitless	Inactive pathway	NA
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: Radionuclides						
Contaminated zone	DCNUCC(1)		See Table 4-4	cm^3/g	Site-Specific	ECF-HANFORD-10-0429
Unsaturated zone	DCNUCU(1, 1)			cm^3/g		
Saturated zone	DCNUCS(1)			cm^3/g		

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
OCCUPANCY, INHALATION AND EXTERNAL GAMMA DATA						
Inhalation rate	INHALR	8,400	7,300	m^3/y	20 m^3/day x 365 days/yr	OSWER 9285.6-03
Mass loading for inhalation	MLINH	0.0001	1.4E-8	g/m^3	(1/ PEF), where PEF = 7.3 x 10^{10} m^3/kg	ECF-HANFORD-11-0033
Exposure duration	ED	30	25	yr		OSWER Directive 9285.6-03
Inhalation shielding factor	SHF3	0.4	0.4	unitless	RESRAD default	ANL 2009
External gamma shielding factor	SHF1	0.7	0.4	unitless	60% shielding	EPA/540-R-00-007, Equation 4
Indoor time fraction	FIND	0.5	0.17	unitless	(6 hr/d x 250 d/yr) / 8,760 hr/yr	Assumption
Outdoor time fraction	FOTD	0.25	0.057	unitless	(2 hr/d x 250 d/yr) / 8,760 hr/yr	Assumption
Shape of the contaminated zone (circular or non-circular)	FS	Circular	Circular	unitless	RESRAD default	ANL 2009
INGESTION PATHWAY (DIETARY DATA)						
Fruits, vegetables and grain consumption	DIET(1)	160	NA	kg/yr	Inactive pathway	NA
Leafy vegetable consumption	DIET(2)	14	NA	kg/yr	Inactive pathway	NA
Milk consumption	DIET(3)	92	NA	L/yr	Inactive pathway	NA
Meat and poultry consumption	DIET(4)	63	NA	kg/yr	Inactive pathway	NA
Fish consumption	DIET(5)	5.4	NA	kg/yr	Inactive pathway	NA
Other seafood consumption	DIET(6)	0.9	NA	kg/yr	Inactive pathway	NA
Soil ingestion rate	SOIL	36.5	18.25	g/yr	(50 mg/day x 365 days/yr) / 1000 mg/g	OSWER Directive 9285.6-03
Drinking water intake	DW1	510	NA	L/yr	Inactive Pathway	NA
Contamination fraction of drinking water	FDW	1	NA	kg/yr	Inactive Pathway	NA
Contamination fraction of household water	FHHW	1	NA	kg/yr	Inactive pathway	NA
Contamination fraction of livestock water	FLW	1	NA	unitless	Inactive pathway	NA
Contamination fraction of irrigation water	FIRW	1	NA	unitless	Inactive pathway	NA
Contamination fraction of aquatic food	FR9	0.5	NA	unitless	Inactive pathway	NA
Contaminated fraction of plant food	FPLANT	-1	NA	unitless	Inactive pathway	NA
Contaminated fraction of meat	FMEAT	-1	NA	unitless	Inactive pathway	NA
Contaminated fraction of milk	FMILK	-1	NA	unitless	Inactive pathway	NA

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	Code	Default Value	User Input Value	Units	Comments	Reference
INGESTION PATHWAY (NON-DIETARY DATA)						
Livestock fodder intake for meat	LP15	68	NA	kg/day	Inactive pathway	NA
Livestock fodder intake for milk	LP16	55	NA	kg/day	Inactive pathway	NA
Livestock water intake for meat	LW15	50	NA	L/day	Inactive pathway	NA
Livestock water intake for milk	LW15	160	NA	L/day	Inactive pathway	NA
Livestock intake of soil	LS1	0.5	NA	kg/day	Inactive pathway	NA
Mass loading for foliar deposition	MLFD	0.0001	NA	g/m^3	Inactive pathway	NA
Depth of soil mixing layer	DM	0.15	0.15	m	RESRAD default	ANL 2009
Depth of roots	DROOT	0.9	NA	m	Inactive pathway	NA
Groundwater fractional usage: Drinking water	FGWDW	1	NA	unitless	Inactive pathway	NA
Groundwater fractional usage: Household water	FGWHH	1	NA	unitless	Inactive pathway	NA
Groundwater fractional usage: Livestock water	FGWLW	1	NA	unitless	Inactive pathway	NA
Groundwater fractional usage: Irrigation water	FGWIR	1	NA	unitless	Inactive pathway	NA
PLANT TRANSPORT FACTORS						
Wet weight crop yield: non-leafy vegetables	YV(1)	0.7	NA	kg/m^2	Inactive pathway	NA
Wet weight crop yield: leafy vegetables	YV(2)	1.5	NA	kg/m^2	Inactive pathway	NA
Wet weight crop yield: fodder	YV(3)	1.1	NA	kg/m^2	Inactive pathway	NA
Length of growing season: non-leafy vegetables	TE(1)	0.17	NA	years	Inactive pathway	NA
Length of growing season: leafy vegetables	TE(2)	0.25	NA	years	Inactive pathway	NA
Length of growing season: fodder	TE(3)	0.08	NA	years	Inactive pathway	NA
Translocation factor: non-leafy vegetables	TIV(1)	0.1	NA	unitless	Inactive pathway	NA
Translocation factor: leafy vegetables	TIV(2)	1	NA	unitless	Inactive pathway	NA
Translocation factor: fodder	TIV(3)	1	NA	unitless	Inactive pathway	NA
Weathering removal constant	WLAM	20	NA	y^{-1}	Inactive pathway	NA
Wet foliar interception fraction: non-leafy vegetables	RWET(1)	0.25	NA	unitless	Inactive pathway	NA

Table 4-3: Assigned Values for RESRAD Input Parameters for the CERCLA Industrial Worker

RESRAD Version 7.0					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Wet foliar interception fraction: leafy vegetables	RWET(2)	0.25	NA	unitless	Inactive pathway	NA
Wet foliar interception fraction: fodder	RWET(3)	0.25	NA	unitless	Inactive pathway	NA
Dry foliar interception fraction: non-leafy vegetables	RDRY(1)	0.25	NA	unitless	Inactive pathway	NA
Dry foliar interception fraction: leafy vegetables	RDRY(2)	0.25	NA	unitless	Inactive pathway	NA
Dry foliar interception fraction: fodder	RDRY(3)	0.25	NA	unitless	Inactive pathway	NA
STORAGE TIMES BEFORE USE						
Fruits, non-leafy vegetables and grain	STOR_T(1)	14	NA	days	Inactive pathway	NA
Leafy vegetables	STOR_T(2)	1	NA	days	Inactive pathway	NA
Milk	STOR_T(3)	1	NA	days	Inactive pathway	NA
Meat	STOR_T(4)	20	NA	days	Inactive pathway	NA
Fish	STOR_T(5)	7	NA	days	Inactive pathway	NA
Crustacea and mollusks	STOR_T(6)	7	NA	days	Inactive pathway	NA
Well water	STOR_T(7)	1	NA	days	Inactive pathway	NA
Surface water	STOR_T(8)	1	NA	days	Inactive pathway	NA
Livestock fodder	STOR_T(9)	45	NA	days	Inactive pathway	NA

NOTE:
NA = Not applicable.

Table 4-4: Radionuclide-specific Distribution Coefficients (Kd)

Radionuclide COPCs	Contaminated Zone Layer (cm^3/g)[1]	Unsaturated Zone and Saturated Zone (cm^3/g)[1]
Am-241	200	200
C-14	200	200
Co-60	50	50
Cs-137	50	50
H-3	0	0
I-129	1	1
Ni-63	30	30
Np-237	15	15
Pu-238	200	200
Pu-239	200	200
Pu-241	200	200
Se-79	0	0
Sn-126	0	0
Sr-90	25	25
Tc-99	0	0
U-233	50	50
U-234	50	50
U-235	50	50
U-238	50	50

Note:

1. ECF-HANFORD-10-0429, 2013, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 Areas and 300 Area Remedial Investigation/ Feasibility Study Report*, Rev. 1

Table 4-5. Assigned Values for Intake Parameters (CERCLA Industrial Worker)

Parameter	Units	Symbol	Assigned Value	Source
General Information				
Soil concentration	mg/kg	Cs	Chemical-specific	Calculated value
Contaminant concentration in air	$\mu g/m^3$	CA	Chemical-specific	Calculated value
Exposure frequency	days/year	EF	250	Attachment 1 of OSWER Directive 9200.1-120
Exposure duration, ED	years	ED	25	Attachment 1 of OSWER Directive 9200.1-120
Exposure time	hrs/day	ET	8	Attachment 1 of OSWER Directive 9200.1-120
Body weight	kg	BW	80	Attachment 1 of OSWER Directive 9200.1-120
Carcinogenic Averaging Time	days	ATc	25,550	Exhibit 6-11 of EPA/540/1-89/002 (70 years x 365 days/year)
Noncarcinogenic Averaging Time	days	ATnc	9,125	Exhibit 6-11 of EPA/540/1-89/002 (25 years x 365 days/year)
Soil Ingestion Route				
Soil ingestion rate	mg/day	IR_S	50	Attachment 1 of OSWER Directive 9200.1-120
Fraction of Intake	unitless	FI	1	Conservative Assumption
Inhalation Pathway				
Particle Emissions Factor (site-specific calculated value)	m^3/kg	PEF	7.3E+10	ECF-HANFORD-11-0033
Volatilization Factor	m^3/kg	VF	0	No VOCs
Dermal Contact Route				
Skin surface area	cm^2	SA	3,527	Attachment 1 of OSWER Directive 9200.1-120
Soil adherence factor	mg/cm^2	AF	0.12	Attachment 1 of OSWER Directive 9200.1-120
Dermal absorption fraction	unitless	ABS_d	Chemical-specific	0 for all nan-radiological COPCs included in this EMCF
Event frequency	events/day	EV	1	Conservative Assumption

Table 4-5. Assigned Values for Intake Parameters (CERCLA Industrial Worker)

Parameter	Units	Symbol	Assigned Value	Source
Conversion Factors				
Conversion factor 1	kg/mg	CF1	0.000001	Calculated value
Conversion factor 2	hours/day	CF2	24	Calculated value
Conversion factor 3	μg/m^3	CF3	1,000	Calculated value

Notes:

ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 area Remedial Investigation/ Feasibility Study Reports*.

EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*.

OSWER Directive 9200.1-120, *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors*

Table 4-6. Summary of Exposure Factors for MTCTA Industrial Worker Scenario

Parameter	Units	Symbol	Assigned Value	Source
Soil Ingestion Pathway				
Soil ingestion rate	mg/day	SIR	50	MTCA Method C, Equations 745-1 and 745-2
Gastrointestinal Absorption Fraction	unitless	AB1	1	
Exposure frequency	unitless	EF	0.4	
Exposure duration	years	ED	20	
Average Body Weight over the exposure duration	kg	ABW	70	
Unit correction factor	kg/mg	UCF1	10^{-6}	
Carcinogenic averaging time	years	ATc	75	MTCA Method C, Equation 745-2
Noncarcinogenic averaging time	days	ATnc	20	MTCA Method C, Equation 745-1
Inhalation Pathway				
Particulate Emissions Factor(site-specific calculated value)	m^3/kg	PEF	7.3E10	ECF-HANFORD-11-0033
Breathing rate	m^3/day	BR	20	MTCA Method C, WAC 173-340-750(4)(b)(ii)(A) and 750-2
Inhalation Absorption Fraction	unitless	ABS	1	
Exposure frequency	unitless	EF	1	
Exposure duration, adult	years	EDa	30	MTCA Method C, Equation 750-2
Carcinogenic averaging time	years	ATc	75	
Exposure duration, noncarcinogenic	years	EDnc	6	MTCA Method C, Equation 750-1
Noncarcinogenic averaging time	years	ATnc	6	

Notes:

ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 area Remedial Investigation/ Feasibility Study Reports*.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."

WAC 173-340-750, "Cleanup Standards to Protect Air Quality."

Table 7-1: Summary of Radiological Risk Assessment Results Based on 4-inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA A plus B

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0.18	4.3E-11	4.2E-13	4.5E-09	4.6E-09	8E-12	8E-14	8E-10	8E-10	4.2E-11	3.9E-13	4.2E-09	4.3E-09	8E-12	7E-14	8E-10	8E-10	2.4E-11	8.3E-14	9.0E-10	9.2E-10	4E-12	1E-14	2E-10	2E-10
C-14	3.4	6.2E-16	2.5E-11	2.9E-12	2.8E-11	2E-15	9E-11	1E-11	1E-10	0.0E+00	1.4E-28	1.5E-29	1.5E-28	0E+00	5E-28	5E-29	5E-28	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	1.8E-06	3.3E-16	2.3E-10	1.8E-06	0E+00	0E+00	0E+00	0E+00	7.9E-09	1.5E-18	9.8E-13	8.0E-09	0E+00	0E+00	0E+00	0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	27.7	6.7E-07	9.7E-16	9.8E-10	6.7E-07	2E-05	3E-14	3E-08	2E-05	2.6E-07	3.7E-16	3.8E-10	2.6E-07	7E-06	1E-14	1E-08	7E-06	5.9E-17	8.5E-26	8.6E-20	5.9E-17	2E-15	2E-24	2E-18	2E-15
H-3	0	0.0E+00	1.3E-09	2.6E-13	1.3E-09	0E+00	0E+00	0E+00	0E+00	0.0E+00	4.3E-23	8.7E-27	4.3E-23	0E+00	0E+00	0E+00	0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	1.7E-19	1.6E-15	6.0E-09	6.0E-09	0E+00	0E+00	0E+00	0E+00	1.2E-19	1.1E-15	4.1E-09	4.1E-09	0E+00	0E+00	0E+00	0E+00	1.7E-23	1.1E-19	3.9E-13	3.9E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0.0E+00	6.1E-17	3.1E-11	3.1E-11	0E+00	0E+00	0E+00	0E+00	0.0E+00	4.5E-17	2.3E-11	2.3E-11	0E+00	0E+00	0E+00	0E+00	0.0E+00	4.3E-20	2.2E-14	2.2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1.3E-07	3.2E-13	3.1E-09	1.4E-07	0E+00	0E+00	0E+00	0E+00	1.3E-07	3.1E-13	3.1E-09	1.3E-07	0E+00	0E+00	0E+00	0E+00	6.9E-08	1.6E-13	1.6E-09	7.1E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	5.5E-13	5.4E-13	5.3E-09	5.3E-09	0E+00	0E+00	0E+00	0E+00	4.0E-13	3.9E-13	3.8E-09	3.8E-09	0E+00	0E+00	0E+00	0E+00	1.8E-12	2.9E-16	3.0E-12	4.8E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0.31	2.2E-11	6.3E-13	6.0E-09	6.0E-09	7E-12	2E-13	2E-09	2E-09	2.2E-11	6.3E-13	6.0E-09	6.0E-09	7E-12	2E-13	2E-09	2E-09	2.2E-11	6.0E-13	5.8E-09	5.8E-09	7E-12	2E-13	2E-09	2E-09
Pu-241	1.2	1.1E-12	1.2E-14	1.1E-10	1.1E-10	1E-12	1E-14	1E-10	1E-10	1.4E-12	1.3E-14	1.4E-10	1.4E-10	2E-12	2E-14	2E-10	2E-10	8.1E-13	2.8E-15	3.1E-11	3.2E-11	1E-12	3E-15	4E-11	4E-11
Se-79	2.4	6.4E-15	8.4E-17	1.3E-10	1.3E-10	2E-14	2E-16	3E-10	3E-10	1.6E-16	2.1E-18	3.1E-12	3.1E-12	4E-16	5E-18	7E-12	7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	31.7	1.2E-06	1.9E-15	5.5E-10	1.2E-06	4E-05	6E-14	2E-08	4E-05	2.9E-08	4.7E-17	1.4E-11	2.9E-08	9E-07	1E-15	4E-10	9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	17.1	1.7E-09	3.7E-15	2.5E-09	4.1E-09	3E-08	6E-14	4E-08	7E-08	6.1E-10	1.3E-15	9.0E-10	1.5E-09	1E-08	2E-14	2E-08	3E-08	4.0E-20	8.7E-26	5.8E-20	9.8E-20	7E-19	1E-24	1E-18	2E-18
Tc-99	0	5.3E-13	1.7E-16	5.5E-11	5.6E-11	0E+00	0E+00	0E+00	0E+00	1.3E-14	4.2E-18	1.4E-12	1.4E-12	0E+00	0E+00	0E+00	0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
U-233	0	4.0E-10	3.2E-13	3.4E-09	3.8E-09	0E+00	0E+00	0E+00	0E+00	1.5E-09	3.3E-13	3.4E-09	4.9E-09	0E+00	0E+00	0E+00	0E+00	2.4E-08	4.9E-13	4.9E-09	2.9E-08	0E+00	0E+00	0E+00	0E+00
U-234	0.26	7.1E-12	3.1E-13	3.3E-09	3.3E-09	2E-12	8E-14	9E-10	9E-10	2.9E-11	3.1E-13	3.3E-09	3.3E-09	7E-12	8E-14	8E-10	9E-10	6.5E-09	2.7E-13	3.0E-09	9.5E-09	2E-09	7E-14	8E-10	2E-09
U-235	0.0089	5.6E-08	2.8E-13	3.4E-09	5.9E-08	5E-10	3E-15	3E-11	5E-10	5.6E-08	2.8E-13	3.4E-09	5.9E-08	5E-10	3E-15	3E-11	5E-10	5.4E-08	2.9E-13	3.3E-09	5.7E-08	5E-10	3E-15	3E-11	5E-10
U-238	0.19	3.7E-08	2.7E-13	4.2E-09	4.1E-08	7E-09	5E-14	8E-10	8E-09	3.7E-08	2.6E-13	4.1E-09	4.1E-08	7E-09	5E-14	8E-10	8E-09	3.1E-08	2.2E-13	3.5E-09	3.4E-08	6E-09	4E-14	7E-10	7E-09
			Cumulative ELCR			**6E-05**	9E-11	9E-08	**6E-05**					**8E-06**	4E-13	3E-08	**8E-06**					**8E-09**	3E-13	3E-09	**1E-08**

Table 7-2: Summary of Radiological Risk Assessment Results Results Based on 4-inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA C

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	0	6E-16	3E-11	3E-12	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	1E-28	1E-29	2E-28	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	7.1	7E-07	1E-15	1E-09	7E-07	5E-06	7E-15	7E-09	5E-06	3E-07	4E-16	4E-10	3E-07	2E-06	3E-15	3E-09	2E-06	6E-17	9E-26	9E-20	6E-17	4E-16	6E-25	6E-19	4E-16
H-3	0	0E+00	1E-09	3E-13	1E-09	0E+00	0E+00	0E+00	0E+00	0E+00	4E-23	9E-27	4E-23	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	4.5	0E+00	6E-17	3E-11	3E-11	0E+00	3E-16	1E-10	1E-10	0E+00	5E-17	2E-11	2E-11	0E+00	2E-16	1E-10	1E-10	0E+00	4E-20	2E-14	2E-14	0E+00	2E-19	1E-13	1E-13
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	0	6E-15	8E-17	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	2E-16	2E-18	3E-12	3E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	53.1	1E-06	2E-15	6E-10	1E-06	6E-05	1E-13	3E-08	6E-05	3E-08	5E-17	1E-11	3E-08	2E-06	3E-15	7E-10	2E-06	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	3	2E-09	4E-15	2E-09	4E-09	5E-09	1E-14	7E-09	1E-08	6E-10	1E-15	9E-10	2E-09	2E-09	4E-15	3E-09	5E-09	4E-20	9E-26	6E-20	1E-19	1E-19	3E-25	2E-19	3E-19
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	0	4E-10	3E-13	3E-09	4E-09	0E+00	0E+00	0E+00	0E+00	1E-09	3E-13	3E-09	5E-09	0E+00	0E+00	0E+00	0E+00	2E-08	5E-13	5E-09	3E-08	0E+00	0E+00	0E+00	0E+00
U-234	0	7E-12	3E-13	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	3E-11	3E-13	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	6E-09	3E-13	3E-09	9E-09	0E+00	0E+00	0E+00	0E+00
U-235	0.013	6E-08	3E-13	3E-09	6E-08	7E-10	4E-15	4E-11	8E-10	6E-08	3E-13	3E-09	6E-08	7E-10	4E-15	4E-11	8E-10	5E-08	3E-13	3E-09	6E-08	7E-10	4E-15	4E-11	7E-10
U-238	0.28	4E-08	3E-13	4E-09	4E-08	1E-08	7E-14	1E-09	1E-08	4E-08	3E-13	4E-09	4E-08	1E-08	7E-14	1E-09	1E-08	3E-08	2E-13	3E-09	3E-08	9E-09	6E-14	1E-09	1E-08
		Cumulative ELCR				**7E-05**	2E-13	4E-08	**7E-05**					**3E-06**	9E-14	7E-09	**3E-06**					**9E-09**	7E-14	1E-09	**1E-08**

Table 7-3: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA E

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	0	6E-16	3E-11	3E-12	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	1E-28	1E-29	2E-28	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	5.1	7E-07	1E-15	1E-09	7E-07	3E-06	5E-15	5E-09	3E-06	3E-07	4E-16	4E-10	3E-07	1E-06	2E-15	2E-09	1E-06	6E-17	9E-26	9E-20	6E-17	3E-16	4E-25	4E-19	3E-16
H-3	0	0E+00	1E-09	3E-13	1E-09	0E+00	0E+00	0E+00	0E+00	0E+00	4E-23	9E-27	4E-23	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	3.8	6E-15	8E-17	1E-10	1E-10	2E-14	3E-16	5E-10	5E-10	2E-16	2E-18	3E-12	3E-12	6E-16	8E-18	1E-11	1E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	18.5	1E-06	2E-15	6E-10	1E-06	2E-05	4E-14	1E-08	2E-05	3E-08	5E-17	1E-11	3E-08	5E-07	9E-16	3E-10	5E-07	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	2.5	2E-09	4E-15	2E-09	4E-09	4E-09	9E-15	6E-09	1E-08	6E-10	1E-15	9E-10	2E-09	2E-09	3E-15	2E-09	4E-09	4E-20	9E-26	6E-20	1E-19	1E-19	2E-25	1E-19	2E-19
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	2	4E-10	3E-13	3E-09	4E-09	8E-10	6E-13	7E-09	8E-09	1E-09	3E-13	3E-09	5E-09	3E-09	7E-13	7E-09	1E-08	2E-08	5E-13	5E-09	3E-08	5E-08	1E-12	1E-08	6E-08
U-234	0.45	7E-12	3E-13	3E-09	3E-09	3E-12	1E-13	1E-09	1E-09	3E-11	3E-13	3E-09	3E-09	1E-11	1E-13	1E-09	1E-09	6E-09	3E-13	3E-09	9E-09	3E-09	1E-13	1E-09	4E-09
U-235	0.012	6E-08	3E-13	3E-09	6E-08	7E-10	3E-15	4E-11	7E-10	6E-08	3E-13	3E-09	6E-08	7E-10	3E-15	4E-11	7E-10	5E-08	3E-13	3E-09	6E-08	6E-10	4E-15	4E-11	7E-10
U-238	0.28	4E-08	3E-13	4E-09	4E-08	1E-08	7E-14	1E-09	1E-08	4E-08	3E-13	4E-09	4E-08	1E-08	7E-14	1E-09	1E-08	3E-08	2E-13	3E-09	3E-08	9E-09	6E-14	1E-09	1E-08
		Cumulative ELCR				**3E-05**	9E-13	3E-08	**3E-05**					**2E-06**	9E-13	1E-08	**2E-06**					**6E-08**	1E-12	1E-08	**7E-08**

Table 7-4: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA F plus G

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	12.5	6E-16	3E-11	3E-12	3E-11	8E-15	3E-10	4E-11	4E-10	0E+00	1E-28	1E-29	2E-28	0E+00	2E-27	2E-28	2E-27	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	3.2	7E-07	1E-15	1E-09	7E-07	2E-06	3E-15	3E-09	2E-06	3E-07	4E-16	4E-10	3E-07	8E-07	1E-15	1E-09	8E-07	6E-17	9E-26	9E-20	6E-17	2E-16	3E-25	3E-19	2E-16
H-3	0	0E+00	1E-09	3E-13	1E-09	0E+00	0E+00	0E+00	0E+00	0E+00	4E-23	9E-27	4E-23	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	2.4	6E-15	8E-17	1E-10	1E-10	2E-14	2E-16	3E-10	3E-10	2E-16	2E-18	3E-12	3E-12	4E-16	5E-18	7E-12	7E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	2.6	1E-06	2E-15	6E-10	1E-06	3E-06	5E-15	1E-09	3E-06	3E-08	5E-17	1E-11	3E-08	7E-08	1E-16	4E-11	7E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	0.3	2E-09	4E-15	2E-09	4E-09	5E-10	1E-15	7E-10	1E-09	6E-10	1E-15	9E-10	2E-09	2E-10	4E-16	3E-10	5E-10	4E-20	9E-26	6E-20	1E-19	1E-20	3E-26	2E-20	3E-20
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	1.5	4E-10	3E-13	3E-09	4E-09	6E-10	5E-13	5E-09	6E-09	1E-09	3E-13	3E-09	5E-09	2E-09	5E-13	5E-09	7E-09	2E-08	5E-13	5E-09	3E-08	4E-08	7E-13	7E-09	4E-08
U-234	0.3	7E-12	3E-13	3E-09	3E-09	2E-12	9E-14	1E-09	1E-09	3E-11	3E-13	3E-09	3E-09	9E-12	9E-14	1E-09	1E-09	6E-09	3E-13	3E-09	9E-09	2E-09	8E-14	9E-10	3E-09
U-235	0.01	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	5E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	6E-10
U-238	0.24	4E-08	3E-13	4E-09	4E-08	9E-09	6E-14	1E-09	1E-08	4E-08	3E-13	4E-09	4E-08	9E-09	6E-14	1E-09	1E-08	3E-08	2E-13	3E-09	3E-08	7E-09	5E-14	8E-10	8E-09
		Cumulative ELCR				**5E-06**	3E-10	1E-08	**5E-06**					**9E-07**	7E-13	9E-09	**9E-07**					**5E-08**	9E-13	9E-09	**5E-08**

Table 7-5: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA H plus I

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	3.5	6E-16	3E-11	3E-12	3E-11	2E-15	9E-11	1E-11	1E-10	0E+00	1E-28	1E-29	2E-28	0E+00	5E-28	5E-29	5E-28	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	0	7E-07	1E-15	1E-09	7E-07	0E+00	0E+00	0E+00	0E+00	3E-07	4E-16	4E-10	3E-07	0E+00	0E+00	0E+00	0E+00	6E-17	9E-26	9E-20	6E-17	0E+00	0E+00	0E+00	0E+00
H-3	75.8	0E+00	1E-09	3E-13	1E-09	0E+00	1E-07	2E-11	1E-07	0E+00	4E-23	9E-27	4E-23	0E+00	3E-21	7E-25	3E-21	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	2.7	6E-15	8E-17	1E-10	1E-10	2E-14	2E-16	3E-10	3E-10	2E-16	2E-18	3E-12	3E-12	4E-16	6E-18	8E-12	8E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	7.7	1E-06	2E-15	6E-10	1E-06	9E-06	1E-14	4E-09	9E-06	3E-08	5E-17	1E-11	3E-08	2E-07	4E-16	1E-10	2E-07	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	0	2E-09	4E-15	2E-09	4E-09	0E+00	0E+00	0E+00	0E+00	6E-10	1E-15	9E-10	2E-09	0E+00	0E+00	0E+00	0E+00	4E-20	9E-26	6E-20	1E-19	0E+00	0E+00	0E+00	0E+00
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	1.6	4E-10	3E-13	3E-09	4E-09	6E-10	5E-13	5E-09	6E-09	1E-09	3E-13	3E-09	5E-09	2E-09	5E-13	6E-09	8E-09	2E-08	5E-13	5E-09	3E-08	4E-08	8E-13	8E-09	5E-08
U-234	0.35	7E-12	3E-13	3E-09	3E-09	2E-12	1E-13	1E-09	1E-09	3E-11	3E-13	3E-09	3E-09	1E-11	1E-13	1E-09	1E-09	6E-09	3E-13	3E-09	9E-09	2E-09	9E-14	1E-09	3E-09
U-235	0.0078	6E-08	3E-13	3E-09	6E-08	4E-10	2E-15	3E-11	5E-10	6E-08	3E-13	3E-09	6E-08	4E-10	2E-15	3E-11	5E-10	5E-08	3E-13	3E-09	6E-08	4E-10	2E-15	3E-11	4E-10
U-238	0.18	4E-08	3E-13	4E-09	4E-08	7E-09	5E-14	7E-10	7E-09	4E-08	3E-13	4E-09	4E-08	7E-09	5E-14	7E-10	7E-09	3E-08	2E-13	3E-09	3E-08	6E-09	4E-14	6E-10	6E-09
Cumulative ELCR						**9E-06**	1E-07	1E-08	**9E-06**					**2E-07**	7E-13	8E-09	**2E-07**					**5E-08**	9E-13	1E-08	**6E-08**

Table 7-6: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA J

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	13.7	6E-16	3E-11	3E-12	3E-11	9E-15	3E-10	4E-11	4E-10	0E+00	1E-28	1E-29	2E-28	0E+00	2E-27	2E-28	2E-27	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	5.7	7E-07	1E-15	1E-09	7E-07	4E-06	6E-15	6E-09	4E-06	3E-07	4E-16	4E-10	3E-07	1E-06	2E-15	2E-09	1E-06	6E-17	9E-26	9E-20	6E-17	3E-16	5E-25	5E-19	3E-16
H-3	0	0E+00	1E-09	3E-13	1E-09	0E+00	0E+00	0E+00	0E+00	0E+00	4E-23	9E-27	4E-23	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0.067	6E-13	5E-13	5E-09	5E-09	4E-14	4E-14	4E-10	4E-10	4E-13	4E-13	4E-09	4E-09	3E-14	3E-14	3E-10	3E-10	2E-12	3E-16	3E-12	5E-12	1E-13	2E-17	2E-13	3E-13
Pu-239	0.038	2E-11	6E-13	6E-09	6E-09	8E-13	2E-14	2E-10	2E-10	2E-11	6E-13	6E-09	6E-09	8E-13	2E-14	2E-10	2E-10	2E-11	6E-13	6E-09	6E-09	8E-13	2E-14	2E-10	2E-10
Pu-241	0.14	1E-12	1E-14	1E-10	1E-10	2E-13	2E-15	2E-11	2E-11	1E-12	1E-14	1E-10	1E-10	2E-13	2E-15	2E-11	2E-11	8E-13	3E-15	3E-11	3E-11	1E-13	4E-16	4E-12	4E-12
Se-79	11.3	6E-15	8E-17	1E-10	1E-10	7E-14	9E-16	1E-09	1E-09	2E-16	2E-18	3E-12	3E-12	2E-15	2E-17	4E-11	4E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	0	1E-06	2E-15	6E-10	1E-06	0E+00	0E+00	0E+00	0E+00	3E-08	5E-17	1E-11	3E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	4	2E-09	4E-15	2E-09	4E-09	7E-09	1E-14	1E-08	2E-08	6E-10	1E-15	9E-10	2E-09	2E-09	5E-15	4E-09	6E-09	4E-20	9E-26	6E-20	1E-19	2E-19	3E-25	2E-19	4E-19
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	0	4E-10	3E-13	3E-09	4E-09	0E+00	0E+00	0E+00	0E+00	1E-09	3E-13	3E-09	5E-09	0E+00	0E+00	0E+00	0E+00	2E-08	5E-13	5E-09	3E-08	0E+00	0E+00	0E+00	0E+00
U-234	0	7E-12	3E-13	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	3E-11	3E-13	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	6E-09	3E-13	3E-09	9E-09	0E+00	0E+00	0E+00	0E+00
U-235	0.01	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	5E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	6E-10
U-238	0.22	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09	3E-08	2E-13	3E-09	3E-08	7E-09	5E-14	8E-10	8E-09
		Cumulative ELCR				**4E-06**	3E-10	2E-08	**4E-06**					**1E-06**	1E-13	7E-09	**1E-06**					**7E-09**	8E-14	1E-09	**8E-09**

Table 7-7: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA L1 plus L2

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	53.8	6E-16	3E-11	3E-12	3E-11	3E-14	1E-09	2E-10	2E-09	0E+00	1E-28	1E-29	2E-28	0E+00	7E-27	8E-28	8E-27	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	3.5	7E-07	1E-15	1E-09	7E-07	2E-06	3E-15	3E-09	2E-06	3E-07	4E-16	4E-10	3E-07	9E-07	1E-15	1E-09	9E-07	6E-17	9E-26	9E-20	6E-17	2E-16	3E-25	3E-19	2E-16
H-3	4.7	0E+00	1E-09	3E-13	1E-09	0E+00	6E-09	1E-12	6E-09	0E+00	4E-23	9E-27	4E-23	0E+00	2E-22	4E-26	2E-22	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	390	0E+00	6E-17	3E-11	3E-11	0E+00	2E-14	1E-08	1E-08	0E+00	5E-17	2E-11	2E-11	0E+00	2E-14	9E-09	9E-09	0E+00	4E-20	2E-14	2E-14	0E+00	2E-17	9E-12	9E-12
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	1.6	6E-15	8E-17	1E-10	1E-10	1E-14	1E-16	2E-10	2E-10	2E-16	2E-18	3E-12	3E-12	3E-16	3E-18	5E-12	5E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	8.9	1E-06	2E-15	6E-10	1E-06	1E-05	2E-14	5E-09	1E-05	3E-08	5E-17	1E-11	3E-08	3E-07	4E-16	1E-10	3E-07	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	2	2E-09	4E-15	2E-09	4E-09	3E-09	7E-15	5E-09	8E-09	6E-10	1E-15	9E-10	2E-09	1E-09	3E-15	2E-09	3E-09	4E-20	9E-26	6E-20	1E-19	8E-20	2E-25	1E-19	2E-19
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	1.5	4E-10	3E-13	3E-09	4E-09	6E-10	5E-13	5E-09	6E-09	1E-09	3E-13	3E-09	5E-09	2E-09	5E-13	5E-09	7E-09	2E-08	5E-13	5E-09	3E-08	4E-08	7E-13	7E-09	4E-08
U-234	0.25	7E-12	3E-13	3E-09	3E-09	2E-12	8E-14	8E-10	8E-10	3E-11	3E-13	3E-09	3E-09	7E-12	8E-14	8E-10	8E-10	6E-09	3E-13	3E-09	9E-09	2E-09	7E-14	7E-10	2E-09
U-235	0.01	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	5E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	6E-10
U-238	0.23	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	1E-09	9E-09	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09	3E-08	2E-13	3E-09	3E-08	7E-09	5E-14	8E-10	8E-09
		Cumulative ELCR				**1E-05**	7E-09	3E-08	**1E-05**					**1E-06**	7E-13	2E-08	**1E-06**					**5E-08**	9E-13	9E-09	**5E-08**

Table 7-8: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA P

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	2.2	4E-11	4E-13	5E-09	5E-09	1E-10	9E-13	1E-08	1E-08	4E-11	4E-13	4E-09	4E-09	9E-11	9E-13	9E-09	9E-09	2E-11	8E-14	9E-10	9E-10	5E-11	2E-13	2E-09	2E-09
C-14	0	6E-16	3E-11	3E-12	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	1E-28	1E-29	2E-28	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0.83	2E-06	3E-16	2E-10	2E-06	2E-06	3E-16	2E-10	2E-06	8E-09	1E-18	1E-12	8E-09	7E-09	1E-18	8E-13	7E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	32.1	7E-07	1E-15	1E-09	7E-07	2E-05	3E-14	3E-08	2E-05	3E-07	4E-16	4E-10	3E-07	8E-06	1E-14	1E-08	8E-06	6E-17	9E-26	9E-20	6E-17	2E-15	3E-24	3E-18	2E-15
H-3	308	0E+00	1E-09	3E-13	1E-09	0E+00	4E-07	8E-11	4E-07	0E+00	4E-23	9E-27	4E-23	0E+00	1E-20	3E-24	1E-20	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0.81	2E-19	2E-15	6E-09	6E-09	1E-19	1E-15	5E-09	5E-09	1E-19	1E-15	4E-09	4E-09	9E-20	9E-16	3E-09	3E-09	2E-23	1E-19	4E-13	4E-13	1E-23	9E-20	3E-13	3E-13
Ni-63	85	0E+00	6E-17	3E-11	3E-11	0E+00	5E-15	3E-09	3E-09	0E+00	5E-17	2E-11	2E-11	0E+00	4E-15	2E-09	2E-09	0E+00	4E-20	2E-14	2E-14	0E+00	4E-18	2E-12	2E-12
Np-237	1.5	1E-07	3E-13	3E-09	1E-07	2E-07	5E-13	5E-09	2E-07	1E-07	3E-13	3E-09	1E-07	2E-07	5E-13	5E-09	2E-07	7E-08	2E-13	2E-09	7E-08	1E-07	2E-13	2E-09	1E-07
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	10.7	2E-11	6E-13	6E-09	6E-09	2E-10	7E-12	6E-08	6E-08	2E-11	6E-13	6E-09	6E-09	2E-10	7E-12	6E-08	6E-08	2E-11	6E-13	6E-09	6E-09	2E-10	6E-12	6E-08	6E-08
Pu-241	39.9	1E-12	1E-14	1E-10	1E-10	4E-11	5E-13	4E-09	4E-09	1E-12	1E-14	1E-10	1E-10	5E-11	5E-13	6E-09	6E-09	8E-13	3E-15	3E-11	3E-11	3E-11	1E-13	1E-09	1E-09
Se-79	4.6	6E-15	8E-17	1E-10	1E-10	3E-14	4E-16	6E-10	6E-10	2E-16	2E-18	3E-12	3E-12	7E-16	1E-17	1E-11	1E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	0	1E-06	2E-15	6E-10	1E-06	0E+00	0E+00	0E+00	0E+00	3E-08	5E-17	1E-11	3E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	82.2	2E-09	4E-15	2E-09	4E-09	1E-07	3E-13	2E-07	3E-07	6E-10	1E-15	9E-10	2E-09	5E-08	1E-13	7E-08	1E-07	4E-20	9E-26	6E-20	1E-19	3E-18	7E-24	5E-18	8E-18
Tc-99	24	5E-13	2E-16	6E-11	6E-11	1E-11	4E-15	1E-09	1E-09	1E-14	4E-18	1E-12	1E-12	3E-13	1E-16	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	1.9	4E-10	3E-13	3E-09	4E-09	8E-10	6E-13	6E-09	7E-09	1E-09	3E-13	3E-09	5E-09	3E-09	6E-13	7E-09	9E-09	2E-08	5E-13	5E-09	3E-08	5E-08	9E-13	9E-09	5E-08
U-234	0.72	7E-12	3E-13	3E-09	3E-09	5E-12	2E-13	2E-09	2E-09	3E-11	3E-13	3E-09	3E-09	2E-11	2E-13	2E-09	2E-09	6E-09	3E-13	3E-09	9E-09	5E-09	2E-13	2E-09	7E-09
U-235	0.025	6E-08	3E-13	3E-09	6E-08	1E-09	7E-15	8E-11	1E-09	6E-08	3E-13	3E-09	6E-08	1E-09	7E-15	8E-11	1E-09	5E-08	3E-13	3E-09	6E-08	1E-09	7E-15	8E-11	1E-09
U-238	0.52	4E-08	3E-13	4E-09	4E-08	2E-08	1E-13	2E-09	2E-08	4E-08	3E-13	4E-09	4E-08	2E-08	1E-13	2E-09	2E-08	3E-08	2E-13	3E-09	3E-08	2E-08	1E-13	2E-09	2E-08
		Cumulative ELCR				**2E-05**	4E-07	3E-07	**2E-05**					**8E-06**	1E-11	2E-07	**9E-06**					**2E-07**	8E-12	8E-08	**3E-07**

Table 7-9: Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA R

Nuclide	EPC (pCi/g)	T=0 Year								T=41.3 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	0	6E-16	3E-11	3E-12	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	1E-28	1E-29	2E-28	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	0	7E-07	1E-15	1E-09	7E-07	0E+00	0E+00	0E+00	0E+00	3E-07	4E-16	4E-10	3E-07	0E+00	0E+00	0E+00	0E+00	6E-17	9E-26	9E-20	6E-17	0E+00	0E+00	0E+00	0E+00
H-3	2.5	0E+00	1E-09	3E-13	1E-09	0E+00	3E-09	7E-13	3E-09	0E+00	4E-23	9E-27	4E-23	0E+00	1E-22	2E-26	1E-22	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	1E-07	3E-13	3E-09	1E-07	0E+00	0E+00	0E+00	0E+00	7E-08	2E-13	2E-09	7E-08	0E+00	0E+00	0E+00	0E+00
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	0	6E-15	8E-17	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00	2E-16	2E-18	3E-12	3E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	0	1E-06	2E-15	6E-10	1E-06	0E+00	0E+00	0E+00	0E+00	3E-08	5E-17	1E-11	3E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	0.37	2E-09	4E-15	2E-09	4E-09	6E-10	1E-15	9E-10	2E-09	6E-10	1E-15	9E-10	2E-09	2E-10	5E-16	3E-10	6E-10	4E-20	9E-26	6E-20	1E-19	1E-20	3E-26	2E-20	4E-20
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	2.4	4E-10	3E-13	3E-09	4E-09	1E-09	8E-13	8E-09	9E-09	1E-09	3E-13	3E-09	5E-09	4E-09	8E-13	8E-09	1E-08	2E-08	5E-13	5E-09	3E-08	6E-08	1E-12	1E-08	7E-08
U-234	0.22	7E-12	3E-13	3E-09	3E-09	2E-12	7E-14	7E-10	7E-10	3E-11	3E-13	3E-09	3E-09	6E-12	7E-14	7E-10	7E-10	6E-09	3E-13	3E-09	9E-09	1E-09	6E-14	7E-10	2E-09
U-235	0.01	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	6E-08	3E-13	3E-09	6E-08	6E-10	3E-15	3E-11	6E-10	5E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	6E-10
U-238	0.22	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09	3E-08	2E-13	3E-09	3E-08	7E-09	5E-14	8E-10	8E-09
				Cumulative ELCR		**1E-08**	3E-09	1E-08	**2E-08**					**1E-08**	9E-13	1E-08	**2E-08**					**7E-08**	1E-12	1E-08	**8E-08**

Table 7-10 Summary of Radiological Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario at EA U

Nuclide	EPC (pCi/g)	T=0 Year							
		RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00
C-14	1.7	6E-16	3E-11	3E-12	3E-11	1E-15	4E-11	5E-12	5E-11
Co-60	0	2E-06	3E-16	2E-10	2E-06	0E+00	0E+00	0E+00	0E+00
Cs-137	2.1	7E-07	1E-15	1E-09	7E-07	1E-06	2E-15	2E-09	1E-06
H-3	0	0E+00	1E-09	3E-13	1E-09	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	2E-15	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	6E-17	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Np-237	0.6	1E-07	3E-13	3E-09	1E-07	8E-08	2E-13	2E-09	8E-08
Pu-238	0	6E-13	5E-13	5E-09	5E-09	0E+00	0E+00	0E+00	0E+00
Pu-239	0	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	0	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00
Se-79	2.8	6E-15	8E-17	1E-10	1E-10	2E-14	2E-16	4E-10	4E-10
Sn-126	6.3	1E-06	2E-15	6E-10	1E-06	7E-06	1E-14	3E-09	7E-06
Sr-90	4.2	2E-09	4E-15	2E-09	4E-09	7E-09	2E-14	1E-08	2E-08
Tc-99	0	5E-13	2E-16	6E-11	6E-11	0E+00	0E+00	0E+00	0E+00
U-233	2.1	4E-10	3E-13	3E-09	4E-09	8E-10	7E-13	7E-09	8E-09
U-234	0.31	7E-12	3E-13	3E-09	3E-09	2E-12	1E-13	1E-09	1E-09
U-235	0.0089	6E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	5E-10
U-238	0.21	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09
				Cumulative ELCR		**9E-06**	4E-11	3E-08	**9E-06**

Nuclide	T=41.3 Year							
	RSR (1/(pCi/g)				Risk (unitless)			
	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	4E-11	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00
C-14	0E+00	1E-28	1E-29	2E-28	0E+00	2E-28	2E-29	3E-28
Co-60	8E-09	1E-18	1E-12	8E-09	0E+00	0E+00	0E+00	0E+00
Cs-137	3E-07	4E-16	4E-10	3E-07	5E-07	8E-16	8E-10	5E-07
H-3	0E+00	4E-23	9E-27	4E-23	0E+00	0E+00	0E+00	0E+00
I-129	1E-19	1E-15	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00
Ni-63	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00
Np-237	1E-07	3E-13	3E-09	1E-07	8E-08	2E-13	2E-09	8E-08
Pu-238	4E-13	4E-13	4E-09	4E-09	0E+00	0E+00	0E+00	0E+00
Pu-239	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	1E-12	1E-14	1E-10	1E-10	0E+00	0E+00	0E+00	0E+00
Se-79	2E-16	2E-18	3E-12	3E-12	4E-16	6E-18	9E-12	9E-12
Sn-126	3E-08	5E-17	1E-11	3E-08	2E-07	3E-16	9E-11	2E-07
Sr-90	6E-10	1E-15	9E-10	2E-09	3E-09	6E-15	4E-09	6E-09
Tc-99	1E-14	4E-18	1E-12	1E-12	0E+00	0E+00	0E+00	0E+00
U-233	1E-09	3E-13	3E-09	5E-09	3E-09	7E-13	7E-09	1E-08
U-234	3E-11	3E-13	3E-09	3E-09	9E-12	1E-13	1E-09	1E-09
U-235	6E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	5E-10
U-238	4E-08	3E-13	4E-09	4E-08	8E-09	6E-14	9E-10	9E-09
Cumulative ELCR					**8E-07**	1E-12	2E-08	**8E-07**

Nuclide	T=1000 Year							
	RSR (1/(pCi/g)				Risk (unitless)			
	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	2E-11	8E-14	9E-10	9E-10	0E+00	0E+00	0E+00	0E+00
C-14	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Co-60	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cs-137	6E-17	9E-26	9E-20	6E-17	1E-16	2E-25	2E-19	1E-16
H-3	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	2E-23	1E-19	4E-13	4E-13	0E+00	0E+00	0E+00	0E+00
Ni-63	0E+00	4E-20	2E-14	2E-14	0E+00	0E+00	0E+00	0E+00
Np-237	7E-08	2E-13	2E-09	7E-08	4E-08	1E-13	1E-09	4E-08
Pu-238	2E-12	3E-16	3E-12	5E-12	0E+00	0E+00	0E+00	0E+00
Pu-239	2E-11	6E-13	6E-09	6E-09	0E+00	0E+00	0E+00	0E+00
Pu-241	8E-13	3E-15	3E-11	3E-11	0E+00	0E+00	0E+00	0E+00
Se-79	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sn-126	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Sr-90	4E-20	9E-26	6E-20	1E-19	2E-19	4E-25	2E-19	4E-19
Tc-99	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
U-233	2E-08	5E-13	5E-09	3E-08	5E-08	1E-12	1E-08	6E-08
U-234	6E-09	3E-13	3E-09	9E-09	2E-09	8E-14	9E-10	3E-09
U-235	5E-08	3E-13	3E-09	6E-08	5E-10	3E-15	3E-11	5E-10
U-238	3E-08	2E-13	3E-09	3E-08	6E-09	5E-14	7E-10	7E-09
Cumulative ELCR					**1E-07**	1E-12	1E-08	**1E-07**

Table 7-11: Maximum Risk Assessment Results Results Based on 4-Inches Isolation Barrier for CERCLA Industrial Worker Scenario

Exposure Pathways	Exposure Areas									
	A plus B	C	E	F plus G	H plus I	J	L1 plus L2	P	R	U
External Gamma	6E-05	7E-05	3E-05	5E-06	9E-06	4E-06	1E-05	2E-05	7E-08	9E-06
Inhalation	9E-11	2E-13	9E-13	3E-10	1E-07	3E-10	7E-09	4E-07	1E-12	4E-11
Soil Ingestion	9E-08	4E-08	3E-08	1E-08	1E-08	2E-08	3E-08	3E-07	1E-08	3E-08
Cumulative ELCR	6E-05	7E-05	3E-05	5E-06	9E-06	4E-06	1E-05	2E-05	8E-08	9E-06

Table 7-12: Nonradiological Risk Assessment Results for three UPRs under CERCLA Industrial Worker Scenario

Exposure Pathways	UPR-81		UPR-82		UPR-86	
	ELCR	**HI**	**ELCR**	**HI**	**ELCR**	**HI**
Ingestion	0E+00	2E-02	0E+00	6E-03	0E+00	2E-03
Inhalation	7E-09	1E-05	4E-09	2E-06	1E-09	6E-07
Dermal Contact	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cumulative Risk	**7E-09**	0.02	**4E-09**	**0.01**	**1E-09**	**0.002**

Table 7-13: Nonradiological Risk Assessment Results for three UPRs under WAC Industrial Worker Scenario

Exposure Pathways	UPR-81		UPR-82		UPR-86	
	ELCR	**HI**	**ELCR**	**HI**	**ELCR**	**HI**
Ingestion	0E+00	1E-02	0E+00	4E-03	0E+00	1E-03
Inhalation	4E-08	4E-05	2E-08	8E-06	6E-09	3E-06
Cumulative Risk	**4E-08**	**0.01**	**2E-08**	**0.004**	**6E-09**	**0.001**

Appendix A
SOFTWARE INSTALLATION AND CHECKOUT FORMS FOR RESRAD

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.876 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   INTERA-0740
7. Operating System (include version number):
   Windows 8.1
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 0, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    PASS
16. Test Performed By: M Rahman
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Passed; Installation added to HISI Entry

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD — Software Version No.: 7.0

Prepared By:

	Signature	Print	Date
19. Software Owner (Signature)		WE Nichols	
20. Test Personnel: Sign	M. Rahman	M RAHMAN	11-16-15
Sign			
Sign			

Approved By:

	Signature	Print	Date
21. Software SME (Signature)		N/R per SMP	

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.852 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   Intera-00474
7. Operating System (include version number):
   Windows 10 Pro
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 2, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    Test results matched expected results; pass.
16. Test Performed By: SL Lindberg
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Approved; installation added to HISI entry software user list.

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD — Software Version No.: 7.0

Prepared By:

19.		WE Nichols	
	Software Owner (Signature)	Print	Date
20. Test Personnel:	[signature]	SL Lindberg	08/03/2016
	Sign	Print	Date
	Sign	Print	Date
	Sign	Print	Date

Approved By:

21.		N/R per SMP	
	Software SME (Signature)	Print	Date

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APPENDIX B

Results of Intake and Risk Assessment for Nonradiological Contaminants at UPRs under CERCLA Industrial Worker Exposure Scenario

Table B-1: Determination of Nonradiological Soil Concentrations at three UPRs

	Units	UPR-81	UPR-82	UPR-86					
		release	release	release					
Waste Type	N/A	CWP2	P2	P2					
sample yr		1969	1969	1971					
^{137}Cs Conc (Ci/L)		1.63E-03	0.35	0.12					
Cs ratio		4.00	0.75	0.25					
Volume	L	136260	9841	64345					
Impacted Soil Volume[1]	gal	36000	2600	17000		ft^3	18654	1347	8809
Constituents	**Units**	**UPR-81**	**UPR-82**	**UPR-86**	**Mobile?**	**Units**	**UPR-81**	**UPR-82**	**UPR-86**
	Inventory					**Concentration**			
Al(OH)4 -	kg	3.26E+04	0.00E+00	0.00E+00	No	mg/kg	28944	0	0
Al					No	mg/kg	8220	0	0
Bi	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
butanol	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
Ca	kg	8.20E+01	1.11E+00	2.38E+00	No	mg/kg	73	14	4
Cl-	kg	2.23E+02	6.89E+00	1.48E+01	Yes	mg/kg	NA	NA	NA
CO3--	kg	1.23E+02	1.66E+00	3.56E+00	Yes	mg/kg	NA	NA	NA
Cr	kg	8.68E+01	3.12E+00	6.70E+00	No	mg/kg	77	38	13
DBP	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
F-	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
Fe	kg	5.71E+01	7.71E-01	1.66E+00	No	mg/kg	51	9	3
Hg	kg	0.00E+00	2.39E-03	5.13E-03	No	mg/kg	0.00	0.03	0.01
K	kg	5.36E+01	1.65E+00	3.55E+00	No	mg/kg	48	20	7
La	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
Mn	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
Na	kg	2.03E+04	1.99E+02	4.27E+02	Yes	mg/kg	NA	NA	NA
NH3	kg	1.72E-01	3.85E+00	8.27E+00	Yes	mg/kg	NA	NA	NA
Ni	kg	4.90E+01	7.88E-01	1.69E+00	No	mg/kg	44	10	3
NO2-	kg	7.12E+03	2.08E+02	4.47E+02	Yes	mg/kg	NA	NA	NA
NO3-	kg	2.32E+04	5.48E+01	1.18E+02	Yes	mg/kg	NA	NA	NA
OH-	kg	1.74E+02	2.31E+01	4.97E+01	Yes	mg/kg	NA	NA	NA
Pb	kg	8.13E+01	1.10E+00	2.36E+00	No	mg/kg	72	14	4
PO4---	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
SiO3--	kg	0.00E+00	5.90E+00	1.27E+01	Yes	mg/kg	NA	NA	NA
SO4--	kg	3.53E+02	8.76E+01	1.88E+02	Yes	mg/kg	NA	NA	NA
Sr	kg	5.39E-03	3.35E-04	7.20E-04	No	mg/kg	0	0	0
TOC (total C)	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
U total	kg	1.69E+01	2.28E-01	4.90E-01	No	mg/kg	15	3	1
Zr	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0

1 Impacted Soil Volume (ft^3) = Volume (gallon)/ Soil Porosity/ 7.48 gallon/ft^3

2 Soil Concentration = [Inventory (kg) x 106 mg/kg] /[Impacted soil volume (ft^3) x 28316 cm^3/ft^3 x Soil density (gm/cm^3)/ 1000 gm/kg]

Table B-2: Toxicity Values for Nonradiological Contaminants

Chemical COPCs	CAS#	(Including Reference)[1]				(Including Reference)[1]				GI Factor (%)	Toxicity Values[3]		Dermal Absorption Factor[1]
		Oral SF 1/(mg/kg-d)	Ref	RfDo (mg/kg-d)	Ref	IUR $(ug/m^3)^{-1}$	Ref	RfCi (mg/m^3)	Ref		Dermal SF 1/(mg/kg-d)	RfDd (mg/kg-d)	
Aluminum	7429-90-5			1.00E+00	P			5.00E-03	P	100		1.0E+00	
Chromium	7440-47-3			3.00E-03	I	8.40E-02	S	1.00E-04	I	2.5		7.5E-05	
Iron	7439-89-6			0.7	P					100		7.0E-01	
Mercury	7439-97-6							3.0E-04	I	7			
Nickel	7440-02-0			0.02	I	0.00026	C	0.00009	A	4		8.0E-04	
Total Uranium	#N/A			0.003	I			0.00004	A	100		3.0E-03	

[1] EPA Regional Screening Level (RSL) Tables, May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

References Cited in RSL Tables:

I = IRIS (Integrated Risk Information System Values)

P = PPRTV (Provisional Peer Reviewed Toxicity Values)

A = ATSDR (Agency for Toxic Substances and Disease Registry)

Table B-3: Chemical Concentrations in Air Calculations
Waste Management Unit Area C

	Equation	CA	=	[	CS	x	CF	]	x	[	(1/PEF)	+	(1/VF)	]
	Units	ug/m^3			mg/kg		ug/mg				m^3/kg		m^3/kg	
UPRs														
81	Aluminum	1.13E-04	=	[	8,219.51	x	1000	]	x	[	1.37E-11	+	ND	]
	Chromium	1.06E-06	=	[	77.18	x	1000	]	x	[	1.37E-11	+	ND	]
	Iron	6.95E-07	=	[	50.75	x	1000	]	x	[	1.37E-11	+	ND	]
	Mercury	0.00E+00	=	[	-	x	1000	]	x	[	1.37E-11	+	ND	]
	Nickel	5.97E-07	=	[	43.57	x	1000	]	x	[	1.37E-11	+	ND	]
	Total Uranium	2.06E-07	=	[	15.03	x	1000	]	x	[	1.37E-11	+	ND	]
	Aluminum	0.00E+00	=	[	-	x	1000	]	x	[	1.37E-11	+	ND	]
	Chromium	5.25E-07	=	[	38.34	x	1000	]	x	[	1.37E-11	+	ND	]
	Iron	1.30E-07	=	[	9.48	x	1000	]	x	[	1.37E-11	+	ND	]
	Mercury	4.02E-10	=	[	0.03	x	1000	]	x	[	1.37E-11	+	ND	]
	Nickel	1.33E-07	=	[	9.69	x	1000	]	x	[	1.37E-11	+	ND	]
	Total Uranium	3.85E-08	=	[	2.81	x	1000	]	x	[	1.37E-11	+	ND	]
86	Aluminum	0.00E+00	=	[	-	x	1000	]	x	[	1.37E-11	+	ND	]
	Chromium	1.73E-07	=	[	12.60	x	1000	]	x	[	1.37E-11	+	ND	]
	Iron	4.27E-08	=	[	3.12	x	1000	]	x	[	1.37E-11	+	ND	]
	Mercury	1.32E-10	=	[	0.01	x	1000	]	x	[	1.37E-11	+	ND	]
	Nickel	4.36E-08	=	[	3.19	x	1000	]	x	[	1.37E-11	+	ND	]
	Total Uranium	1.26E-08	=	[	0.92	x	1000	]	x	[	1.37E-11	+	ND	]

CA = Chemical concentration in air
CS = chemical concentration in soil
CF = Conversion Factor
PEF = Particulate Emission Factor
VF = Volatilization Factor

Table B-4: Daily Intake Calculations: Adult Industrial Worker
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 81
Waste Management Area C

Equation	CDIingestion	=	[	C_S	x	IR_S	x	FI	x	CF1	x	EF	x	ED	]	/	[	BW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		days/year		years				kg		days	

CARCINOGENIC EFFECTS

Aluminum	1.26E-03	=	[	8,219.51	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	1.18E-05	=	[	77.18	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Iron	7.76E-06	=	[	50.75	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	6.66E-06	=	[	43.57	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	2.30E-06	=	[	15.03	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]

NONCARCINOGENIC EFFECTS

Aluminum	3.52E-03	=	[	8,219.51	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	3.30E-05	=	[	77.18	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Iron	2.17E-05	=	[	50.75	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	1.87E-05	=	[	43.57	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	6.43E-06	=	[	15.03	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]

CDIingestion = chronic daily chemical intake via soil ingestion
CS = chemical concentration in soil
IR = soil ingestion rate
FI = fraction of intake
CF1 = conversion factor
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table B-5: Daily Intake Calculations: Adult Industrial Worker
Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 81
Waste Management Area C

Equation	EC	= [	CA	x	EF	x	ET	x	ED	]	/	[(	AT	x	CF2	)]
Units	ug/m³		ug/m³		days/year		hrs/day		years				days		hrs/day	
CARCINOGENIC EFFECTS																
Aluminum	9.18E-06	= [	1.1E-04	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Chromium	8.62E-08	= [	1.1E-06	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Iron	5.67E-08	= [	7.0E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Mercury	0.00E+00	= [	0.0E+00	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Nickel	4.87E-08	= [	6.0E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Total Uranium	1.68E-08	= [	2.1E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
NONCARCINOGENIC EFFECTS																
Aluminum	2.57E-05	= [	1.1E-04	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Chromium	2.41E-07	= [	1.1E-06	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Iron	1.59E-07	= [	7.0E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Mercury	0.00E+00	= [	0.0E+00	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Nickel	1.36E-07	= [	6.0E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Total Uranium	4.70E-08	= [	2.1E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]

EC = Exposure concentration of chemical
EF = exposure frequency
ED = exposure duration
CA = chemical concentration in air
ET = exposure time
AT = averaging time
CF2 = conversion factor

Table B-6: Daily Intake Calculations: Adult Industrial Worker
Dermal Contact with Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 81
Waste Management Area C

Equation	DAD_{dermal}	=	[	C_S	x	CF3	x	SA	x	AF	x	ABS	x	EV	x	EF	x	ED	]	/	[	BW	x	AT	]
Units	mg/kg-day			mg/kg		kg/mg		cm^2		mg/cm^2-event		unitless		Events/day		days/year		years				kg		days	
CARCINOGENIC EFFECTS																									
Aluminum	NC	=	[	8,219.51	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	NC	=	[	77.18	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Iron	NC	=	[	50.75	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	NC	=	[	-	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	NC	=	[	43.57	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	NC	=	[	15.03	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
NONCARCINOGENIC EFFECTS																									
Aluminum	NC	=	[	8219.51	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	NC	=	[	77.18	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Iron	NC	=	[	50.75	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	NC	=	[	0.00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	NC	=	[	43.57	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	NC	=	[	15.03	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]

DAD_{dermal} = daily absorbed chemical dose
CS = chemical concentration in soil
CF3 = conversion factor
SA = skin surface area available for contact
AF =soil to skin adherence factor
ABS = absorption factor
NA = Not Available
NC = Not Calculated

EV = Event Frequency
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table B-7: Risk Characterization
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 81
Waste Management Area C

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CSFo**	**=**	**CR**	**CDI**	**/**	**RfDo**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Ingestion of Chemicals in Soil										
Aluminum	1.26E-03	x	0.00E+00	=	0E+00	3.52E-03	/	1.00E+00	=	3.5E-03
Chromium	1.18E-05	x	0.00E+00	=	0E+00	3.30E-05	/	3.00E-03	=	1.1E-02
Iron	7.76E-06	x	0.00E+00	=	0E+00	2.17E-05	/	7.00E-01	=	3.1E-05
Mercury	0.00E+00	x	0.00E+00	=	0E+00	0.00E+00	/	0.00E+00	=	NA
Nickel	6.66E-06	x	0.00E+00	=	0E+00	1.87E-05	/	2.00E-02	=	9.3E-04
Total Uranium	2.30E-06	x	0.00E+00	=	0E+00	6.43E-06	/	3.00E-03	=	2.1E-03
			Pathway total	=	0E+00			Pathway total	=	1.8E-02

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects						
Equation	**EC**	**x**	**IUR**	**=**	**CR**	**EC**	**/[**	**Rfc**	**x**	**CF**	**]=**	**HQ**
Units	**ug/m^3**		**(ug/m^3)$^{-1}$**		**unitless**	**ug/m^3**		**mg/m^3**		ug/mg		**unitless**
Aluminum	9.18E-06	x	0.00E+00	=	0.0E+00	2.57E-05	/[	5.00E-03	x	1000	]=	5.1E-06
Chromium	8.62E-08	x	8.40E-02	=	7.2E-09	2.41E-07	/[	1.00E-04	x	1000	]=	2.4E-06
Iron	5.67E-08	x		=	NA	1.59E-07	/[		x	1000	]=	NA
Mercury	0.00E+00	x	0.00E+00	=	0.0E+00	0.00E+00	/[	3.00E-04	x	1000	]=	0.0E+00
Nickel	4.87E-08	x	2.60E-04	=	1.3E-11	1.36E-07	/[	9.00E-05	x	1000	]=	1.5E-06
Total Uranium	1.68E-08	x		=	NA	4.70E-08	/[	4.00E-05	x	1000	]=	1.2E-06
			Pathway total =		7.3E-09					Pathway total =		1.0E-05

Dermal Contact with Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DAD**	**x**	**SF_{ABS}**	**=**	**CR**	**DAD**	**/**	**RfD_{ABS}**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	NC	x	0.00E+00	=	NA	NC	/	1.00E+00	=	NA
Chromium	NC	x		=	NA	NC	/	7.50E-05	=	NA
Iron	NC	x		=	NA	NC	/	7.00E-01	=	NA
Mercury	NC	x		=	NA	NC	/		=	NA
Nickel	NC	x		=	NA	NC	/	8.00E-04	=	NA
Total Uranium	NC	x		=	NA	NC	/	3.00E-03	=	NA
			Pathway total =		**0.0E+00**			Pathway total =		0.00E+00

Chemical Totals	**Carcinogenic Effects**			**Noncarcinogenic Effects**		
Aluminum	Sum of all pathways	=	NA	Sum of all pathways	=	4E-03
Chromium	Sum of all pathways	=	7.2E-09	Sum of all pathways	=	1E-02
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	3E-05
Mercury	Sum of all pathways	=	NA	Sum of all pathways	=	NA
Nickel	Sum of all pathways	=	1.3E-11	Sum of all pathways	=	9E-04
Total Uranium	Sum of all pathways	=	NA	Sum of all pathways	=	2E-03

	Total Carcinogenic Risk All Pathways and Chemicals = 7.3E-09	Total Noncarcinogenic Risk All Pathways and Chemicals = 1.8E-02

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Bold indicates risk exceeding the de-minimis level: greater than 1E-05 for carcinogenic risks and greater than 1E+00 for noncaner risks.

Table B-8: Daily Intake Calculations: Adult Industrial Worker
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 82
Waste Management Area C

Equation	CDIingestion	=	[	C_S	x	IR_S	x	FI	x	CF1	x	EF	x	ED	]	/	[	BW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		days/year		years				kg		days	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	5.86E-06	=	[	38.34	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Iron	1.45E-06	=	[	9.48	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	4.49E-09	=	[	0.03	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	1.48E-06	=	[	9.69	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	4.29E-07	=	[	2.81	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	1.64E-05	=	[	38.34	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Iron	4.06E-06	=	[	9.48	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	1.26E-08	=	[	0.03	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	4.15E-06	=	[	9.69	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	1.20E-06	=	[	2.81	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]

CDIingestion = chronic daily chemical intake via soil ingestion
CS = chemical concentration in soil
IR = soil ingestion rate
FI = fraction of intake
CF1 = conversion factor
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

**Table B-9: Daily Intake Calculations: Adult Industrial Worker
Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 82
Waste Management Area C**

Equation	EC	= [	CA	x	EF	x	ET	x	ED	]	/	[(	AT	x	CF2	)]
Units	ug/m³		ug/m³		days/year		hrs/day		years				days		hrs/day	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.0E+00	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Chromium	4.28E-08	=	[	5.3E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Iron	1.06E-08	=	[	1.3E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Mercury	3.28E-11	=	[	4.0E-10	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Nickel	1.08E-08	=	[	1.3E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Total Uranium	3.14E-09	=	[	3.8E-08	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.0E+00	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Chromium	1.20E-07	=	[	5.3E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Iron	2.97E-08	=	[	1.3E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Mercury	9.18E-11	=	[	4.0E-10	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Nickel	3.03E-08	=	[	1.3E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Total Uranium	8.78E-09	=	[	3.8E-08	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]

EC = Exposure concentration of chemical
CA = chemical concentration in air
CF2 = conversion factor
EF = exposure frequency
ET = exposure time
ED = exposure duration
AT = averaging time

Table B-10: Daily Intake Calculations: Adult Industrial Worker
Dermal Contact with Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 82
Waste Management Area C

Equation	**DAD_{dermal}**	**=**	**[**	**C_S**	**x**	**CF3**	**x**	**SA**	**x**	**AF**	**x**	**ABS**	**x**	**EV**	**x**	**EF**	**x**	**ED**	**]**	**/**	**[**	**BW**	**x**	**AT**	**]**
Units	**mg/kg-day**			**mg/kg**		**kg/mg**		**cm^2**		**mg/cm^2-event**		**unitless**		**Events/day**		**days/year**		**years**				**kg**		**days**	

CARCINOGENIC EFFECTS

Aluminum	NC	=	[	-	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	NC	=	[	38.34	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Iron	NC	=	[	9.48	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	NC	=	[	0.03	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	NC	=	[	9.69	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	NC	=	[	2.81	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]

NONCARCINOGENIC EFFECTS

Aluminum	NC	=	[	0.00E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	NC	=	[	3.83E+01	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Iron	NC	=	[	9.48E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	NC	=	[	2.94E-02	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	NC	=	[	9.69E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	NC	=	[	2.81E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]

DAD_{dermal} = daily absorbed chemical dose
CS = chemical concentration in soil
CF3 = conversion factor
SA = skin surface area available for contact
AF =soil to skin adherence factor
ABS = absorption factor
NA = Not Available
NC = Not Calculated
EV = Event Frequency
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table B-11: Risk Characterization
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 82
Waste Management Area C

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CSFo**	**=**	**CR**	**CDI**	**/**	**RfDo**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Ingestion of Chemicals in Soil										
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.00E+00	=	0.00E+00
Chromium	5.86E-06	x	0.00E+00	=	0.00E+00	1.64E-05	/	3.00E-03	=	5.47E-03
Iron	1.45E-06	x	0.00E+00	=	0.00E+00	4.06E-06	/	7.00E-01	=	5.80E-06
Mercury	4.49E-09	x	0.00E+00	=	0.00E+00	1.26E-08	/	0.00E+00	=	NA
Nickel	1.48E-06	x	0.00E+00	=	0.00E+00	4.15E-06	/	2.00E-02	=	2.07E-04
Total Uranium	4.29E-07	x	0.00E+00	=	0.00E+00	1.20E-06	/	3.00E-03	=	4.01E-04
			Pathway total	=	0.00E+00			Pathway total	=	6.08E-03

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects						
Equation	**EC**	**x**	**IUR**	**=**	**CR**	**EC**	**/[**	**Rfc**	**x**	**CF**	**]=**	**HQ**
Units	**ug/m^3**		**(ug/m^3)$^{-1}$**		**unitless**	**ug/m^3**		**mg/m^3**		ug/mg		**unitless**
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/[	5.00E-03	x	1000	]=	0.00E+00
Chromium	4.28E-08	x	8.40E-02	=	3.60E-09	1.20E-07	/[	1.00E-04	x	1000	]=	1.20E-06
Iron	1.06E-08	x		=	NA	2.97E-08	/[		x	1000	]=	NA
Mercury	3.28E-11	x	0.00E+00	=	0.00E+00	9.18E-11	/[	3.00E-04	x	1000	]=	3.06E-10
Nickel	1.08E-08	x	2.60E-04	=	2.81E-12	3.03E-08	/[	9.00E-05	x	1000	]=	3.37E-07
Total Uranium	3.14E-09	x		=	NA	8.78E-09	/[	4.00E-05	x	1000	]=	2.19E-07
			Pathway total =		3.60E-09					Pathway total =		1.76E-06

Dermal Contact with Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DAD**	**x**	**SF_{ABS}**	**=**	**CR**	**DAD**	**/**	**RfD_{ABS}**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	NC	x	0.00E+00	=	NA	NC	/	1.00E+00	=	NA
Chromium	NC	x		=	NA	NC	/	7.50E-05	=	NA
Iron	NC	x		=	NA	NC	/	7.00E-01	=	NA
Mercury	NC	x		=	NA	NC	/		=	NA
Nickel	NC	x		=	NA	NC	/	8.00E-04	=	NA
Total Uranium	NC	x		=	NA	NC	/	3.00E-03	=	NA
			Pathway total =		**0.00E+00**			Pathway total =		0.00E+00

Chemical Totals

	Carcinogenic Effects			Noncarcinogenic Effects		
Aluminum	Sum of all pathways	=	NA	Sum of all pathways	=	NA
Chromium	Sum of all pathways	=	3.60E-09	Sum of all pathways	=	5.5E-03
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	5.8E-06
Mercury	Sum of all pathways	=	NA	Sum of all pathways	=	3.1E-10
Nickel	Sum of all pathways	=	2.81E-12	Sum of all pathways	=	2.1E-04
Total Uranium	Sum of all pathways	=	NA	Sum of all pathways	=	4.0E-04

Total Carcinogenic Risk All Pathways and Chemicals = 3.60E-09	Total Noncarcinogenic Risk All Pathways and Chemicals = 6.09E-03

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Bold indicates risk exceeding the de-minimis level: greater than 1E-05 for carcinogenic risks and greater than 1E+00 for noncaner risks.

Table B-12: Daily Intake Calculations: Adult Industrial Worker
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 86
Waste Management Area C

Equation	CDIingestion	=	[	C_S	x	IR_S	x	FI	x	CF1	x	EF	x	ED	]	/	[	BW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		days/year		years				kg		days	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	1.93E-06	=	[	12.60	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Iron	4.77E-07	=	[	3.12	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	1.48E-09	=	[	0.01	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	4.87E-07	=	[	3.19	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	1.41E-07	=	[	0.92	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	25,550	]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	5.40E-06	=	[	12.60	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Iron	1.33E-06	=	[	3.12	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	4.13E-09	=	[	0.01	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	1.36E-06	=	[	3.19	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	3.95E-07	=	[	0.92	x	50	x	1	x	1.00E-06	x	250	x	25	]	/	[	80	x	9,125	]

CDIingestion = chronic daily chemical intake via soil ingestion
CS = chemical concentration in soil
IR = soil ingestion rate
FI = fraction of intake
CF1 = conversion factor
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table B-13: Daily Intake Calculations: Adult Industrial Worker Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 86 Waste Management Area C

Equation	EC	= [	CA	x	EF	x	ET	x	ED	]	/	[(	AT	x	CF2	)]
Units	ug/m³		ug/m³		days/year		hrs/day		years				days		hrs/day	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	= [	0.0E+00	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Chromium	1.41E-08	= [	1.7E-07	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Iron	3.48E-09	= [	4.3E-08	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Mercury	1.08E-11	= [	1.3E-10	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Nickel	3.56E-09	= [	4.4E-08	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]
Total Uranium	1.03E-09	= [	1.3E-08	x	250	x	8.0	x	25	]	/	[(	25,550	x	24	)]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	= [	0.0E+00	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Chromium	3.94E-08	= [	1.7E-07	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Iron	9.75E-09	= [	4.3E-08	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Mercury	3.02E-11	= [	1.3E-10	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Nickel	9.96E-09	= [	4.4E-08	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]
Total Uranium	2.89E-09	= [	1.3E-08	x	250	x	8.0	x	25	]	/	[(	9,125	x	24	)]

EC = Exposure concentration of chemical
CA = chemical concentration in air
CF2 = conversion factor
EF = exposure frequency
ET = exposure time
ED = exposure duration
AT = averaging time

Table B-14: Daily Intake Calculations: Adult Industrial Worker
Dermal Contact with Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 86
Waste Management Area C

Equation	DAD_{dermal}	=	[	C_S	x	CF3	x	SA	x	AF	x	ABS	x	EV	x	EF	x	ED	]	/	[	BW	x	AT	]
Units	mg/kg-day			mg/kg		kg/mg		cm^2		mg/cm^2-event		unitless		Events/day		days/year		years				kg		days	
CARCINOGENIC EFFECTS																									
Aluminum	NC	=	[	-	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Chromium	NC	=	[	12.60	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Iron	NC	=	[	3.12	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Mercury	NC	=	[	0.01	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Nickel	NC	=	[	3.19	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
Total Uranium	NC	=	[	0.92	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	25,550	]
NONCARCINOGENIC EFFECTS																									
Aluminum	NC	=	[	0.00E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Chromium	NC	=	[	1.26E+01	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Iron	NC	=	[	3.12E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Mercury	NC	=	[	9.65E-03	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Nickel	NC	=	[	3.19E+00	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]
Total Uranium	NC	=	[	9.23E-01	x	1.00E-06	x	3,527	x	0.12	x	NA	x	1	x	250	x	25	]	/	[	80	x	9,125	]

DAD_{dermal} = daily absorbed chemical dose
CS = chemical concentration in soil
CF3 = conversion factor
SA = skin surface area available for contact
AF =soil to skin adherence factor
ABS = absorption factor
NA = Not Available
NC = Not Calculated
EV = Event Frequency
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table B-16: Risk Characterization
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 86
Waste Management Area C

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CSFo**	**=**	**CR**	**CDI**	**/**	**RfDo**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Ingestion of Chemicals in Soil										
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.00E+00	=	0.00E+00
Chromium	1.93E-06	x	0.00E+00	=	0.00E+00	5.40E-06	/	3.00E-03	=	1.80E-03
Iron	4.77E-07	x	0.00E+00	=	0.00E+00	1.33E-06	/	7.00E-01	=	1.91E-06
Mercury	1.48E-09	x	0.00E+00	=	0.00E+00	4.13E-09	/	0.00E+00	=	NA
Nickel	4.87E-07	x	0.00E+00	=	0.00E+00	1.36E-06	/	2.00E-02	=	6.82E-05
Total Uranium	1.41E-07	x	0.00E+00	=	0.00E+00	3.95E-07	/	3.00E-03	=	1.32E-04
			Pathway total	=	0.00E+00			Pathway total	=	2.00E-03

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects						
Equation	**EC**	**x**	**IUR**	**=**	**CR**	**EC**	**/[**	**Rfc**	**x**	**CF**	**]=**	**HQ**
Units	**ug/m^3**		**(ug/m^3)$^{-1}$**		**unitless**	**ug/m^3**		**mg/m^3**		ug/mg		**unitless**
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/[	5.00E-03	x	1000	]=	0.00E+00
Chromium	1.41E-08	x	8.40E-02	=	1.18E-09	3.94E-08	/[	1.00E-04	x	1000	]=	3.94E-07
Iron	3.48E-09	x		=	NA	9.75E-09	/[		x	1000	]=	NA
Mercury	1.08E-11	x	0.00E+00	=	0.00E+00	3.02E-11	/[	3.00E-04	x	1000	]=	1.01E-10
Nickel	3.56E-09	x	2.60E-04	=	9.25E-13	9.96E-09	/[	9.00E-05	x	1000	]=	1.11E-07
Total Uranium	1.03E-09	x		=	NA	2.89E-09	/[	4.00E-05	x	1000	]=	7.22E-08
			Pathway total =		1.18E-09					Pathway total =		5.77E-07

Dermal Contact with Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DAD**	**x**	**SF_{ABS}**	**=**	**CR**	**DAD**	**/**	**RfD_{ABS}**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	NC	x	0.00E+00	=	NA	NC	/	1.00E+00	=	NA
Chromium	NC	x		=	NA	NC	/	7.50E-05	=	NA
Iron	NC	x		=	NA	NC	/	7.00E-01	=	NA
Mercury	NC	x		=	NA	NC	/		=	NA
Nickel	NC	x		=	NA	NC	/	8.00E-04	=	NA
Total Uranium	NC	x		=	NA	NC	/	3.00E-03	=	NA
			Pathway total =		**0.00E+00**			Pathway total =		0.00E+00

Chemical Totals

	Carcinogenic Effects			Noncarcinogenic Effects		
Aluminum	Sum of all pathways	=	NA	Sum of all pathways	=	NA
Chromium	Sum of all pathways	=	1.18E-09	Sum of all pathways	=	1.8E-03
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	1.9E-06
Mercury	Sum of all pathways	=	NA	Sum of all pathways	=	1.0E-10
Nickel	Sum of all pathways	=	9.25E-13	Sum of all pathways	=	6.8E-05
Total Uranium	Sum of all pathways	=	NA	Sum of all pathways	=	1.3E-04
	Total Carcinogenic Risk All Pathways and Chemicals	=	1.18E-09	Total Noncarcinogenic Risk All Pathways and Chemicals	=	2.00E-03

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Bold indicates risk exceeding the de-minimis level: greater than 1E-05 for carcinogenic risks and greater than 1E+00 for noncaner risks.

Table B-17: Nonradiological Risk Assessment Results for three UPRs under CERCLA Industrial Worker Scenario

Exposure Pathways	UPR-81		UPR-82		UPR-86	
	ELCR	HI	ELCR	HI	ELCR	HI
Ingestion	0E+00	2E-02	0E+00	6E-03	0E+00	2E-03
Inhalation	7E-09	1E-05	4E-09	2E-06	1E-09	6E-07
Dermal Contact	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cumulative Risk	**7E-09**	**0.02**	**4E-09**	**0.01**	**1E-09**	**0.002**

APPENDIX C
Results of Intake and Risk Assessment for Nonradiological Contaminants at UPRs under WAC Industrial Worker Exposure Scenario

Table C-1: Determination of Nonradiological Soil Concentrations at three UPRs

	Units	UPR-81	UPR-82	UPR-86					
		release	release	release					
Waste Type	N/A	CWP2	P2	P2					
sample yr		1969	1969	1971					
^{137}Cs Conc (Ci/L)		1.63E-03	0.35	0.12					
Cs ratio		4.00	0.75	0.25					
Volume	L	136260	9841	64345					
Impacted Soil Volume[1]	gal	36000	2600	17000		ft^3	18654	1347	8809
Constituents	**Units**	**UPR-81**	**UPR-82**	**UPR-86**	**Mobile?**	**Units**	**UPR-81**	**UPR-82**	**UPR-86**
		Inventory					**Concentration**		
Al(OH)4 -	kg	3.26E+04	0.00E+00	0.00E+00	No	mg/kg	28944	0	0
Al					No	mg/kg	8220		
Bi	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
butanol	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
Ca	kg	8.20E+01	1.11E+00	2.38E+00	No	mg/kg	73	14	4
Cl-	kg	2.23E+02	6.89E+00	1.48E+01	Yes	mg/kg	NA	NA	NA
CO3--	kg	1.23E+02	1.66E+00	3.56E+00	Yes	mg/kg	NA	NA	NA
Cr	kg	8.68E+01	3.12E+00	6.70E+00	No	mg/kg	77	38	13
DBP	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
F-	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
Fe	kg	5.71E+01	7.71E-01	1.66E+00	No	mg/kg	51	9	3
Hg	kg	0.00E+00	2.39E-03	5.13E-03	No	mg/kg	0.00	0.03	0.01
K	kg	5.36E+01	1.65E+00	3.55E+00	No	mg/kg	48	20	7
La	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
Mn	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0
Na	kg	2.03E+04	1.99E+02	4.27E+02	Yes	mg/kg	NA	NA	NA
NH3	kg	1.72E-01	3.85E+00	8.27E+00	Yes	mg/kg	NA	NA	NA
Ni	kg	4.90E+01	7.88E-01	1.69E+00	No	mg/kg	44	10	3
NO2-	kg	7.12E+03	2.08E+02	4.47E+02	Yes	mg/kg	NA	NA	NA
NO3-	kg	2.32E+04	5.48E+01	1.18E+02	Yes	mg/kg	NA	NA	NA
OH-	kg	1.74E+02	2.31E+01	4.97E+01	Yes	mg/kg	NA	NA	NA
Pb	kg	8.13E+01	1.10E+00	2.36E+00	No	mg/kg	72	14	4
PO4---	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
SiO3--	kg	0.00E+00	5.90E+00	1.27E+01	Yes	mg/kg	NA	NA	NA
SO4--	kg	3.53E+02	8.76E+01	1.88E+02	Yes	mg/kg	NA	NA	NA
Sr	kg	5.39E-03	3.35E-04	7.20E-04	No	mg/kg	0	0	0
TOC (total C)	kg	0.00E+00	0.00E+00	0.00E+00	Yes	mg/kg	NA	NA	NA
U total	kg	1.69E+01	2.28E-01	4.90E-01	No	mg/kg	15	3	1
Zr	kg	0.00E+00	0.00E+00	0.00E+00	No	mg/kg	0	0	0

1 Impacted Soil Volume (ft^3) = Volume (gallon)/ Soil Porosity/ 7.48 gallon/ft^3

2 Soil Concentration = [Inventory (kg) x 106 mg/kg] /[Impacted soil volume (ft^3) x 28316 cm^3/ft^3 x Soil density (gm/cm^3)/ 1000 gm/kg]

Table C-2: Toxicity Values for Nonradiological Contaminants

Chemical COPCs	CAS#	Oral Toxicity Value (Including Reference)[1]				Inhalation Toxicity Values (Including Reference)[1]				GI Factor (%)	Calculated Dermal Toxicity Values[3]		Dermal Absorption Factor[1]	Calculated Inhalation Toxicity Values (Including Reference)[1]	
		Oral SF 1/(mg/kg-d)	Ref	RfDo (mg/kg-d)	Ref	IUR $(ug/m^3)^{-1}$	Ref	RfCi (mg/m^3)	Ref		Dermal SF 1/(mg/kg-d)	RfDd (mg/kg-d)		CPF (kg-day /mg)	RfDi (mg/kg-day)
Aluminum	7429-90-5			1.00E+00	P			5.00E-03	P	100		1.0E+00		0	1.4.E-03
Chromium	7440-47-3			3.00E-03	I	8.40E-02	S	1.00E-04	I	2.5		7.5E-05		294	2.9.E-05
Iron	7439-89-6			0.7	P					100		7.0E-01			
Mercury	7439-97-6							3.0E-04	I	7					8.6.E-05
Nickel	7440-02-0			0.02	I	0.00026	C	0.00009	A	4		8.0E-04		0.91	2.6.E-05
Total Uranium	#N/A			0.003	I			0.00004	A	100		3.0E-03			1.1.E-05

[1] EPA Regional Screening Level (RSL) Tables, May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

References Cited in RSL Tables:

I = IRIS (Integrated Risk Information System Values)

P = PPRTV (Provisional Peer Reviewed Toxicity Values)

A = ATSDR (Agency for Toxic Substances and Disease Registry)

Table C-3: Chemical Concentrations in Air Calculations
Waste Management Unit Area C

UPRs	Equation	CA	= [	CS	x	CF	] x [	(1/PEF)	+	(1/VF)	]
	Units	ug/m^3		mg/kg		ug/mg		m^3/kg		m^3/kg	
81	Aluminum	1.13E-04	= [	8,219.51	x	1000	] x [	1.37E-11	+	ND	]
	Chromium	1.06E-06	= [	77.18	x	1000	] x [	1.37E-11	+	ND	]
	Iron	6.95E-07	= [	50.75	x	1000	] x [	1.37E-11	+	ND	]
	Mercury	0.00E+00	= [	-	x	1000	] x [	1.37E-11	+	ND	]
	Nickel	5.97E-07	= [	43.57	x	1000	] x [	1.37E-11	+	ND	]
	Total Uranium	2.06E-07	= [	15.03	x	1000	] x [	1.37E-11	+	ND	]
82	Aluminum	0.00E+00	= [	-	x	1000	] x [	1.37E-11	+	ND	]
	Chromium	5.25E-07	= [	38.34	x	1000	] x [	1.37E-11	+	ND	]
	Iron	1.30E-07	= [	9.48	x	1000	] x [	1.37E-11	+	ND	]
	Mercury	4.02E-10	= [	0.03	x	1000	] x [	1.37E-11	+	ND	]
	Nickel	1.33E-07	= [	9.69	x	1000	] x [	1.37E-11	+	ND	]
	Total Uranium	3.85E-08	= [	2.81	x	1000	] x [	1.37E-11	+	ND	]
86	Aluminum	0.00E+00	= [	-	x	1000	] x [	1.37E-11	+	ND	]
	Chromium	1.73E-07	= [	12.60	x	1000	] x [	1.37E-11	+	ND	]
	Iron	4.27E-08	= [	3.12	x	1000	] x [	1.37E-11	+	ND	]
	Mercury	1.32E-10	= [	0.01	x	1000	] x [	1.37E-11	+	ND	]
	Nickel	4.36E-08	= [	3.19	x	1000	] x [	1.37E-11	+	ND	]
	Total Uranium	1.26E-08	= [	0.92	x	1000	] x [	1.37E-11	+	ND	]

CA = Chemical concentration in air
CS = chemical concentration in soil
CF = Conversion Factor
PEF = Particulate Emission Factor
VF = Volatilization Factor

Table C-4: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 81
Waste Management Area C

Equation	CDIingestion	=	[	CS	x	SIR	x	ABI	x	UCF	x	EF	x	ED	]	/	[	ABW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		unitless		years				kg		years	

CARCINOGENIC EFFECTS

Aluminum	6.26E-04	=	[	8,219.51	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Chromium	5.88E-06	=	[	77.18	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Iron	3.87E-06	=	[	50.75	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Mercury	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Nickel	3.32E-06	=	[	43.57	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Total Uranium	1.14E-06	=	[	15.03	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]

NONCARCINOGENIC EFFECTS

Aluminum	2.35E-03	=	[	8.22E+03	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Chromium	2.21E-05	=	[	7.72E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Iron	1.45E-05	=	[	5.08E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Mercury	0.00E+00	=	[	0.00E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Nickel	1.24E-05	=	[	4.36E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Total Uranium	4.29E-06	=	[	1.50E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]

CDIingestion = chronic daily intake via soil ingestion
CS = chemical concentration in soil
SIR = soil ingestion rate
ABI = Gastrointestinal Absorption Fraction
UCF = unit conversion factor
EF = exposure frequency
ED = exposure duration
ABW = Average body weight
AT = averaging time

Table C-5: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 81
Waste Management Area C

Equation	CDI	=	[	CA	x	EF	x	BR	x	ED	]	/	[(	AT	x	ABW	x	UCF	)]
Units	mg/kg-day			ug/m³		unitless		m³/day		years				years		kg		ug/mg	
CARCINOGENIC EFFECTS																			
Aluminum	1.29E-08	=	[	1.1E-04	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Chromium	1.21E-10	=	[	1.1E-06	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Iron	7.95E-11	=	[	7.0E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Mercury	0.00E+00	=	[	0.0E+00	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Nickel	6.82E-11	=	[	6.0E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Total Uranium	2.35E-11	=	[	2.1E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
NONCARCINOGENIC EFFECTS																			
Aluminum	3.22E-08	=	[	1.1E-04	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Chromium	3.02E-10	=	[	1.1E-06	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Iron	1.99E-10	=	[	7.0E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Mercury	0.00E+00	=	[	0.0E+00	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Nickel	1.71E-10	=	[	6.0E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Total Uranium	5.88E-11	=	[	2.1E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]

CDI = chronic daily intake via inhalation
CA = chemical concentration in air
EF = exposure frequency
BR = Breathing Rate
ED = exposure duration
AT = averaging time
ABW = Average body weight
UCF = unit conversion factor

Table C-6: Risk Characterization under MTCA Method C
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 81
Waste Management Area C

Ingestion of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CPFo**	**=**	**CR**	**CDI**	**/**	**RfDo**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	6.26E-04	x	0.00E+00	=	0.00E+00	2.35E-03	/	1.00E+00	=	2.35E-03
Chromium	5.88E-06	x	0.00E+00	=	0.00E+00	2.21E-05	/	3.00E-03	=	7.35E-03
Iron	3.87E-06	x	0.00E+00	=	0.00E+00	1.45E-05	/	7.00E-01	=	2.07E-05
Mercury	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	0.00E+00	=	NA
Nickel	3.32E-06	x	0.00E+00	=	0.00E+00	1.24E-05	/	2.00E-02	=	6.22E-04
Total Uranium	1.14E-06	x	0.00E+00	=	0.00E+00	4.29E-06	/	3.00E-03	=	1.43E-03
			Pathway total	=	0.00E+00			Pathway total	=	1.18E-02

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CPFi**	**=**	**CR**	**CDI**	**/**	**RfDi**	**=**	**HQ**
Units	**mg/kg-day**		**kg-day/mg**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	1.29E-08	x	0.00E+00	=	0.00E+00	3.22E-08	/	1.43E-03	=	2.25E-05
Chromium	1.21E-10	x	2.94E+02	=	3.55E-08	3.02E-10	/	2.86E-05	=	1.06E-05
Iron	7.95E-11	x	0.00E+00	=	0.00E+00	1.99E-10	/	0.00E+00	=	NA
Mercury	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	8.57E-05	=	0.00E+00
Nickel	6.82E-11	x	9.10E-01	=	6.21E-11	1.71E-10	/	2.57E-05	=	6.63E-06
Total Uranium	2.35E-11	x	0.00E+00	=	0.00E+00	5.88E-11	/	1.14E-05	=	5.15E-06
			Pathway total =		3.56E-08			Pathway total =		4.49E-05

Chemical Totals

	Carcinogenic Effects			Noncarcinogenic Effects		
Aluminum	Sum of all pathways	=	NA	Sum of all pathways	=	2.4E-03
Chromium	Sum of all pathways	=	3.55E-08	Sum of all pathways	=	7.4E-03
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	2.1E-05
Mercury	Sum of all pathways	=	NA	Sum of all pathways	=	**NA**
Nickel	Sum of all pathways	=	6.21E-11	Sum of all pathways	=	6.3E-04
Total Uranium	Sum of all pathways	=	NA	Sum of all pathways	=	1.4E-03
	Total Carcinogenic Risk All Pathways and Chemicals	=	4E-08	Total Noncarcinogenic Risk All Pathways and Chemicals	=	1.2E-02

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Bold indicates risk exceeding the de-minimis level: greater than 1E-06 for carcinogenic risks and greater than 1E+00 for noncaner risks.

Table C-7: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 82
Waste Management Area C

Equation	CDIingestion	=	[	CS	x	SIR	x	ABI	x	UCF	x	EF	x	ED	]	/	[	ABW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		unitless		years				kg		years	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Chromium	2.92E-06	=	[	38.34	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Iron	7.23E-07	=	[	9.48	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Mercury	2.24E-09	=	[	0.03	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Nickel	7.38E-07	=	[	9.69	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Total Uranium	2.14E-07	=	[	2.81	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.00E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Chromium	1.10E-05	=	[	3.83E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Iron	2.71E-06	=	[	9.48E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Mercury	8.39E-09	=	[	2.94E-02	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Nickel	2.77E-06	=	[	9.69E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Total Uranium	8.02E-07	=	[	2.81E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]

CDIingestion = chronic daily intake via soil ingestion
CS = chemical concentration in soil
SIR = soil ingestion rate
ABI = Gastrointestinal Absorption Fraction
UCF = unit conversion factor
EF = exposure frequency
ED = exposure duration
ABW = Average body weight
AT = averaging time

Table C-8: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 82
Waste Management Area C

Equation	CDI	=	[	CA	x	EF	x	BR	x	ED	]	/	[(	AT	x	ABW	x	UCF	)]
Units	mg/kg-day			ug/m³		unitless		m³/day		years				years		kg		ug/mg	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.0E+00	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Chromium	6.00E-11	=	[	5.3E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Iron	1.48E-11	=	[	1.3E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Mercury	4.60E-14	=	[	4.0E-10	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Nickel	1.52E-11	=	[	1.3E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Total Uranium	4.39E-12	=	[	3.8E-08	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]

Equation	CDI	=	[	CA	x	EF	x	BR	x	ED	]	/	[(	AT	x	ABW	x	UCF	)]
Units	mg/kg-day			ug/m³		unitless		m³/day		years				years		kg		ug/mg	

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.0E+00	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Chromium	1.50E-10	=	[	5.3E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Iron	3.71E-11	=	[	1.3E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Mercury	1.15E-13	=	[	4.0E-10	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Nickel	3.79E-11	=	[	1.3E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Total Uranium	1.10E-11	=	[	3.8E-08	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]

CDI = chronic daily intake via inhalation
CA = chemical concentration in air
EF = exposure frequency
BR = Breathing Rate
ED = exposure duration
AT = averaging time
ABW = Average body weight
UCF = unit conversion factor

Table C-9: Risk Characterization under MTCA Method C
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 82
Waste Management Area C

Ingestion of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CPFo**	**=**	**CR**	**CDI**	**/**	**RfDo**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)-1**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.00E+00	=	0.00E+00
Chromium	2.92E-06	x	0.00E+00	=	0.00E+00	1.10E-05	/	3.00E-03	=	3.65E-03
Iron	7.23E-07	x	0.00E+00	=	0.00E+00	2.71E-06	/	7.00E-01	=	3.87E-06
Mercury	2.24E-09	x	0.00E+00	=	0.00E+00	8.39E-09	/	0.00E+00	=	NA
Nickel	7.38E-07	x	0.00E+00	=	0.00E+00	2.77E-06	/	2.00E-02	=	1.38E-04
Total Uranium	2.14E-07	x	0.00E+00	=	0.00E+00	8.02E-07	/	3.00E-03	=	2.67E-04
			Pathway total	=	0.00E+00			Pathway total	=	4.06E-03

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**CDI**	**x**	**CPFi**	**=**	**CR**	**CDI**	**/**	**RfDi**	**=**	**HQ**
Units	**mg/kg-day**		**kg-day/mg**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Aluminum	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.43E-03	=	0.00E+00
Chromium	6.00E-11	x	2.94E+02	=	1.76E-08	1.50E-10	/	2.86E-05	=	5.25E-06
Iron	1.48E-11	x	0.00E+00	=	0.00E+00	3.71E-11	/	0.00E+00	=	NA
Mercury	4.60E-14	x	0.00E+00	=	0.00E+00	1.15E-13	/	8.57E-05	=	1.34E-09
Nickel	1.52E-11	x	9.10E-01	=	1.38E-11	3.79E-11	/	2.57E-05	=	1.48E-06
Total Uranium	4.39E-12	x	0.00E+00	=	0.00E+00	1.10E-11	/	1.14E-05	=	9.61E-07
			Pathway total =		1.77E-08			Pathway total =		7.69E-06

Chemical Totals

	Carcinogenic Effects			Noncarcinogenic Effects		
Aluminum	Sum of all pathways	=	NA	Sum of all pathways	=	**NA**
Chromium	Sum of all pathways	=	1.76E-08	Sum of all pathways	=	3.7E-03
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	3.9E-06
Mercury	Sum of all pathways	=	NA	Sum of all pathways	=	1.3E-09
Nickel	Sum of all pathways	=	1.38E-11	Sum of all pathways	=	1.4E-04
Total Uranium	Sum of all pathways	=	NA	Sum of all pathways	=	2.7E-04

Total Carcinogenic Risk			Total Noncarcinogenic Risk		
All Pathways and Chemicals	=	2E-08	All Pathways and Chemicals	=	4.1E-03

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Bold indicates risk exceeding the de-minimis level: greater than 1E-06 for carcinogenic risks and greater than 1E+00 for noncaner risks.

Table C-10: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Ingestion of Chemicals in Shallow Vadose Soil (upto 15 ft) - UPR 86
Waste Management Area C

Equation	CDIingestion	=	[	CS	x	SIR	x	ABI	x	UCF	x	EF	x	ED	]	/	[	ABW	x	AT	]
Units	mg/kg-day			mg/kg		mg soil/day		unitless		kg/mg		unitless		years				kg		years	

CARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	-	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Chromium	9.60E-07	=	[	12.60	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Iron	2.38E-07	=	[	3.12	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Mercury	7.36E-10	=	[	0.01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Nickel	2.43E-07	=	[	3.19	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]
Total Uranium	7.03E-08	=	[	0.92	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	75	]

NONCARCINOGENIC EFFECTS

Aluminum	0.00E+00	=	[	0.00E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Chromium	3.60E-06	=	[	1.26E+01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Iron	8.91E-07	=	[	3.12E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Mercury	2.76E-09	=	[	9.65E-03	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Nickel	9.10E-07	=	[	3.19E+00	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]
Total Uranium	2.64E-07	=	[	9.23E-01	x	50	x	1	x	1.00E-06	x	0.4	x	20	]	/	[	70	x	20	]

CDIingestion = chronic daily intake via soil ingestion
CS = chemical concentration in soil
SIR = soil ingestion rate
ABI = Gastrointestinal Absorption Fraction
UCF = unit conversion factor
EF = exposure frequency
ED = exposure duration
ABW = Average body weight
AT = averaging time

Table C-11: Daily Intake Calculations: Adult Industrial Worker under MTCA Method C
Inhalation of Chemicals in Shallow Vadose Zone Soil - UPR 86
Waste Management Area C

Equation	CDI	=	[	CA	x	EF	x	BR	x	ED	]	/	[(	AT	x	ABW	x	UCF	)]
Units	mg/kg-day			ug/m^3		unitless		m^3/day		years				years		kg		ug/mg	
CARCINOGENIC EFFECTS																			
Aluminum	0.00E+00	=	[	0.0E+00	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Chromium	1.97E-11	=	[	1.7E-07	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Iron	4.88E-12	=	[	4.3E-08	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Mercury	1.51E-14	=	[	1.3E-10	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Nickel	4.99E-12	=	[	4.4E-08	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]
Total Uranium	1.44E-12	=	[	1.3E-08	x	1	x	20	x	30	]	/	[(	75	x	70	x	1000	)]

Equation	CDI	=	[	CA	x	EF	x	BR	x	ED	]	/	[(	AT	x	ABW	x	UCF	)]
Units	mg/kg-day			ug/m^3		unitless		m^3/day		years				years		kg		ug/mg	
NONCARCINOGENIC EFFECTS																			
Aluminum	0.00E+00	=	[	0.0E+00	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Chromium	4.93E-11	=	[	1.7E-07	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Iron	1.22E-11	=	[	4.3E-08	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Mercury	3.78E-14	=	[	1.3E-10	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Nickel	1.25E-11	=	[	4.4E-08	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]
Total Uranium	3.61E-12	=	[	1.3E-08	x	1	x	20	x	6	]	/	[(	6	x	70	x	1000	)]

CDI = chronic daily intake via inhalation
CA = chemical concentration in air
EF = exposure frequency
BR = Breathing Rate
ED = exposure duration
AT = averaging time
ABW = Average body weight
UCF = unit conversion factor

Table C-12: Risk Characterization under MTCA Method C
Adult Industrial Worker Exposed to Shallow Vadose Soil (upto 15 ft) - UPR 86
Waste Management Area C

Ingestion of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	CDI	x	CPFo	=	CR	CDI	/	RfDo	=	HQ
Units	mg/kg-day		(mg/kg-day)-1		unitless	mg/kg-day		mg/kg-day		unitless
	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.00E+00	=	0.00E+00
Chromium	9.60E-07	x	0.00E+00	=	0.00E+00	3.60E-06	/	3.00E-03	=	1.20E-03
Chromium	2.38E-07	x	0.00E+00	=	0.00E+00	8.91E-07	/	7.00E-01	=	1.27E-06
Iron	7.36E-10	x	0.00E+00	=	0.00E+00	2.76E-09	/	0.00E+00	=	NA
Mercury	2.43E-07	x	0.00E+00	=	0.00E+00	9.10E-07	/	2.00E-02	=	4.55E-05
Nickel	7.03E-08	x	0.00E+00	=	0.00E+00	2.64E-07	/	3.00E-03	=	8.79E-05
Total Uranium			Pathway total	=	0.00E+00			Pathway total	=	1.34E-03

Inhalation of Chemicals in Soil

	Carcinogenic Effects					Noncarcinogenic Effects				
	CDI	x	CPFi	=	CR	CDI	/	RfDi	=	HQ
Equation	mg/kg-day		kg-day/mg		unitless	mg/kg-day		mg/kg-day		unitless
Units	0.00E+00	x	0.00E+00	=	0.00E+00	0.00E+00	/	1.43E-03	=	0.00E+00
Chromium	1.97E-11	x	2.94E+02	=	5.80E-09	4.93E-11	/	2.86E-05	=	1.73E-06
Chromium	4.88E-12	x	0.00E+00	=	0.00E+00	1.22E-11	/	0.00E+00	=	NA
Iron	1.51E-14	x	0.00E+00	=	0.00E+00	3.78E-14	/	8.57E-05	=	4.41E-10
Mercury	4.99E-12	x	9.10E-01	=	4.54E-12	1.25E-11	/	2.57E-05	=	4.85E-07
Nickel	1.44E-12	x	0.00E+00	=	0.00E+00	3.61E-12	/	1.14E-05	=	3.16E-07
Total Uranium			Pathway total =		5.81E-09			Pathway total =		2.53E-06

Chemical Totals	Carcinogenic Effects			Noncarcinogenic Effects		
	Sum of all pathways	=	NA	Sum of all pathways	=	**NA**
Chromium	Sum of all pathways	=	5.80E-09	Sum of all pathways	=	1.2E-03
Chromium	Sum of all pathways	=	NA	Sum of all pathways	=	1.3E-06
Iron	Sum of all pathways	=	NA	Sum of all pathways	=	4.4E-10
Mercury	Sum of all pathways	=	4.54E-12	Sum of all pathways	=	4.6E-05
Nickel	Sum of all pathways	=	NA	Sum of all pathways	=	8.8E-05
Total Uranium						

Total Carcinogenic Risk All Pathways and Chemicals = 6E-09	Total Noncarcinogenic Risk All Pathways and Chemicals = 1.3E-03

Bold indicates risk exceeding the de-minimis level: greater than 1E-06 for carcinogenic risks and greater than 1E+00 for noncaner risks.

DI = Chemical Daily Intake; from Tables
SF = Cancer Slope Factor; from Tables
CR = Cancer Risk
RfD = Noncancer Reference Dose; from Tables
HQ = Hazard Quotient
NA = not applicable

Table C-13: Nonradiological Risk Assessment Results for three UPRs under WAC Industrial Worker Scenario

Exposure Pathways	UPR-81		UPR-82		UPR-86	
	ELCR	HI	ELCR	HI	ELCR	HI
Ingestion	0E+00	1E-02	0E+00	4E-03	0E+00	1E-03
Inhalation	4E-08	4E-05	2E-08	8E-06	6E-09	3E-06
Cumulative Risk	**4E-08**	**0.01**	**2E-08**	**0.004**	**6E-09**	**0.001**

ENVIRONMENTAL MODEL CALCULATION COVER PAGE

Section 1: Completed by Responsible Manager

0
RELEASE/ISSUE

Project: Waste Management Area C(WMA C)

Date: 11/17/2016

Calculation Title & Description: Radiological Risk Assessments for Three Unplanned Releases within Waste Management Area C

Section 2: Completed by Preparer

Calculation No.: RPP-CALC-61238 Revision No.: 0

Revision History

Revision No.	Description	Date	Affected Pages
0		11/17/2017	All

Section 3: Completed by Responsible Manager

Document Control

1. Is document intended to be controlled within SmartPlant? ☒ Yes ☐ No
2. Does document contain scientific and technical information intended for public use? ☒ Yes ☐ No
3. Does document contain controlled-use information? ☐ Yes ☒ No

Section 4: Training and Software Installation Approval (Completed Prior to Performing Calculation)

Modeler-Required Training Completed:

WE Nichols/Principal Engineer	[signature]	17 NOV 2016
Training Coordinator (Name/Position)	Signature	Date

Software Installation and Checkout Certified:

WE Nichols / Principal Engineer	[signature]	17 NOV 2016
Integration Lead (Name/Position)	Signature	Date

Section 5: Document Review & Approval

Md Mahmudur Rahman/Sr. Risk Assessor	[signature]	11/17/2016
Preparer (Name/Position)	Signature	Date
S. Lindberg/Sr. Risk Assessor	[signature]	11/17/2016
Checker (Name/Position)	Signature	Date
Doug Evans/Sr. Risk Assessor	[signature]	11/17/2016
Senior Reviewer (Name/Position)	Signature	Date
Andrea Hopkins/Env. Compliance/WRPS	[signature]	11/17/2016
Responsible Manager (Name/Position)	Signature	Date

 A-6006-716 (REV 0)

Contents

Appendices

Tables

Terms

BRA	baseline risk assessment
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
ELCR	Excess lifetime cancer risk
EMCF	Environmental model calculation file
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
FGR	federal guidance report
K_d	distribution coefficient factor
MTCA	Model Toxics Control Act
OSWER	Office of Solid Waste and Emergency Response
pCi	pico-Curies
PEF	Particulate Emission Factor
RCRA	*Resource Conservation and Recovery Act of 1976*
RESRAD	RESidual RADioactivity computer code
RSR	risk to source ratio
USEPA	U.S. Environmental Protection Agency
UPR	unplanned release
WAC	*Washington Administrative Code*
WMA	Waste Management Area

1 Purpose

This environmental model calculation file (EMCF) presents the results of human health risk assessments for the radionuclide soil contamination within three unplanned release (UPR) locations - 200-E-81 (UPR-81), 200-E-82 (UPR-82), and 200-E-86 (UPR-86) at Waste Management Area (WMA) C. Due to very high levels of radiological contamination, soil samples were not collected at these UPR locations as part of the original investigation. Therefore, radiological risk assessments of these WMA C UPRs were not performed as part of the baseline risk assessment (BRA).

For the soil contamination associated with UPRs, radiological risks are estimated under baseline conditions assuming a CERCLA industrial worker exposure scenario. As a conservative approach, no soil cover was considered. It should be noted that several remedial alternatives such as isolation barriers and/or infiltration barriers are being considered in support of *RCRA Corrective Measure Study Report for Waste Management Area C*. Due to the presence of elevated radiological contaminants, the remedial alternative proposed is a 3-ft isolation barrier at each UPR. Therefore, an additional radiological risk assessment was performed for the three UPRs, assuming a 3-ft concrete cover to determine the impacts of the isolation barrier with respect to the total risk at each UPR under post-remediation conditions.

2 Background

The CERCLA industrial worker exposure scenario in vadose zone material is one of six CERCLA scenarios selected to represent the range of receptors that could be exposed to COPCs in soil from WMA C and was evaluated as part of RPP-RPT-58329, *Baseline Risk Assessment for Waste Management Area C,* Rev. 0. All exposure scenarios identified for evaluation at WMA C are fully described in RPP-RPT-47479, *Exposure Scenarios for the Waste Management Area C Performance Assessment*. It is noted that following issuance of the baseline risk assessment (BRA), the assigned exposure parameters for all exposure scenarios were updated in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*. However, to be consistent with the BRA, the updated values documented in RPP-ENV-58813 are not used in this EMCF.

Additional details regarding the exposure parameters are presented in Section 4, Assumptions and Inputs

3 Methodology

The section summarizes the risk assessment methodology for radiological contaminants. The methodology calculates an excess lifetime cancer risk (ELCR), which is the incremental increase in the probability of developing cancer during an individual's lifetime in addition to the background probability of developing cancer.

3.1 Radiological Risk Assessment Methodology

This section summarizes the methodology used to calculate cumulative ELCRs for radiological contaminants. The methodology was implemented using the RESidual RADioactivity computer code (RESRAD) Version 7.0 (ANL, 2014), a noted departure from the BRA, which used RESRAD Version 6.5 (ANL, 2009).

The following steps document the methodology used to calculate individual and cumulative risks for radiological contaminantion associated with the UPRs, assuming an industrial worker exposure scenario. Steps 1 through 8 are performed independently for the baseline conditions assuming no cover and for the post-remediation conditions assuming a 3-ft cover.

1. Enter the industrial worker exposure scenario-applicable user input parameters listed in Table 4-1 into the RESRAD model.
2. Enter a unit concentration of 1 pCi/g and COPC-specific distribution coefficient, K_d (Table 4-2) for each of the 22 COPCs identified for the WMA C (see section 4.2) for the source term.
3. Run RESRAD and review the results to identify the year(s) at which peak risk occurs for each COPC.
4. Rerun RESRAD with times for calculation corresponding to the years of peak risk, as identified in Step 2.
5. Open the Health Risk Report and obtain the pathway-specific and cumulative risk to source ratios (RSR) for each radiological COPC at each year of peak risk and copy the results into a Microsoft Excel®workbook.
6. Multiply the COPC-specific RSR by the corresponding source-term concentration for each COPC (Table 4-3) to calculate the individual risk.
7. Sum the individual risks to calculate the cumulative ELCR for each year of peak risk, as identified in Step 2.
8. Compare the maximum results of the cumulative ELCR with the acceptable risk criteria to identify whether unacceptable risks are present and if so, identify the primary risk contributors.

4 Assumptions and Inputs

This section provides key assumptions and inputs used in calculating cancer risk for the CERCLA industrial worker exposure scenario. It also documents the process used to identify COPCs and calculate the COPC-specific concentrations.

4.1 Exposure Scenario Inputs and Assumptions

The RESRAD inputs used during both risk assessments (no cover and 3-ft concrete cover) are presented in Table 4-1. The radionuclide-specific K_ds are presented in Table 4-2. Other key assumptions are as follows:

- An adult is the receptor for the CERCLA industrial worker scenario.
- The direct contact and inhalation exposure pathways are considered potentially complete for the industrial worker scenario. The exposure routes involved with this scenario are incidental soil ingestion, inhalation of dust, and external gamma exposure.
- The CERCLA industrial worker exposure scenario is a long-term receptor (25-year exposure duration) exposed as a full-time employee working on-site, spending 2 hours outdoors and 6 hours indoors during an 8-hour work day. The receptor is on the site for 250 days per year. An incidental soil ingestion rate of 50 mg/day is assumed. The inhalation rate for the receptor is 20 m^3 per day. The gamma shielding factor is asummed to be 0.4. The receptor could potentially be exposed to shallow vadose zone material (0 to 15 ft below ground surface).
- The area of the contaminated zone is assumed to be 310 m^2 (UPR-82), which represents the largest estimated leak area of the three UPRs.

- Under the 2007 Washington State Model Toxics Control Act (MTCA) (Revised Code of Washington 70.105D, “Hazardous Waste Cleanup — Model Toxics Control Act”) cleanup regulations (Washington Administrative Code [WAC] 173-340-740, “Unrestricted Land Use Soil Cleanup Standards”), the point of compliance for soil cleanup levels based on the direct contact pathway is defined as the zone extending from the ground surface to 15 ft below ground surface (bgs). Therefore, the thickness of the contaminated zone for the BRA and this EMCF is assumed to be 15 ft or 4.6 m.
- No soil cover is assumed for the baseline conditions. However, three (3) feet of a concrete isolation barrier is assumed as cover thickness during the calculation of radiological risk to a CERCLA industrial worker under post-remediation conditions.

4.2 Contaminants of Potential Concern and Source-term Concentrations

The contaminants of potential concern (COPCs) and associated source term concentrations for the UPRs are presented in the following sections.

4.2.1 Identification of Radiological COPCs

Four exclusion criteria were used to identify soil COPCs for each UPR. Radionuclides that met one or more of the criteria were excluded. Radionuclides that did not meet any of the exclusion criteria were carried forward into the risk assessment. Application of the exclusion criteria resulted in the identification of 22 COPCs as shown in Table 4-3. The exclusion criteria are described as follows.

1. Exclusion of Radionuclides Based on Data Quality Objectives

Table 4-11 of RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study* presented primary radionuclide constituents for WMA C. Therefore, all other radionuclides included in RPP-ENV-33418, *Hanford C-Farm Leak Inventory Assessments Report* but not identified as a primary constituent in Table 4-11 of RPP-RPT-38152 are excluded from further consideration.

2. Exclusion of Radionuclides Based on Mobility of Radionuclides

Based on the results of the past leak analysis (RPP-RPT-59197, *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington*), mobile radiological contaminants are not expected to be present within the contaminated zone (0 to 4.6 m [15 ft] bgs) under baseline conditions. Therefore, only non-mobile radiological contaminants are considered during the risk assessments.

Table 6-11 of RPP-ENV-58782, *Performance Assessment for Waste Management Area C, Hanford Site, Washington* presented the K_d values for various radionuclides for WMA C. These K_d values are documented in Table 4-2 of this EMCF. According to that report, the maximum K_d value that produces an impact to groundwater is approximately 0.15 mL/g (without any gravel correction) within the 1,000-year compliance time frame, and approximately 1.5 mL/g (without any gravel correction) within the 10,000-year compliance time frame. Therefore, radionuclides with K_d value <0.15 mL/g are excluded due to high mobility in the vadose zone. Four (4) radionuclides were excluded based on K_ds corresponding to high mobility.

3. Exclusion of Radionuclides with Half-Lives of Less than 3 Years

Radionuclides with half-lives of less than 3 years are eliminated from further consideration as soil COPCs. They are either insignificant dose and risk contributors due to decay or contributions are already

accounted for as daughter products of a parent radionuclide. Five (5) radionuclides were excluded based on a half-life less than 3 years.

4. Exclusion of Naturally-Occuring Radionuclides

The radionuclides considered to be naturally occurring and not directly related to Hanford Site operations or processes are eliminated from further consideration as soil COPCs. Six naturally-occurring radionuclides associated with background radiation (^{40}K, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, and ^{232}Th) were excluded.

4.2.2 Determination of Source-term for Radiological COPCs

The steps utilized during the calculation of the non-mobile source term concentrations for three UPRs are summarized in the following section.

1. Radiological Inventory (pCi)

Radionuclide inventories for each UPR were obtained from RPP-ENV-33418. Those inventories were decayed from 1/1/2001 (the decay date for HDW Rev. 5 values) to 1/1/2017 to represent the current inventories for those radionuclides.

2. Computation of Contaminated Soil Mass (g)

Initially, the volume of contaminated soils was calculated by dividing the estimated leak volume by assuming a soil porosity of 0.258, based on site-wide value of Hanford formation of sany gravel (Table 6.3 of PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*). The mass of the contaminated soil was calculated by multiplying the volume of the contaminated soil by assuming a soil density of 2.13 kg/L, consistent with the effective bulk density value assumed for backfill (gravelly) in the WMA C Performance Assessment (Table 3-5 of RPP-RPT-58949, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA C Performance Assessment and RCRA Closure Analysis*).

3. Determination of Soil Concentration (pCi/g)

The inventories of the radiological contaminants are assumed to be uniformly distributed throughout the affected soil volume. Hence, the inventory for each radionuclide was divided by the contaminated soil mass to determine the soil concentration for each radiological COPC.

Table 4-4 presents the source term concentration for each radiological COPC within each UPR.

4.3 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at WMA C and the likelihood of adverse health effects to potentially exposed populations. The toxicity assessment for radiological COPC is summarized below.

RESRAD version 6.5, used during the BRA utilizes Federal Guidance Report (FGR) No. 13 includes the risk coefficient values for all radionuclides (EPA 2002). Default DCFPAK 3.02 Morbidity risk factors within RESRAD version 7.0 were utilized during this risk assessment. These risk coefficient slope factors are presented in units of pCi^{-1} (internal pathways) or (risk/year)/(pCi/g) (external pathways).

4.4 Risk Characterization

In Title 40, *Code of Federal Regulations*, Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan," the EPA considers remedial action at a site when cumulative ELCR to any current or

future population exceeds a risk range of 10^{-4} to 10^{-6} (i.e., one case of cancer in ten thousand to one case of cancer in one million). Excess lifetime cancer risks below 10^{-6} are considered acceptable whereas excess lifetime cancer risks above 10^{-4} are considered unacceptable. Risks between 10^{-4} to 10^{-6} are generally referred to as the "acceptable risk range." Therefore, for radiological COPCs, the ELCRs were compared to the EPA acceptable target risk range of 10^{-4} to 10^{-6}. When the total cumulative ELCR exceeds 10^{-4}, those individual COPCs with a risk greater than 10^{-6} (those analytes that contribute greater than 1% of total cumulative ELCR) are identified as major risk contributors.

5 Software Applications

RESRAD Version 7.0 was used during the determination of risk per unit concentration under both baseline and post-remediation conditions. Actual risk calculations were performed on electronic spreadsheets using Microsoft Excel. Electronic versions of all spreadsheets are provided with calculations included to facilitate comparison with hand calculations and checking of logical functions. This approach meets the requirements for "Single Use Software" as described in PRC-PRO-EP-40205, *CHPRC Environmental Calculation Preparation and Issue*. These spreadsheets are listed below in Section 6.

5.1 Approved Software

RESRAD Version 7.0 is approved for use by CHPRC at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309, *Controlled Software Management*. The installed RESRAD software was tested in accordance with the procedure per CHPRC-00209, 2009, *RESRAD Software Management Plan*. RESRAD was registered on the Hanford Information System Inventory (HISI) and identified as approved for use.

5.1.1 Description

The following represent the description of RESRAD software package used in the calculation:

- RESRAD for Windows,
- Version 7.0, Created February 24, 2014
- HISI Identification Number: 2102
- Workstation type and property number: Intera property -00740 (Subcontractor Supplied Unique Property ID) and WF21752.

5.1.2 Software Installation and Checkout

The software installation and checkout forms for RESRAD are provided in Appendix A to this Environmental Calculation.

5.1.3 Statement of Valid Software Application

The following presents the statement that RESRAD is a valid software application.

- RESRAD was developed for DOE to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material. RESRAD has been used for this purpose in support of previous decision documents developed at the Hanford Site.

- RESRAD as it has been used in this Environmental Calculation has been implemented within the range of its limitations. The parameters used in the modeling (shown in Tables 4-1 and 4-2) are included in the modeling input files accompanying this Environmental Calculation, and also in the modeling output files where they are shown alongside the default parameters provided with the model. The modeling input and output files for RESRAD are listed in Section 6.

6 Calculation

The following section of the report presents the information about the input and output files associated with the radiological and nonradiological risk assessment calculation. The risk assessment calculations were verified independently by utilizing the methodology, assumptions and inputs described in Sections 3 and 4.

6.1 Original Radiological Risk Assessment Calculation

The ELCR results were calculated with RESRAD and Microsoft Excel® using the methodology described in Section 3 and the inputs presented in Section 4. The input RESRAD files are listed below.

- Input RESRAD file to identify Years at Peak Risk - INDUSTRIAL_WORKER_No_Cover.RAD
- Input RESRAD file to assess Risk per Unit Concentration for UPRs with no soil cover - RISK_INDUSTRIAL_WORKER_No_Cover.RAD
- Input RESRAD file to identify years of peak risk and to assess risk per unit concentration for UPRs with 3 ft of Concrete Cover - INDUSTRIAL_WORKER_3_Ft_Cover.RAD

RESRAD output health risk file name for calculating risk per unit concentration for UPRs with no soil cover is RISK_INDUSTRIAL_WORKER_No_Cover.INT

RESRAD output health risk file name for calculating risk per unit concentration for UPRs with 3 ft of Concrete Cover is INDUSTRIAL_WORKER_3_Ft_Cover.INT

ELCR calculations are a set of Excel worksheets contained in the Excel workbooks "Rad_Risk_UPRs.xlsx". Results of the calculations are presented in Section 7.

All input and output files -.RAD, and .INT files are archived under this ECFM number (RPP-CALC-61238) in the Environmental Risk Modeling Archive.

6.2 QC Review of Original Risk Assessment Calculation

A QC review was performed independently to verify the results of the original radiological risk assessment.

6.2.1 QC Review of Original Radiological Risk Assessment Calculation

Two types of QC reviews were performed and are described below.

6.2.1.1 Verification of RESRAD Input Values

All RESRAD input values that entered into the "INDUSTRIAL_WORKER_No_Cover.RAD" file were compared to the values presented in Table 4-1 and Table 4-2 to verify that the RESRAD file and input parameters were consistent. The following parameters were checked:

- Set Pathways- verify all of the active pathways are turned on. For the CERCLA Industrial Worker, the active pathways are external gamma, inhalation (without radon), and soil ingestion.
- Contaminated zone

- Cover and contaminated zone hydrological data
- Occupancy, inhalation, and external gamma data
- Ingestion (non-dietary)
- Radionuclide-specific Distribution Coefficients (K_d) values corresponding to the identified COPCs.
- Soil radionuclide concentrations based on a unit concentration of 1 pCi/g, followed by verification of source term concentrations for all UPRs
- Calculation times- confirm that all of the relevant years are in the table, including the year of maximum risk if it is not at year 0 or 1,000.

6.2.1.2 Verification of Risk Calculations

Verification of radiological risk calculations was performed independently by using the methodologies presented in Section 3.0. The results of the radiological risk calculations were compared to the original risk calculations to verify accurate transcription of data from the RESRAD health risk report file into the Microsoft Excel® worksheet and to verify the formulas used for each radionuclide-specific risk result for all pathways were not corrupted and correct formulas were used. Below is a step-by-step description of the review process:

- Verify calculation times of year 0, year 1,000 and the year of maximum risk.
- Obtain a copy of the RSR data that was generated by originator (this will be in Microsoft Excel® format).
- Obtain the RSR data that was generated by the QC reviewer (note this is found in the Health Risk report).
- Copy and paste the RSR data from the Health Risk Report generated by the QC reviewer into the same Microsoft Excel® workbook with the RSR data generated by the originator. Perform this step for years 0 and 1,000.
- Insert a column and enter the EPCs for each radiological COPC for each UPR.
- Insert another column to calculate the total risk for each radiological COPC by entering the formula provided below:

$$\text{Risk} = \text{Source Term Concentration (pCi/g)} \times \text{RSR (Risk/(pCi/g))}$$

- Compare the originator results to the QC review results and very the two sets of results are the same by the following process:

The results of the first review step did not identify any transcription errors. The results of the second review step did not identify errors associated with formulas used to calculate risk or transcription errors.

7 Results/Conclusions

The CERCLA industrial worker exposure scenario was considered for the baseline radiological risk assessments of contaminated soils associated with the WMA C UPRs. The CERLA industrial worker exposure

scenario with the additional assumption of a 3-ft concrete cover was considered for a radiological risk assessment to assess probable post-remediation conditions as well. The following sections summarize the results of the radiological risk assessments.

7.1 Results/Conclusions for Radiological Risk Assessment

Table 7-1 presents the year of maximum risk for each radiological contaminant under baseline and post-remediation condition. The results of the radiological risk assessment under baseline conditions (assuming no soil cover) are summarized for UPR-81, UPR-82, and UPR-86 in Table 7-2, Table 7-3, and Table 7-4, respectively. The results of the radiological risk under post-remediation condition (assuming 3 ft of concrete cover) are summarized for UPR-81, UPR-82, and UPR-86 in Table 7-5, Table 7-5, and Table 7-7, respectively. Table 7-78 presents the peak ELCR calculated within the 1000-year time period considered for the three UPRs.

The total cumulative ELCR for each UPR are compared with respect to EPA's acceptable target risk range of 10^{-4} to 10^{-6}. The results presented in Tables 7-2 through 7-4 showed that at the year of maximum ELCR (year 0), the total cumulative ELCR for all UPRs are greater than EPA's acceptable target risk range of 10^{-4} to 10^{-6} assuming baseline conditions. Cs-137 was identified major risk contributor (>99% of total risk) for all three UPRs. Sr-90 was identified as major risk contributor for UPR-81. The results presented in Tables 7-5 through 7-6 showed that the total cumulative ELCR for all UPRs are within or less than EPA's acceptable target risk range of 10^{-4} to 10^{-6} assuming post-remediation conditions.

8 References

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CHPRC-00209, 2009, *RESRAD Software Management Plan*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

NUREG/CR 6697, 2000, *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes*. NUREG/CR-6697, ANL/EAD/TM-98. U.S. Nuclear Regulatory Commission. November 2000.

OSWER Directive 9285.6-03, 1991, *Risk Assessment Guidance For Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, "Standard Default Exposure Factors" Interim Final*, Office of Emergency and Remedial Response, Toxics Integration Branch, U.S. Environmental Protection Agency, Washington, D.C.

PNNL-15160, *Hanford Site Climatological Summary 2004 With Historical Data*. Pacific Northwest National Laboratory, Richland, Washington.

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RPP-RPT-58329, 2014, *Baseline Risk Assessment for Waste Management Area C,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-33418, 2016. *Hanford C-Farm Leak Inventory Assessments Report,* Rev. 4, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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RPP-RPT-59197, 2016, *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Tables

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
Dose and Risk Libraries	Internal (ingestion and inhalation) dose coefficients	mrem/pCi	DCFPAK3.02 (Adult)	Updated internal dose coefficients based on ICRP Publication 107	ICRP, 2008
	External dose coefficients	mrem/yr per pCi/g	DCFPAK3.02	Updated external dose coefficients based on ICRP Publication 107	ICRP, 2008
	Risk factors	Risk/pCi, Risk/yr per pCi/g	DCFPAK3.02 Morbidity	Updated risk coefficients based on ICRP Publication 107	ICRP, 2008
Graphic Parameters	Number of points	NA	32	RESRAD default	--
Exposure Pathways	External gamma: Inhalation: Plant ingestion: Meat ingestion: Milk ingestion: Aquatic foods: Drinking water: Soil ingestion: Radon:	NA	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Industrial Worker Scenario	--
R011 – Contaminated Zone (CZ)	Area of CZ	m^2	310	Site-specific Parameter	Site-Specific Parameter
	Thickness of CZ	m	4.6	Direct contact exposure applies to the upper 4.6 m (15 ft)	--
	Length Parallel to Aquifer Flow	m	NA	Not applicable[a]	--
	Does Initial Contamination Penetrate Water Table?	NA	No	Not applicable[a]	--
R012 –Principal Radionuclides Concentrations	All radionuclide contaminants of concern	pCi/g	1	Unit concentrations are input to obtain radionuclide-specific risk-to-source ratios (risk per pCi/g) at time of peak.	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
R013 - Cover and CZ Hydrological Data	Cover Depth	m	0 0.9144	Baseline Condition: no cover assumed Post-Remediation Condition: 3 ft of Concrete Cover	--
	Density of Cover Material	g/cm^3	NA 2.4	No Soil Cover Average Density (Minimum =2.2 and Maximum = 2.6)	 Figure 8.1-1, NUREG/CR 6697, Attachment C
	Cover Erosion Rate	m/yr	NA 2.045E-06	No Soil Cover Based on maximum erosion rate of 5.6 E-7 cm/day for concrete.	 Figure 8.2-1 NUREG/CR 6697, Attachment C
	Density of CZ	g/cm^3	2.13	--	PNNL-18564, Table 6.2, value for C Tank Farm Bf – backfill
	CZ Erosion Rate	m/yr	0.001	RESRAD default	--
	CZ Total Porosity	Unitless	0.258	--	PNNL-18564, Table 6.3, site-wide value for Hg – Hanford formation sandy gravel
	CZ Field Capacity	Unitless	0.061	--	PNNL-18564, Table 6.5, best-estimate value for Hg – Hanford formation sandy gravel
	CZ Hydraulic Conductivity	m/yr	176.6		PNNL-18564, Table 6.7, value for C Tank Farm Bf – backfill (5.6E-04 cm/s x 86,400 s/day x 365 day/yr x 0.01 m/cm = 176.6 m/yr)
	CZ b Parameter	Unitless	2.96		PNNL-18564, Table 6.8, value for Hg – Hanford formation sandy gravel)
	Humidity in Air	g/cm^3	8	RESRAD default	--
	Evapotranspiration Coefficient	Unitless	0.91	EPA, Region X guidance	Letter from EPA
	Wind Speed	m/s	3.4	Hanford Site average	PNNL-15160, Table 5.1

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Precipitation	m/yr	0.177	Based on 6.98 in. (0.177 m) normal annual rainfall	PNNL-15160, Table 4.1
	Irrigation Rate	m/yr	0	No irrigation assumed for the Inner Area of the Central Plateau	--
	Irrigation Mode	NA	Overhead	RESRAD default	--
	Runoff Coefficient	Unitless	0.2	RESRAD default	--
	Watershed Area for Nearby Stream or Pond	m^2	NA	Not applicable[a]	--
	Accuracy for Water/Soil Computations	Unitless	NA	Not applicable[a]	--
R014 – Saturated Zone (SZ) Hydrological Data	Density of SZ	g/cm^3	NA	Not applicable[a]	--
	SZ Total Porosity	Unitless	NA	Not applicable[a]	--
	SZ Effective Porosity	Unitless	NA	Not applicable[a]	--
	SZ Field Capacity	Unitless	NA	Not applicable[a]	--
	SZ Hydraulic Conductivity	m/yr	NA	Not applicable[a]	--
	SZ Hydraulic Gradient	Unitless	NA	Not applicable[a]	--
	SZ b Parameter	Unitless	NA	Not applicable[a]	--
	Water Table Drop Rate	m/yr	NA	Not applicable[a]	--
	Well Pump Intake Depth	m below water table	NA	Not applicable[a]	--
	Nondispersion (ND) or Mass-Balance (MB)	NA	NA	Not applicable[a]	--
	Well Pumping Rate	m^3/yr	NA	Not applicable[a]	--
R015 - Uncontaminated and Unsaturated Strata Hydrological Data	Number of Unsaturated Strata	NA	NA	Not applicable[a]	--
	Thickness	m	NA	Not applicable[a]	--
	Soil Density	g/cm^3	NA	Not applicable[a]	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Total Porosity	Unitless	NA	Not applicable[a]	--
	Effective Porosity	Unitless	NA	Not applicable[a]	--
	Field Capacity	Unitless	NA	Not applicable[a]	--
	Soil-specific b Parameter	Unitless	NA	Not applicable[a]	--
	Hydraulic Conductivity	m/yr	NA	Not applicable[a]	--
R016 - Distribution Coefficients (K_d) and Leach Rates	CZ K_d	mL/g	Contaminant-specific (see Table 4-2)	K_d values used are consistent with those used for the WMA C Performance Assessment.	RPP-ENV-58782, Table 6-11 (< 2 mm material)
	Time Since Material Placement	yr	0	RESRAD default	--
	Leach Rate	yr^{-1}	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Solubility Limit	mol/L	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Radiation Dose Limit	mrem/yr	25	RESRAD default	--
R017 - Inhalation and External Gamma	Inhalation Rate	m^3/yr	7,300	20 m^3/day x 365 day/yr = 7,300 m^3/yr	OSWER Directive 9285.6-03, Section 3.3
	Mass Loading for Inhalation	g/m^3	1.37E-08	Derived from particulate emission factor (PEF) using 1/PEF x 1000 g/kg, where PEF = 7.30E+10 m^3/kg	ECF-HANFORD-11-0033
	Exposure duration	Yr	25	Site-specific	OSWER 9285.6-03
	Indoor Dust Filtration Factor	Unitless	0.4	RESRAD default	--
	External Gamma Shielding Factor	Unitless	0.4	60 % shielding	EPA/540-R-00-007, Equation 4
	Indoor Time Fraction	Unitless	0.17	(6 hr/d x 250 d/yr) / 8,760 hr/yr = 0.17	OSWER 9355.4-24
	Outdoor Time Fraction	Unitless	0.057	(2 hr/day x 250 days/yr) / 8,760 hr/yr = 0.057	OSWER 9355.4-24
	Shape Factor	NA	Circular	RESRAD default	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
R018 - Ingestion Pathway Data, Dietary Parameters	Fruits, Vegetables, and Grain Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Leafy Vegetable Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Milk Consumption	L/yr	NA	Incomplete exposure pathway	--
	Meat and Poultry Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Fish Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Other Seafood Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Soil Ingestion	g/yr	18.25	(50 mg/day x 365 days/yr) / 1,000 mg/g = 18.25 g/yr	OSWER Directive 9285.6-03
	Drinking Water Intake	L/yr	NA	Incomplete exposure pathway	--
	Drinking Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Household Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Livestock Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Irrigation Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Aquatic Food Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Plant Food Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Meat Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Milk Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
R019 - Ingestion Pathway Data, Nondietary	Livestock Fodder Intake for Meat	kg/d	NA	Incomplete exposure pathway	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Livestock Fodder Intake for Milk	kg/d	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Meat	L/d	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Milk	L/d	NA	Incomplete exposure pathway	--
	Livestock Intake of Soil	kg/d	NA	Incomplete exposure pathway	--
	Mass Loading for Foliar Deposition	g/m^3	NA	Incomplete exposure pathway	--
	Depth of Soil Mixing Layer	m	0.15	RESRAD default	--
	Depth of Roots	m	NA	Incomplete exposure pathway	--
R020 – Groundwater Usage	Groundwater Fractional Usage - Drinking Water	Unitless	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Household Usage	Unitless	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Livestock Water	Unitless	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage – Irrigation	Unitless	NA	Incomplete exposure pathway	--
R021 – Radon	Radon parameters are not used; Radon is not a Hanford Site contaminant of potential concern.				

Notes:

a. Not applicable – the following parameters are not used in the model when drinking water and food ingestion pathways are suppressed: contaminated zone length parallel to aquifer flow; watershed area; accuracy for water/soil computations; saturated zone hydrological data (R014); and uncontaminated, unsaturated strata hydrological data (R015).

CZ = contaminated zone.
NA = not applicable.
RESRAD = RESidual RADioactivity code (ANL, 2014).
DOE = U.S. Department of Energy.
K_d = soil-water distribution coefficient.
SZ = saturated zone.

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OSWER Directive 9285.6-03, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" Interim Final*.

OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*.

PNNL-15160, *Hanford Site Climatological Summary 2004 With Historical Data*.

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report*.

Table 4-2. Radionuclide-specific Distribution Coefficients (K_d)

Radionuclide COPCs	**Contaminated Zone Layer (cm^3/g)[a]**	**Unsaturated Zone and Saturated Zone (cm^3/g)[a]**
Am-241	600	600
C-14	1	1
Cm-243	350	350
Cm-244	350	350
Cs-137	100	100
Eu-152	10	10
Eu-154	10	10
Eu-155	10	10
I-129	0.2	0.2
Ni-63	3	3
Np-237	10	10
Pu-238	600	600
Pu-239	600	600
Pu-240	600	600
Pu-241	600	600
Sn-126	0.5	0.5
Sr-90	10	10
U-233	0.6	0.6
U-234	0.6	0.6
U-235	0.6	0.6
U-236	0.6	0.6
U-238	0.6	0.6

Note:
[a]RPP-ENV-58782, 2016, *Performance Assessment for Waste Management Area C*, *Handord Site, Washington*, Rev. 1

Table 4-3. Identification of COPCs in Affected Soil for Three UPRs

Radionuclide	Included in DQO?[a]	K_d[b] (mL/g)	Mobile in Soil?[c]	Half Life (yr)	Half-life > 3 years?[d]	COPC?
H-3	Yes	0	Yes	12.32	Yes	No
C-14	Yes	1	No	5715	Yes	Yes
Ni-59	No	3	No	7.6E+04	Yes	No
Co-60	Yes	0	Yes	5.271	Yes	No
Ni-63	Yes	3	No	101	Yes	Yes
Se-79	Yes	0.1	Yes	2.9E+05	Yes	No
Sr-90	Yes	10	No	28.78	Yes	Yes
Y-90	No	--	No	7.31E-03	No	No
Zr-93	No	300	No	1.5E+06	Yes	No
Nb-93m	No	0	Yes	16.1	Yes	No
Tc-99	Yes	0	Yes	2.13E+05	Yes	No
Ru-106	No	--	No	1.020	No	No
Cd-113m	No	--	No	14.1	Yes	No
Sb-125	Yes	--	No	2.758	No	No
Sn-126	Yes	0.5	No	2.3E+05	Yes	Yes
I-129	Yes	0.2	No	1.57E+07	Yes	Yes
Cs-134	No	--	No	2.065	No	No
Cs-137	Yes	100	No	30.07	Yes	Yes
Ba-137m	No	--	No	4.852E-06	No	No
Sm-151	No	10	No	90	Yes	No
Eu-152	Yes	10	No	13.54	Yes	Yes
Eu-154	Yes	10	No	8.593	Yes	Yes
Eu-155	Yes	10	No	4.75	Yes	Yes
Ra-226	No	10	No	1599	Yes	No
Ac-227	No	350	No	21.772	Yes	No
Ra-228	No	10	No	5.76	Yes	No
Th-229	No	300	No	7.3E+03	Yes	No
Pa-231	No	300	No	3.28E+04	Yes	No
Th-232	Yes	300	No	1.40E+10	Yes	No[e]
U-232	No	0.6	No	69.8	Yes	No
U-233	Yes	0.6	No	1.592E+05	Yes	Yes
U-234	Yes	0.6	No	2.46E+05	Yes	Yes
U-235	Yes	0.6	No	7.04E+08	Yes	Yes
U-236	Yes	0.6	No	2.342E+07	Yes	Yes
Np-237	Yes	10	No	2.14E+06	Yes	Yes
Pu-238	Yes	600	No	87.7	Yes	Yes

Table 4-3. Identification of COPCs in Affected Soil for Three UPRs

Radionuclide	Included in DQO?[a]	K_d[b] (mL/g)	Mobile in Soil?[c]	Half Life (yr)	Half-life > 3 years?[d]	COPC?
U-238	Yes	0.6	No	4.47E+09	Yes	Yes
Pu-239	Yes	600	No	2.410E+04	Yes	Yes
Pu-240	Yes	600	No	6.56E+03	Yes	Yes
Am-241	Yes	600	No	432.7	Yes	Yes
Pu-241	Yes	600	No	14.4	Yes	Yes
Cm-242	Yes	--	No	4.46E-01	No	No
Pu-242	No	600	No	3.75E+05	Yes	No
Am-243	No	600	No	7.37E+03	Yes	No
Cm-243	Yes	350	No	29.1	Yes	Yes
Cm-244	Yes	350	No	18.1	Yes	Yes

Notes:

a. "Yes" indicates analyte was identified as a primary radionuclide in RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*, Table 4-11, Primary Radiological Parameters.

b. Source = RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*, Table 6-11, Distribution Coefficient (K_d) Values Used to Approximate Transport of Radionuclides in the Base Case.

c. It is assumed that radionuclides with $K_d > 0.15$ mL/g are non-mobile and would be expected to remain in the initial leak affected zone. Mobile radionuclides ($K_d < 0.15$ mL/g) are assumed to have migrated to depth.

d. Radionuclides with half-lives less than three years are eliminated because they are either insignificant risk contributors or their contributions are already included with their parent.

e. Thorium-232 is considered a naturally occurring background radionuclide and is therefore eliminated.

COPC = contaminant of potential concern.
DQO = data quality objectives.
K_d = distribution coefficient.

Table 4-4. Source Term Concentrations for Radiological COPCs

COPCs	**Soil Concentration (pCi/g)**		
	UPR-81	**UPR-82**	**UPR-86**
Am-241	2,628.2	593.9	195.2
C-14	518.7	269.4	88.6
Cm-243	0.0	0.1	2E-02
Cm-244	0.1	0.9	0.3
Cs-137	211,647	45,504,201	14,959,774
Eu-152	1.1	40.7	13.4
Eu-154	52.6	2032.3	668.1
Eu-155	10.2	395.9	130.2
I-129	84.7	0.9	0.3
Ni-63	328,667.4	10,464.2	3,440.2
Np-237	0.6	41.4	13.6
Pu-238	52.1	19.3	6.3
Pu-239	2,445.6	455.5	149.8
Pu-240	576.7	111.6	36.7
Pu-241	2939.1	700.3	230.2
Sn-126	0.97	204.9	67.4
Sr-90	177,620.8	152,724.5	50,209.1
U-233	40.2	1E-04	4E-05
U-234	5.6	1.0	0.3
U-235	0.2	4E-02	1E-02
U-236	0.1	2E-02	8E-03
U-238	5.0	0.9	0.3

Table 7-1. Year of Maximum Risk for Radiological COPCs Under Baseline and Post-Remediation Condition

COPCs	**No Soil Cover**	**3' of Concrete Cover**
	Year at Maximum Risk	**Year at Maximum Risk**
Am-241	0	1000
C-14	0	NA
Cm-243	0	0
Cm-244	0	0
Cs-137	0	0
Eu-152	0	0
Eu-154	0	0
Eu-155	0	0
I-129	0	NA
Ni-63	0	NA
Np-237	0	1000
Pu-238	0	1000
Pu-239	0	1000
Pu-240	0	1000
Pu-241	53.8	1000
Sn-126	0	0
Sr-90	0	0
U-233	1000	1000
U-234	1000	1000
U-235	0	1000
U-236	0	1000
U-238	0	0

Table 7-2. Radiological Risk Assessment Results for UPR-81 under CERCLA Industrial Worker Scenario (No Soil Cover)

COPCs	Concentration (pCi/g)	T=0 Year					T=53.8 Year				T=1000 Year			
		Risk (unitless)				% Cont	Risk (unitless)				Risk (unitless)			
		Ground	Inhalation	Soil	Total		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	2,628.2	2E-04	3E-09	1E-05	2E-04	0%	2E-04	2E-09	1E-05	2E-04	4E-05	5E-10	2E-06	4E-05
C-14	518.7	3E-10	7E-09	9E-10	8E-09	0%	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.0	4E-09	3E-15	1E-11	4E-09	0%	1E-09	8E-16	3E-12	1E-09	6E-14	7E-18	3E-14	9E-14
Cm-244	0.1	2E-11	6E-14	2E-10	2E-10	0%	3E-12	8E-15	3E-11	3E-11	5E-14	4E-16	1E-12	1E-12
Cs-137	211,647	1E+00	5E-10	2E-04	1E+00	99%	3E-01	1E-10	6E-05	3E-01	1E-10	5E-20	2E-14	1E-10
Eu-152	1.1	9E-06	3E-15	2E-10	9E-06	0%	6E-07	2E-16	1E-11	6E-07	5E-28	9E-27	5E-23	5E-23
Eu-154	52.6	4E-04	1E-13	1E-08	4E-04	0%	5E-06	2E-15	1E-10	5E-06	0E+00	0E+00	0E+00	0E+00
Eu-155	10.2	1E-06	1E-15	2E-10	1E-06	0%	4E-10	6E-19	1E-13	4E-10	0E+00	0E+00	0E+00	0E+00
I-129	84.7	1E-06	4E-13	5E-07	2E-06	0%	1E-06	3E-13	4E-07	1E-06	6E-09	2E-15	2E-09	9E-09
Ni-63	328,667	0E+00	5E-11	9E-06	9E-06	0%	0E+00	3E-11	6E-06	6E-06	0E+00	3E-14	6E-09	6E-09
Np-237	0.6	2E-06	5E-13	2E-09	2E-06	0%	2E-06	5E-13	2E-09	2E-06	1E-06	4E-13	2E-09	1E-06
Pu-238	52.1	1E-08	7E-11	3E-07	3E-07	0%	7E-09	4E-11	2E-07	2E-07	3E-10	3E-14	1E-10	4E-10
Pu-239	2,445.6	1E-06	4E-09	1E-05	2E-05	0%	1E-06	4E-09	1E-05	2E-05	1E-06	4E-09	1E-05	1E-05
Pu-240	576.7	1E-07	9E-10	3E-06	3E-06	0%	1E-07	9E-10	3E-06	3E-06	1E-07	8E-10	3E-06	3E-06
Pu-241	2,939.1	3E-06	8E-11	3E-07	4E-06	0%	7E-06	9E-11	4E-07	7E-06	2E-06	2E-11	9E-08	2E-06
Sn-126	1.0	2E-05	1E-14	1E-09	2E-05	0%	2E-05	1E-14	1E-09	2E-05	2E-06	1E-15	1E-10	2E-06
Sr-90	177,620.8	7E-03	2E-09	4E-04	7E-03	1%	2E-03	4E-10	1E-04	2E-03	2E-13	5E-20	1E-14	2E-13
U-233	40.2	2E-07	3E-11	1E-07	3E-07	0%	8E-07	3E-11	1E-07	9E-07	5E-06	1E-11	5E-08	5E-06
U-234	5.6	4E-09	4E-12	2E-08	2E-08	0%	5E-09	4E-12	1E-08	2E-08	1E-07	6E-13	3E-09	1E-07
U-235	0.2	3E-07	1E-13	7E-10	3E-07	0%	3E-07	1E-13	6E-10	3E-07	5E-08	3E-14	1E-10	5E-08
U-236	0.1	5E-11	9E-14	4E-10	4E-10	0%	5E-11	8E-14	3E-10	4E-10	7E-12	1E-14	5E-11	6E-11
U-238	5.0	2E-06	3E-12	2E-08	2E-06	0%	1E-06	3E-12	2E-08	1E-06	2E-07	4E-13	2E-09	2E-07
Cumulative ELCRs		**1E+00**	2E-08	6E-04	**1E+00**		**3E-01**	8E-09	2E-04	**3E-01**	5E-05	5E-09	2E-05	7E-05

Table 7-3. Radiological Risk Assessment Results for UPR-82 under CERCLA Industrial Worker Scenario (No Soil Cover)

COPCs	Concentration (pCi/g)	T=0 Year					T=53.8 Year				T=1000 Year			
		Risk (unitless)				% Cont	Risk (unitless)				Risk (unitless)			
		Ground	Inhalation	Soil	Total		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	593.9	5E-05	6E-10	3E-06	5E-05	0%	4E-05	5E-10	2E-06	4E-05	9E-06	1E-10	5E-07	1E-05
C-14	269.4	2E-10	4E-09	5E-10	4E-09	0%	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.1	4E-08	4E-14	2E-10	4E-08	0%	1E-08	1E-14	4E-11	1E-08	8E-13	9E-17	3E-13	1E-12
Cm-244	0.9	2E-10	6E-13	2E-09	2E-09	0%	3E-11	8E-14	3E-10	3E-10	5E-13	4E-15	1E-11	1E-11
Cs-137	45,504,201	2E+02	1E-07	4E-02	2E+02	100%	7E+01	3E-08	1E-02	7E+01	2E-08	1E-17	4E-12	2E-08
Eu-152	40.7	3E-04	1E-13	6E-09	3E-04	0%	2E-05	8E-15	4E-10	2E-05	2E-26	4E-25	2E-21	2E-21
Eu-154	2,032.3	1E-02	5E-12	4E-07	1E-02	0%	2E-04	6E-14	5E-09	2E-04	0E+00	0E+00	0E+00	0E+00
Eu-155	395.9	4E-05	6E-14	1E-08	4E-05	0%	1E-08	2E-17	4E-12	1E-08	0E+00	0E+00	0E+00	0E+00
I-129	0.9	2E-08	4E-15	5E-09	2E-08	0%	1E-08	3E-15	4E-09	2E-08	7E-11	2E-17	3E-11	9E-11
Ni-63	10,464	0E+00	2E-12	3E-07	3E-07	0%	0E+00	1E-12	2E-07	2E-07	0E+00	1E-15	2E-10	2E-10
Np-237	41.4	1E-04	3E-11	1E-07	1E-04	0%	1E-04	3E-11	1E-07	1E-04	9E-05	3E-11	1E-07	9E-05
Pu-238	19.3	4E-09	2E-11	1E-07	1E-07	0%	2E-09	2E-11	6E-08	6E-08	1E-10	1E-14	4E-11	2E-10
Pu-239	455.5	3E-07	7E-10	3E-06	3E-06	0%	3E-07	7E-10	3E-06	3E-06	3E-07	7E-10	2E-06	3E-06
Pu-240	111.6	2E-08	2E-10	6E-07	6E-07	0%	2E-08	2E-10	6E-07	6E-07	2E-08	2E-10	6E-07	6E-07
Pu-241	700.3	8E-07	2E-11	7E-08	8E-07	0%	2E-06	2E-11	9E-08	2E-06	4E-07	5E-12	2E-08	4E-07
Sn-126	204.9	5E-03	2E-12	3E-07	5E-03	0%	4E-03	2E-12	2E-07	4E-03	4E-04	2E-13	2E-08	4E-04
Sr-90	152,725	6E-03	1E-09	4E-04	6E-03	0%	2E-03	4E-10	1E-04	2E-03	2E-13	4E-20	1E-14	2E-13
U-233	0.0	7E-13	1E-16	4E-13	1E-12	0%	3E-12	1E-16	4E-13	3E-12	2E-11	5E-17	2E-13	2E-11
U-234	1.0	7E-10	7E-13	3E-09	4E-09	0%	8E-10	6E-13	3E-09	3E-09	2E-08	1E-13	5E-10	2E-08
U-235	0.0	6E-08	3E-14	1E-10	6E-08	0%	6E-08	2E-14	1E-10	6E-08	1E-08	6E-15	3E-11	1E-08
U-236	0.0	9E-12	2E-14	7E-11	8E-11	0%	8E-12	2E-14	6E-11	7E-11	1E-12	2E-15	9E-12	1E-11
U-238	0.9	3E-07	6E-13	4E-09	3E-07	0%	3E-07	5E-13	3E-09	3E-07	4E-08	8E-14	5E-10	4E-08
Cumulative ELCR		**2E+02**	1E-07	4E-02	**2E+02**		**7E+01**	3E-08	1E-02	**7E+01**	5E-04	1E-09	4E-06	5E-04

Table 7-4. Radiological Risk Assessment Results for UPR-86 under CERCLA Industrial Worker Scenario (No Soil Cover)

COPCs	Concentration (pCi/g)	T=0 Year					T=53.8 Year				T=1000 Year			
		Risk (unitless)				% Cont	Risk (unitless)				Risk (unitless)			
		Ground	Inhalation	Soil	Total		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	195.2	1E-05	2E-10	8E-07	2E-05	0%	1E-05	2E-10	8E-07	1E-05	3E-06	4E-11	2E-07	3E-06
C-14	88.6	5E-11	1E-09	2E-10	1E-09	0%	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.0	1E-08	1E-14	5E-11	1E-08	0%	4E-09	4E-15	1E-11	4E-09	3E-13	3E-17	1E-13	4E-13
Cm-244	0.3	8E-11	2E-13	7E-10	8E-10	0%	1E-11	3E-14	9E-11	1E-10	2E-13	1E-15	4E-12	4E-12
Cs-137	14,959,774	8E+01	4E-08	1E-02	8E+01	100%	2E+01	1E-08	4E-03	2E+01	8E-09	4E-18	1E-12	8E-09
Eu-152	13.4	1E-04	4E-14	2E-09	1E-04	0%	7E-06	2E-15	1E-10	7E-06	5E-27	1E-25	6E-22	6E-22
Eu-154	668.1	4E-03	2E-12	1E-07	4E-03	0%	6E-05	2E-14	2E-09	6E-05	0E+00	0E+00	0E+00	0E+00
Eu-155	130.2	1E-05	2E-14	3E-09	1E-05	0%	5E-09	7E-18	1E-12	5E-09	0E+00	0E+00	0E+00	0E+00
I-129	0.3	5E-09	1E-15	2E-09	7E-09	0%	4E-09	9E-16	1E-09	5E-09	2E-11	6E-18	8E-12	3E-11
Ni-63	3,440	0E+00	5E-13	1E-07	1E-07	0%	0E+00	3E-13	7E-08	7E-08	0E+00	3E-16	6E-11	6E-11
Np-237	13.6	3E-05	1E-11	4E-08	3E-05	0%	3E-05	1E-11	4E-08	3E-05	3E-05	9E-12	4E-08	3E-05
Pu-238	6.3	1E-09	8E-12	3E-08	3E-08	0%	8E-10	5E-12	2E-08	2E-08	4E-11	3E-15	1E-11	5E-11
Pu-239	149.8	9E-08	2E-10	8E-07	9E-07	0%	9E-08	2E-10	8E-07	9E-07	9E-08	2E-10	8E-07	9E-07
Pu-240	36.7	8E-09	6E-11	2E-07	2E-07	0%	8E-09	6E-11	2E-07	2E-07	7E-09	5E-11	2E-07	2E-07
Pu-241	230.2	3E-07	6E-12	2E-08	3E-07	0%	5E-07	7E-12	3E-08	6E-07	1E-07	2E-12	7E-09	1E-07
Sn-126	67.4	2E-03	8E-13	8E-08	2E-03	0%	1E-03	7E-13	7E-08	1E-03	1E-04	7E-14	8E-09	1E-04
Sr-90	50,209	2E-03	4E-10	1E-04	2E-03	0%	5E-04	1E-10	3E-05	6E-04	6E-14	1E-20	4E-15	6E-14
U-233	0.0	2E-13	3E-17	1E-13	4E-13	0%	9E-13	3E-17	1E-13	1E-12	5E-12	2E-17	6E-14	5E-12
U-234	0.3	2E-10	2E-13	9E-10	1E-09	0%	3E-10	2E-13	8E-10	1E-09	7E-09	3E-14	2E-10	7E-09
U-235	0.0	2E-08	9E-15	4E-11	2E-08	0%	2E-08	8E-15	4E-11	2E-08	3E-09	2E-15	9E-12	3E-09
U-236	0.0	3E-12	6E-15	2E-11	3E-11	0%	3E-12	5E-15	2E-11	2E-11	4E-13	7E-16	3E-12	3E-12
U-238	0.3	1E-07	2E-13	1E-09	1E-07	0%	9E-08	2E-13	1E-09	9E-08	1E-08	3E-14	2E-10	1E-08
Cumulative ELCR		**8E+01**	4E-08	1E-02	**8E+01**		**2E+01**	1E-08	4E-03	**2E+01**	2E-04	3E-10	1E-06	2E-04

Table 7-5. Radiological Risk Assessment Results for UPR-81 under CERCLA Industrial Worker Scenario (3-ft Concrete Cover)

COPCs	Concentration (pCi/g)	T=0 Year				T=1000 Year			
		Risk (unitless)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	2,628.2	1E-19	0E+00	0E+00	1E-19	1E-17	0E+00	0E+00	1E-17
C-14	518.7	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.0	3E-22	0E+00	0E+00	3E-22	3E-27	0E+00	0E+00	3E-27
Cm-244	0.1	2E-19	0E+00	0E+00	2E-19	6E-27	0E+00	0E+00	6E-27
Cs-137	211,647	9E-09	0E+00	0E+00	9E-09	1E-18	0E+00	0E+00	1E-18
Eu-152	1.1	8E-13	0E+00	0E+00	8E-13	0E+00	0E+00	0E+00	0E+00
Eu-154	52.6	3E-11	0E+00	0E+00	3E-11	0E+00	0E+00	0E+00	0E+00
Eu-155	10.2	1E-25	0E+00	0E+00	1E-25	0E+00	0E+00	0E+00	0E+00
I-129	84.7	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Ni-63	328,667	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Np-237	0.6	8E-18	0E+00	0E+00	8E-18	2E-17	0E+00	0E+00	2E-17
Pu-238	52.1	3E-21	0E+00	0E+00	3E-21	1E-16	0E+00	0E+00	1E-16
Pu-239	2,445.6	5E-19	0E+00	0E+00	5E-19	6E-19	0E+00	0E+00	6E-19
Pu-240	576.7	8E-22	0E+00	0E+00	8E-22	1E-20	0E+00	0E+00	1E-20
Pu-241	2,939.1	2E-21	0E+00	0E+00	2E-21	4E-19	0E+00	0E+00	4E-19
Sn-126	1.0	2E-13	0E+00	0E+00	2E-13	1E-14	0E+00	0E+00	1E-14
Sr-90	177,621	6E-13	0E+00	0E+00	6E-13	2E-23	0E+00	0E+00	2E-23
U-233	40.2	1E-14	0E+00	0E+00	1E-14	3E-13	0E+00	0E+00	3E-13
U-234	5.6	2E-17	0E+00	0E+00	2E-17	5E-14	0E+00	0E+00	5E-14
U-235	0.2	8E-20	0E+00	0E+00	8E-20	1E-17	0E+00	0E+00	1E-17
U-236	0.1	2E-21	0E+00	0E+00	2E-21	1E-19	0E+00	0E+00	1E-19
U-238	5.0	5E-14	0E+00	0E+00	5E-14	7E-15	0E+00	0E+00	7E-15
Cumulative ELCR		9E-09	0E+00	0E+00	9E-09	4E-13	0E+00	0E+00	4E-13

Table 7-6. Radiological Risk Assessment Results for UPR-82 under CERCLA Industrial Worker Scenario (3-ftf Concrete Cover)

COPCs	Concentration (pCi/g)	T=0 Year				T=1000 Year			
		Risk (unitless)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	593.9	3E-20	0E+00	0E+00	3E-20	2E-18	0E+00	0E+00	2E-18
C-14	269.4	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.1	3E-21	0E+00	0E+00	3E-21	4E-26	0E+00	0E+00	4E-26
Cm-244	0.9	2E-18	0E+00	0E+00	2E-18	5E-26	0E+00	0E+00	5E-26
Cs-137	45,504,201	2E-06	0E+00	0E+00	2E-06	2E-16	0E+00	0E+00	2E-16
Eu-152	40.7	3E-11	0E+00	0E+00	3E-11	0E+00	0E+00	0E+00	0E+00
Eu-154	2,032.3	1E-09	0E+00	0E+00	1E-09	0E+00	0E+00	0E+00	0E+00
Eu-155	395.9	4E-24	0E+00	0E+00	4E-24	0E+00	0E+00	0E+00	0E+00
I-129	0.9	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Ni-63	10,464	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Np-237	41.4	5E-16	0E+00	0E+00	5E-16	1E-15	0E+00	0E+00	1E-15
Pu-238	19.3	1E-21	0E+00	0E+00	1E-21	5E-17	0E+00	0E+00	5E-17
Pu-239	455.5	9E-20	0E+00	0E+00	9E-20	1E-19	0E+00	0E+00	1E-19
Pu-240	111.6	2E-22	0E+00	0E+00	2E-22	2E-21	0E+00	0E+00	2E-21
Pu-241	700.3	4E-22	0E+00	0E+00	4E-22	9E-20	0E+00	0E+00	9E-20
Sn-126	204.9	3E-11	0E+00	0E+00	3E-11	3E-12	0E+00	0E+00	3E-12
Sr-90	152,725	5E-13	0E+00	0E+00	5E-13	2E-23	0E+00	0E+00	2E-23
U-233	0.0	3E-20	0E+00	0E+00	3E-20	1E-18	0E+00	0E+00	1E-18
U-234	1.0	3E-18	0E+00	0E+00	3E-18	8E-15	0E+00	0E+00	8E-15
U-235	0.0	2E-20	0E+00	0E+00	2E-20	2E-18	0E+00	0E+00	2E-18
U-236	0.0	3E-22	0E+00	0E+00	3E-22	3E-20	0E+00	0E+00	3E-20
U-238	0.9	1E-14	0E+00	0E+00	1E-14	1E-15	0E+00	0E+00	1E-15
Cumulative ELCR		2E-06	0E+00	0E+00	2E-06	3E-12	0E+00	0E+00	3E-12

Table 7-7. Radiological Risk Assessment Results for UPR-86 under CERCLA Industrial Worker Scenario (3-ft Concrete Cover)

COPCs	Concentration (pCi/g)	T=0 Year Risk (unitless)				T=1000 Year Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	195.2	1E-20	0E+00	0E+00	1E-20	8E-19	0E+00	0E+00	8E-19
C-14	88.6	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0.0	1E-21	0E+00	0E+00	1E-21	1E-26	0E+00	0E+00	1E-26
Cm-244	0.3	6E-19	0E+00	0E+00	6E-19	2E-26	0E+00	0E+00	2E-26
Cs-137	14,959,774	6E-07	0E+00	0E+00	6E-07	7E-17	0E+00	0E+00	7E-17
Eu-152	13.4	1E-11	0E+00	0E+00	1E-11	0E+00	0E+00	0E+00	0E+00
Eu-154	668.1	4E-10	0E+00	0E+00	4E-10	0E+00	0E+00	0E+00	0E+00
Eu-155	130.2	1E-24	0E+00	0E+00	1E-24	0E+00	0E+00	0E+00	0E+00
I-129	0.3	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Ni-63	3,440	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Np-237	13.6	2E-16	0E+00	0E+00	2E-16	5E-16	0E+00	0E+00	5E-16
Pu-238	6.3	4E-22	0E+00	0E+00	4E-22	2E-17	0E+00	0E+00	2E-17
Pu-239	149.8	3E-20	0E+00	0E+00	3E-20	4E-20	0E+00	0E+00	4E-20
Pu-240	36.7	5E-23	0E+00	0E+00	5E-23	8E-22	0E+00	0E+00	8E-22
Pu-241	230.2	1E-22	0E+00	0E+00	1E-22	3E-20	0E+00	0E+00	3E-20
Sn-126	67.4	1E-11	0E+00	0E+00	1E-11	1E-12	0E+00	0E+00	1E-12
Sr-90	50,209	2E-13	0E+00	0E+00	2E-13	6E-24	0E+00	0E+00	6E-24
U-233	0.0	1E-20	0E+00	0E+00	1E-20	4E-19	0E+00	0E+00	4E-19
U-234	0.3	1E-18	0E+00	0E+00	1E-18	3E-15	0E+00	0E+00	3E-15
U-235	0.0	5E-21	0E+00	0E+00	5E-21	7E-19	0E+00	0E+00	7E-19
U-236	0.0	1E-22	0E+00	0E+00	1E-22	9E-21	0E+00	0E+00	9E-21
U-238	0.3	3E-15	0E+00	0E+00	3E-15	4E-16	0E+00	0E+00	4E-16
Cumulative ELCR		6E-07	0E+00	0E+00	6E-07	1E-12	0E+00	0E+00	1E-12

Table 7-8. Summary Radiological Risk Assessment Results for UPR-81, UPR-82 and UPR-86 under CERCLA Industrial Worker Scenario for Baseline and Post-Remediation Conditions

Scenario	UPR-81	UPR-82	UPR-86
Baseline (No Soil Cover) ELCR	1E+00	2E+02	8E+01
Post-Remediation (3-ft Concrete Cover) ELCR	9E-09	2E-06	6E-07

Appendix A
SOFTWARE INSTALLATION AND CHECKOUT FORM FOR RESRAD

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   [redacted]

3. Executable Size (bytes): 1.876 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Compiled by Vendor (ANL)

5. Operating System (include version number):

   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   INTERA-0740

7. Operating System (include version number):

   Windows 8.1

8. Open Problem Report? (•) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   [redacted]

10. Procedure(s):

    per CHPRC-00210 Rev 0, RESRAD Software Test Plan

11. Libraries:

    N/A

12. Input Files:

    Created in RESRAD per installation test instruction

13. Output Files:

    SUMMARY.REP

14. Test Cases:

    RESRAD-ITC-1

15. Test Case Results:

    PASS

16. Test Performed By: M Rahman

17. Test Results: (•) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

    Passed; Installation added to HISI Entry

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD Software Version No.: 7.0

Prepared By:

19.	WE Nichols	
Software Owner (Signature)	Print	Date

20. Test Personnel:

[signature]	M RAHMAN	11-16-15
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	N/R per SMP	
Software SME (Signature)	Print	Date

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.852 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   Intera-00474
7. Operating System (include version number):
   Windows 10 Pro
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 2, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    Test results matched expected results; pass.
16. Test Performed By: SL Lindberg
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Approved; installation added to HISI entry software user list.

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD — Software Version No.: 7.0

Prepared By:

19. ______	WE Nichols	______
Software Owner (Signature)	Print	Date

20. Test Personnel:

[signature]	SL Lindberg	08/03/2016
Sign	Print	Date
______	______	______
Sign	Print	Date
______	______	______
Sign	Print	Date

Approved By:

21. ______	N/R per SMP	______
Software SME (Signature)	Print	Date

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ENVIRONMENTAL MODEL CALCULATION COVER PAGE

Section 1: Completed by Responsible Manager

RELEASE/ISSUE: 1

Project: Waste Management Area C(WMA C)

Date: 11/17/2016

Calculation Title & Description: Ecological Risk Assessment for UPRs, Surface Contamination and 216-C-8 French Drain

Section 2: Completed by Preparer

Calculation No.: RPP-CALC-61128   Revision No.: 1

Revision History

Revision No.	Description	Date	Affected Pages
0		08/31/2016	All

Section 3: Completed by Responsible Manager

Document Control

1.	Is document intended to be controlled within SmartPlant?	☒ Yes	☐ No
2.	Does document contain scientific and technical information intended for public use?	☒ Yes	☐ No
3.	Does document contain controlled-use information?	☐ Yes	☒ No

Section 4: Training and Software Installation Approval (Completed Prior to Performing Calculation)

Modeler-Required Training Completed:

Training Coordinator (Name/Position)	Signature	Date
WE Nichols/Principal Engineer	[signature]	17 NOV 2016

Software Installation and Checkout Certified:

Integration Lead (Name/Position)	Signature	Date
NOT APPLICABLE		

Section 5: Document Review & Approval

Name/Position		Signature	Date
Md Mahmudur Rahman/Sr. Risk Assessor	Preparer (Name/Position)	[signature]	11/17/2016
S. Lindberg/Sr. Risk Assessor	Checker (Name/Position)	[signature]	11/17/2016
Sue Robinson/Sr. Risk Assessor	Senior Reviewer (Name/Position)	[signature]	11/17/2016
Andrea Hopkins/Env. Compliance/WRPS	Responsible Manager (Name/Position)	[signature]	11/17/2016

A-6006-716 (REV 0)

RPP-CALC-61128
Revision 1

WMA C Ecological Risk Assessment for UPRs, Surface Contamination and 216-C-8 French Drain

Prepared by:
Md Mahmudur Rahman
INTERA, Inc.

Prepared for:
Washington River Protection Solutions, LLC

Date:
Version Revision 1
November 2016

Version History

Version	Date	Author	Change Description
Rev. 0	31-Aug-2016	Md Mahmudur Rahman	Initial Issue
Rev. 1	17-Nov-2016	Md Mahmudur Rahman	1. Radiological ERA for all three 3 UPRs 2. Radiological ERA for Surface Contamination and 216-C-8 French Drain

EMCF CHECK LOG:

File/Name	Purpose	(1) Input documented in the EMCF	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
UPR_Eco_Risk_Evaluation.xlsx	ERA for UPRs	Table 4-1: Concentrations for Nonradiological Contaminants	RPP-RPT-61057 Revision 0: Results of Radiological and Nonradiological Risk Assessment Under Industrial Worker for Soil Contamination Covered with Isolation Barrier	
		Table 4-2: Concentrations for Radiological Contaminants	RPP-CALC-61238: Radiological Risk Assessments for Three Unplanned Releases within Waste Management Area C RPP-CALC-61239: Radiological Risk Assessments for Past Leaks and Releases within Waste Management Area C	
		Tier 1 SSL	Table 6-13 of CHPRC-00784, Revision 1: Tier 1 Risk Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site	
		Tier 2 PRGs	Table 2-9 of CHPRC-01311, Revision 2: Tier 2 Risk Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site Table 6-3 of ECF-HANFORD-11-0158 Revision 1: Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site	
		Hanford Site Soil Background	Table 4-1 of ECF-HANFORD-14-0077	

SL = Checked by Sara Lindberg
NA=Not Applicable

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TERMS

AUF	Area Use Factor
bgs	Below Ground Surface
BRA	Baseline Risk Assessment
CMS	Corrective Measures Study
COPC	Contaminant of Potential Concern
COC	Chemical of Concern
EMCF	Environmental Model Calculation File
ERA	Ecological Risk Assessment
HQ	Hazard Quotient
LOAEL	Lowest-Observed-Adverse-Effect-Level
NOAEL	No-Observed-Adverse-Effect-Level
PRG	Preliminary Remediation Goal
UPR	Unplanned Releases
SLERA	Screening level ecological risk assessment
SMDP	Scientific Management Decision Point
SSL	Soil Screening Level
SSV	Soil Screening Value
TRV	Toxicity Reference Value
WMA	Waste Management Area

1.0 PURPOSE

The purpose of this environmental model calculation file (EMCF) is to document an ecological risk assessment (ERA) for three unplanned releases (UPRs), surface contamination associated with releases and activities within the 241-C Tank Farm, and the 216-C-8 French Drain, located within the Waste Management Area (WMA) C. An ecological risk assessment is necessary to assess the potential for ecological impacts resulting from biota exposure to nonradiological and radiological contaminants of potential concern (COPCs) present in the soil affected by the UPRs, surface contamination, and the 216-C-8 French Drain. This EMCF presents the ecological risk assessment findings.

The biologically active zone in soil is defined as the depth to which soil invertebrates, plants and burrowing animals intrude into the soil column (biointrusion). In CHPRC-00651, *Evaluation of Biointrusion at the Hanford Site for Protection of Ecological Receptor* (CHPRC, 2010), a depth of 10 feet was identified as the biologically active zone within the Central Plateau based upon Hanford specific biointrusion data as well as other biointrusion information from the scientific literature. The biologically active zone is a key element in establishing the completeness of exposure pathways to ecological resources. Contamination in soil below the biologically active zone depth would therefore not represent a source of exposure within the ecological exposure pathway thus rendering the pathway incomplete (no ecological threat). This 10-ft depth has been proposed as a conditional point of compliance for protection of terrestrial ecological receptors in the Central Plateau. Accordingly, past leaks from the six tanks at WMA C occurred at a minimum depth of 20 ft bgs, no ERA was performed for those past leaks.

Information related to the characterization of the ecological setting for WMA C and the basis underlying the tiered Soil Screening Levels (SSLs) and Preliminary Remediation Goals (PRGs) for ecological receptors that are used in this analysis is presented in the WMA C baseline risk assessment (BRA) report (RPP-RPT-58329).

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2.0 BACKGROUND

A screening level ecological risk assessment (SLERA) was previously conducted for ten (10) exposure areas within WMA C, and the results of the SLERA are presented in the BRA report (RPP-RPT-58329). The results of the SLERA for WMA C did not result in the identification of any radiological or nonradiological contaminants of concern. However, because of the very high levels of radiological contamination associated with UPR-81, UPR-82, and UPR-86, soil samples were not collected at the UPRs as part of the original investigation due to safety concerns. In addition, soil samples were not collected for surface contamination located within 241-C Tank Farm or the 216-C-8 French Drain. Accordingly, in the absence of sampling data, the WMA C SLERA did not evaluate these sites as part of the BRA and they are evaluated as part of the WMA C ERA.

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3.0 METHODOLOGY

The ERA for nonradiological and radiological constituents was performed by comparing the estimated concentrations of contaminants (radiological, nonradiological) against their corresponding SSLs or PRGs for ecological receptors. These comparisons result in the identification of constituent that (i) do not pose a potential for ecological risk and require no further evaluation, and (ii) that may pose a risk and require additional evaluation. The ERA involves the calculation of a Hazard Quotient (HQ), which represents an index of risk posed to ecological receptors. The HQ is computed by dividing the concentration of the contaminant in the source exposure media by a soil benchmark , as represented by the following equation:

$$HQ = \frac{Concentration}{Soil\ Benchmark}$$

Soil benchmarks are defined as the higher of either a constituent-specific risk-based concentration protective of ecological receptors or the soil background concentration. For nonradiological contaminants, when an HQ value is less than 1, the concentration is below the soil benchmark and the constituent is deemed to pose a negligible risk and is not retained for further evaluation. HQ values that are greater than 1 indicate a potential for ecological risk and the constituent is defined as a Chemical of Concern (COC) and retained for further evaluation in the Feasibility Study.

In addition to the calculation of an HQ for radiological contaminants, a Sum of the Fraction (SOF) is calculated for each area to determine the cumulative risk of all radiological contaminants. The SOF is computed by summing the HQs for each radionuclide to calculate the SOF. If the SOF is greater than 1, unacceptable risk is present for that area and additional site factors that may mitigate (or enhance) the estimated risk is evaluated in the Scientific Management Decision Point (SMDP) in the ERA.

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4.0 ASSUMPTIONS AND INPUTS

The following documents the assumptions and inputs for the ERA performed for the three WMA C UPRs, the surface contamination within the 241-C Tank Farm, and the 216-C-8 French Drain.

4.1 Soil Concentrations

Table 4-1 summarizes the estimated source term concentrations for nonradiological contaminants, as documented in RPP-CALC-61057. For aluminum, the only source information available for quantifying surface releases is an estimated soil concentration of 0.25 mg/kg. Similarly, for the French Drain (216-C-8), the estimated source concentrations for aluminum, chromium, iron, lead, nickel and uranium (total) are 250, 1.7, 1.1, 1, 1.6 and 0.3 mg/kg, respectively (RPP-CALC-61057). Background concentrations for these constituents are 11,800, 18.5, 23,600, 38, 156 and 22, mg/kg respectively. A comparison of the estimated source concentrations for nonradiological contaminants to their background concentrations indicates the source concentrations are less than 10% of the corresponding background concentrations. Therefore, an ERA was not performed for either site (surface contamination or French Drain).

Table 4-1. Estimated Concentrations for Nonradiological Contaminants.

Nonradiological Contaminants	Soil Concentration (mg/kg)		
	UPR-81	UPR-82	UPR-86
Aluminum[a]	8220	--	--
Chromium	77	38	13
Iron	51	9	3
Lead	72	14	4
Mercury	--	0.03	0.01
Nickel	44	10	3
Uranium (total)	15	3	1

Notes:

a. The equivalent Al concentration calculated using $Al(OH)^{4-}$ soil concentration and the weight ratio of Al/ $Al(OH)^{4-}$ (27/95 = 0.284)

-- = inventory not reported

Table 4-2 summarizes the estimated source term concentrations for radiological contaminants. The source term concentrations for UPRs are documented in RPP-CALC-61238. The source terms for the surface contamination and the 216-C-8 French Drain are documented in RPP-CALC-61239.

Table 4-2. Estimated Concentrations for Radiological Contaminants

Radiological Contaminants	Estimated Soil Concentration (pCi/g)				
	UPR-81	UPR-82	UPR-86	Surface Releases	216-C-8 French Drain
Am-241	2,628.2	593.9	195.2	0.07	--
C-14	518.7	269.4	88.6	0.02	--
Cm-243	0.0	0.1	0.0	2E-08	--
Cm-244	0.1	0.9	0.3	3E-07	--
Cs-137	211,647	45,504,201	14,959,774	5.46	60
Eu-152	1.1	40.7	13.4	2E-05	--
Eu-154	52.6	2032.3	668.1	8E-04	--
Eu-155	10.2	395.9	130.2	1E-04	--
I-129	84.7	0.9	0.3	3E-03	--
Ni-63	328,667.4	10,464.2	3,440.2	5.4	--
Np-237	0.6	41.4	13.6	2E-05	7E-03
Pu-238	52.1	19.3	6.3	8E-04	6E-02
Pu-239	2,445.6	455.5	149.8	5E-02	1E+00
Pu-240	576.7	111.6	36.7	1E-02	4E-01
Pu-241	2939.1	700.3	230.2	0.02	1E+00
Sn-126	0.97	204.9	67.4	3E-05	--
Sr-90	177,620.8	152,724.5	50,209.1	5E+00	502
U-233	40.2	1.4E-04	4E-05	2E-10	5.0E+02
U-234	5.6	1.0	0.3	1E-04	5.6E-07
U-235	0.2	4E-02	1E-02	4.5E-06	4.0E-03
U-236	0.1	2E-02	8E-03	2.4E-06	1.7E-04
U-238	5.0	0.9	0.3	1.1E-04	1.0E-04

Note
-- No inventory reported

4.2 Nonradiological Soil Screening Levels

Tier 1 Soil Screening Levels (SSLs) are available for nonradiological constituents in CHPRC-00784, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*. The latter values, though focused on Hanford ecological receptors, do not incorporate Hanford specific exposure information. Accordingly, Tier 2 soil PRGs for plants, soil invertebrates and wildlife, which represent more refined and site-specific risk based values than the Tier 1 SSLs for nonradiological constituents,were used in the ERA. Tier 2 PRGs for plants and soil invertebrates are presented in ECF-HANFORD-11-0158 Revision 1: *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*. Tier 2 PRGs for wildlife are presented in CHPRC-01311, Revision 2: *Tier 2 Risk Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*. The Tier 2 PRGs and soil background concentrations were used in a two-step process to select a Soil Benchmark for characterizing risk of nonradiological constituents:

1. Selection of the Lowest PRG – The lowest PRG for each nonradiological contaminants was determined by comparing the Tier 2 PRGs for plants, soil invertebrates and wildlife.
2. Determination of Soil Benchmark – The SSV for each contaminant was determined by choosing the maximum of either the lowest Tier 2 PRG or its corresponding site background concentration. The following reports document the bases for the Hanford soil background concentrations used to identify SSVs:
   - DOE/RL-92-24, Vol. 1, Revision 4, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*
   - ECF-HANFORD-11-0038, *Soil Background for Interim Use at The Hanford Site*

The Soil Benchmarks for nonradiological constituents used in the ERA are presented in Table 4-3.

Table 4-3. Soil Benchmarks for Nonradiological Constituents

Nonradiological Constituents	Tier 2 PRGs (mg/kg)			Lowest PRG[c] (mg/kg)	Background Concentration[d] (mg/kg)	Soil Benchmarks[e] (mg/kg)
	Plant[a]	Soil Invertebrates[a]	Wildlife[b]			
Aluminum	--	--	3988	3988	11800	11800
Chromium	259	149	109	109	18.5	109
Iron	--	--	--	--	32600	32600
Lead	9090	1700	156	156	10.2	156
Mercury	0.3	12.5	1.6	0.3	0.013	0.3
Nickel	38	280	247	38	19.1	38
Total Uranium	250	100	22	22	3.21	22

Notes:

a. ECF-HANFORD-11-0158, Rev. 1, Table 6-3
b. CHPRC-01311, Table 2-9
c. Lowest PRG = Minimum of Tier 2 PRGs (Plant, Soil Invertebrates and Wildlife)
d. DOE/RL-92-24, DOE/RL-96-12, ECF-HANFORD-11-0038
e. Tier 2 Soil Benchmark = Maximum of Lowest PRG or Background Concentration
-- Tier 2 PRGs not available

4.3 Radiological Soil Screening Levels

Tier 1 SSLs for wildlife were used to screen for radiological constituents. Tier 1 SSL development for radionuclides is presented in CHPRC-00784, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*. The latter report provides Tier 1 SSLs based on two types of toxicity reference values (TRVs):

- Tier 1 SSLs based on a No-Observed-Adverse-Effect-Level (NOAEL) TRVs; and
- Tier 1 SSLs based on Lowest-Observed-Adverse-Effect-Level (LOAEL) TRVs.

Because they are more appropriate values for use in evaluating risk broadly to ecological communities and populations, and because more refined Tier 2 PRGs are not available for radiological contaminants, the Tier 1 LOAEL-based SSLs were used to evaluate ecological risk

potential for radiological contaminants. Tier 1 LOAEL-based SSLs for radiological contaminants are presented in Table 7-2.

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5.0 SOFTWARE APPLICATIONS

All calculations for this environmental calculation were performed on electronic spreadsheets using Microsoft Excel®.

® Microsoft Excel is a registered product of the Microsoft Corporation.

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6.0 CALCULATION

This section presents the data evaluation spreadsheets and describes the process used to check and verify the accuracy of the spreadsheet formulas and calculation results.

6.1 Original Calculation

Microsoft Excel® was used to perform the ERA using the methodology described in Section 3 and the assumptions and inputs identified in Section 4. The results of the ERA are presented in Section 7.0.

6.2 Calculation Review and Quality Check

A QC review was performed independently for all UPRs and surface releases within WMA C to verify the results of the original calculation. During this process, three types of evaluations were performed. They are summarized below.

- Verification of source term for each constituent – The concentrations for nonradiological and radiological contaminants presented in Table 4-1 and Table 4-2 were verified to ensure these values are consistent with the values documented in referenced sources. The results of this evaluation did not identify any errors.
- Verification of the Tier 1 and Tier 2 Screening Values – The nonradiological and radiological PRGs and SSLs presented in Table 4-3 and Table 7-2 were verified to ensure these values are consistent with the values documented in referenced sources. The results of this evaluation did not identify any errors.
- Verification of Risk Calculation – During this evaluation, ERA was performed for each constituent by using the methodologies presented in Section 3. The results of the risk assessments were compared against the original risk calculations to ensure the formulas used during the calculations of COPC-specific risk were not corrupted and correct formulas were used.

The results of the evaluation did not identify any errors associated with the formulas used during the calculations of risk.

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7.0 RESULTS/CONCLUSIONS

Results of the ERA for the UPRs located at the WMA C are presented below:

7.1 ECOLOGICAL RISK ASSESSEMENT RESULTS

Table 7-1 summarizes the estimated source concentrations and the SSV for each nonradiological constituent at each of the three UPRs (UPR-81, UPR-82 and UPR-86). The HQ values calculated for each constituent are also presented in Table 7-1.

Table 7-1. Summary of Source Term Concentrations, Soil Benchmarks and HQ Values for Nonradiological Constituents at UPR Locations

Nonradiological Contaminants	Soil Concentration (mg/kg)			Soil Benchmarks (mg/kg)	HQs		
	UPR -81	UPR-82	UPR-86		UPR-81	UPR-82	UPR-86
Aluminum	8220	--	--	11,800	0.7	--	--
Chromium	77	38	13	109	0.7	0.4	0.1
Iron	51	9	3	32,600	<0.1	<0.1	<0.1
Lead	72	14	4	156	0.5	0.1	<0.1
Mercury	--	0.03	0.01	0.3	--	0.1	<0.1
Nickel	44	10	3	38	1.1	0.3	0.1
Uranium (total)	15	3	1	22	0.7	0.1	<0.1

Note:
-- = inventory not reported and HQ not reported

As shown in Table 7-1, the HQ for nickel exceeded its respective Soil Benchmark (i.e., HQ values are greater than 1) at UPR-81 (i.e., indicating a potential for ecological risk), while the HQ values for all other nonradiological constituents at UPR-82 and UPR-86 had HQ values less than 1 (i.e., indicating negligible risk potential). It should be noted that the estimated soil concentration for nickel is higher than its Soil Benchmark, which is based on a Tier 2 PRG for vegetation protection. However, this exceedance is considered of little significance for current and future vegetation exposure because the UPR and surrounding areas within and around WMA C are paved and any vegetation is (currently) managed using herbicide applications. For soil invertebrates and wildlife, the estimated exposure concentration for nickel is less than the respective Tier 2 PRGs of 280 mg/kg and 247 mg/kg. Therefore, the HQs for nickel estimated for soil invertebrates and wildlife do not indicate a potential for risk for these receptors.

Table 7-2 summarizes the Tier 1 LOAEL-based SSLs and estimated source concentrations for radiological contaminants. The HQ and SOF results are also presented in Table 7-2.

Table 7-2. Summary of Source Term Concentrations, SSLs, HQs and SOF Values for Radiological Constituents

Radiological Contaminant	Tier 1-SSLs[a] (pCi/g)	Concentration (pCi/g)					HQ = (Concentration/ Tier 1 SSL) (Unitless)				
		UPR-81	UPR-82	UPR-83	Surface	216-C-8	UPR-81	UPR-82	UPR-83	Surface	216-C-8
Am-241	4840	2628.2	593.9	195.2	6.7E-02	--	0.5	0.1	<0.1	<0.1	--
C-14	32	518.7	269.4	88.6	1.6E-02	--	16	8	3	<0.1	--
Cm-243	NA	4E-03	0.05	0.02	1.7E-08	--	NC	NC	NC	NC	--
Cm-244	50800	0.1	0.9	0.3	3.4E-07	--	<0.1	<0.1	<0.1	<0.1	--
Cs-137	924	211,647	45,504,201	14,959,774	5.5	60.4	229	49247	16190	<0.1	<0.1
Eu-152	1740	1.1	40.7	13.4	1.7E-05	--	<0.1	<0.1	<0.1	<0.1	--
Eu-154	1610	52.6	2032.3	668.1	7.9E-04	--	<0.1	1.3	0.4	<0.1	--
Eu-155	33400	10.2	395.9	130.2	1.2E-04	--	<0.1	<0.1	<0.1	<0.1	--
I-129	NA	84.7	0.9	0.3	2.9E-03	--	NC	NC	NC	NC	NC
Ni-63	NA	328667	10464	3440.2	5.4E+00	--	NC	NC	NC	NC	NC
Np-237	7880	0.6	41.4	13.6	2.0E-05	7.5E-03	<0.1	<0.1	<0.1	<0.1	<0.1
Pu-238	5980	52.1	19.3	6.3	8.3E-04	6.0E-02	<0.1	<0.1	<0.1	<0.1	<0.1
Pu-239	6270	2445.6	455.5	149.8	5.3E-02	1.4E+00	0.4	<0.1	<0.1	<0.1	<0.1
Pu-240	NA	576.7	111.6	36.7	1.1E-02	3.6E-01	NC	NC	NC	NC	NC
Pu-241	NA	2939.1	700.3	230.2	2.2E-02	1.3E+00	NC	NC	NC	NC	NC
Sn-126	NA	1.0	204.9	67.4	2.8E-05	--	NC	NC	NC	NC	NC
Sr-90	91	177621	152725	50209	4.5E+00	5.0E+02	1950	1676	551	<0.1	5.5
U-233	NA	40.2	1.4E-04	4E-05	2.3E-10	5.6E-07	NC	NC	NC	NC	NC
U-234	6370	5.6	1.0	0.3	1.1E-04	4.0E-03	<0.1	<0.1	<0.1	<0.1	<0.1
U-235	4360	0.2	4E-02	1E-02	4.5E-06	1.7E-04	<0.1	<0.1	<0.1	<0.1	<0.1
U-236	NA	0.1	2E-02	8E-03	2.4E-06	1.0E-04	NC	NC	NC	NC	NC
U-238	5150	5.0	0.9	0.3	1.1E-04	3.9E-03	<0.1	<0.1	<0.1	<0.1	<0.1
		Sum of the Fraction					2196	50933	16745	0.1	5.6

Footnote
NA = Not available
NC = Not Calculated due to no availability of Tier 1 SSLs.
[a] Table 6-13 of CHPRC-00784, Revision 1
-- = inventory not reported and HQ not reported

As shown in Table 7-2, the SOFs for the three UPRs and the 216-C-8 French Drain are greater than 1 for C-14, Cs-137, Eu-154 (UPR-82 only), and Sr-90 (major dose-contributors). The SOF for surface contamination within 241-C Tank Farm is less than 1 indicating a negligible ecological risk potential.

7.2 SCIENTIFIC MANAGEMENT DECISION POINT (SMPD)

At the SMDP, the results of the ERA are considered in the context of other factors (e.g., spatial coverage, data, chemical specifics, receptors at risk, and confidence in PRGs) to support recommendations on the contaminants of potential ecological concern (COPECs) to be brought forward to the risk manager and considered for the further evaluation. This includes agreement on the assessment endpoints, representative receptors, and complete exposure pathways that correspond to those COPECs. To confidently achieve a SMDP outcome, a number of factors and supporting information will be considered in the conclusion of the risk assessment to assist risk management decisions. These outcomes will be considered within the context of other exposure pathways and receptors evaluated at the same site. Factors that will be considered in the SMDP include, but are not limited to, the following:

- Spatial characteristics of the waste site (area and depth of the waste site)
- Proximity and size of nearby waste sites and unaffected habitat
- Potential for aggregate risk to mobile receptors based on the proximity of nearby waste sites
- Adequacy of site characterization (number and location of samples collected at the site; sample density; characterization of lateral extent of contamination)
- Data quality (presence of analytical qualifiers, adequacy of detection limits)
- Evaluation of risk-based thresholds (i.e., level of confidence, basis, relation to other thresholds such as those for human health or groundwater protection)
- Frequency and magnitude of risk-based thresholds exceedances and the location(s) of those exceedances
- Chemical-specific properties of each COPEC (e.g., does it have the potential to biomagnify in the food web or is it persistent in the environment)
- Receptors and feeding guild(s) affected (e.g., plants, invertebrates, or omnivorous, herbivorous, insectivorous, or carnivorous wildlife)
- Home range of the receptors at risk relative to the area exceeding the PRG
- Ecological receptor behavior and potential for exposure
- Proportion of receptors affected, type of effect, and the likelihood of population- or community-level effects

As discussed in the technical support documents for ecological values in soil for wildlife (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-0784] and *Tier 2 Risk Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311, Revision 2]), the SSLs or PRGs for both nonradiological and radiological constituents are based on the assumption that the size of the waste site inhabited by a receptor is the same size as the area used by the animal and that the area used contains habitat of adequate quality (a questionable assumption for many industrial use sites). In other words, the SSLs and PRGs assume that a wildlife receptor spends 100 percent of its time at the waste site, regardless of habitat quality, and exposed to the contaminants at only that waste site. For mobile wildlife receptors, this is an overly conservative (and typically inaccurate) representation of their exposure potential. More accurate is to define the proportion of the contaminated area that would lie within an organism's home range[1]. This is represented by the fractional Area Use Factor (AUF), which is defined as the ratio of the area of contamination at a waste site to that of the area of an organism's home range. Because the AUF is assumed as equal to the area of contamination in the development of SSL and PRG values, these values will, unadjusted, considerably overstate ecological risks for mobile wildlife receptors. Therefore, the organism home range was identified for the most sensitive mobile wildlife receptor (badger) for radiological constituents and was used to calculated a fractional AUF. The AUF is equal to the home range area divided by the area of site contamination. This AUF was then used to modify the wildlife SSL or PRG to more accurately reflect wildlife mobility relative to the area of contamination for evaluating risk potential. The results of the evaluation are summarized below.

7.2.1 SMDP Evaluation for Radiological Constituents

The SSLs for all dose contributing radiological contaminants are derived based on the most sensitive wildlife receptor (a badger), and incorporates an underlying assumption that the AUF for any given site is 100 percent. The home range for the badger is considerable at 160 hectares. Considering the three UPRs and the 216-C-8 French Drain, the largest area of site contamination is relatively small (0.031 hectares at UPR-82). Accordingly, the fractional AUF for UPR-82 is 0.0002 (0.031/160). Practically, this means that a badger will utilize only a small fraction of the site, assuming that the habitat is suitable, for feeding and other activities that result in exposure to contaminants at UPR-82. The results of the updated HQs based on the refined (AUF-adjusted) SSLs are presented in Table 7-3.

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[1] Home range is defined as the area used by an animal for a variety of activities including territory defense, breeding, feeding, etc.

Table 7-3. Summary of Source Term Concentrations, SSLs, Updated HQs and SOF Values based on AUF for Radiological Constituents

Radiological Contaminants	Tier 1 SSLs[a] (pCi/g)	Concentration (pCi/g)				HQ = (Concentration/ (Tier 1 SSL/AUF)) (Unitless)			
		UPR-81	UPR-82	UPR-86	216-C-8	UPR-81	UPR-82	UPR-86	216-C-8
Am-241	4840	2,628.2	593.9	195.2	--	<0.1	<0.1	<0.1	--
C-14	32	518.7	269.4	88.6	--	<0.1	<0.1	<0.1	--
Cm-243	NA	0.0	0.1	0.0	--	NC	NC	NC	NC
Cm-244	805	0.1	0.9	0.3	--	<0.1	<0.1	<0.1	--
Cs-137	924	211,647	45,504,201	14,959,774	60.40	<0.1	10	3	<0.1
Eu-152	1740	1.1	40.7	13.4	--	<0.1	<0.1	<0.1	--
Eu-154	1610	52.6	2032.3	668.1	--	<0.1	<0.1	<0.1	--
Eu-155	33400	10.2	395.9	130.2	--	<0.1	<0.1	<0.1	--
I-129	NA	84.7	0.9	0.3	--	NC	NC	NC	NC
Ni-63	NA	328,667.4	10,464.2	3,440.2	--	NC	NC	NC	NC
Np-237	7880	0.6	41.4	13.6	0.01	<0.1	<0.1	<0.1	<0.1
Pu-238	5980	52.1	19.3	6.3	0.06	<0.1	<0.1	<0.1	<0.1
Pu-239	6270	2,445.6	455.5	149.8	1.45	<0.1	<0.1	<0.1	<0.1
Pu-240	NA	576.7	111.6	36.7	0.36	NC	NC	NC	NC
Pu-241	NA	2939.1	700.3	230.2	1.27	NC	NC	NC	NC
Sn-126	NA	0.97	204.9	67.4	--	NC	NC	NC	NC
Sr-90	91	177,620.8	152,724.5	50,209.1	502.03	0.4	0.3	0.1	<0.1
U-233	NA	40.2	1.4E-04	4E-05	5.6E-07	NC	NC	NC	NC
U-234	6370	5.6	1.0	0.3	4.0E-03	<0.1	<0.1	<0.1	<0.1
U-235	4360	0.2	4E-02	1E-02	1.7E-04	<0.1	<0.1	<0.1	<0.1
U-236	NA	0.1	2E-02	8E-03	1.0E-04	NC	NC	NC	NC
U-238	5150	5.0	0.9	0.3	3.9E-03	<0.1	<0.1	<0.1	<0.1
		Sum of the Fraction				0.4	10	3	<0.1

Footnote

NA = Not available; NC = Not Calculated due to no availability of Tier 1 SSLs

[a] Table 6-13 of CHPRC-00784, Revision

-- = inventory not reported and HQ not reported

Table 7-3 indicates that the SOFs for UPR-82 and UPR-86 are greater than 1. This suggests that based on AUF alone that there may be a risk to even mobile wildlife receptors. It is important to note, however, that the areas within WMA C and the surrounding areas have man-made physical features including buildings, parking lots, paved areas, and maintained landscaping (herbicide use), which significantly reduce potential attractiveness of the UPRs to mobile wildlife receptors such as a badger. Further, the site is not managed for ecological purposes and there have been no onsite improvements which would create suitable habitat attractive for wildlife receptors. Accordingly, there is little if any ecological habitat associated with the current and future land use for WMA C and these three UPRs. As a result, the high HQs identified in Table 7-3 are likely overestimates of current and future risk potential for the badger.

7.3 CONCLUSIONS

ERAs were performed by assuming potentially complete exposure pathways for ecological receptors to the contaminated soil associated with the three UPR, the surface contamination within the 241-C Tank farm, and the 216-C-8 French Drain locations. Based on an AUF of 1, unacceptable risk was identified at UPR-81 for one nonradiological contaminant, nickel. For radiological contaminants, unacceptable risk was identified at the three UPR locations and the 216-C-8 French Drain area. Based on the AUF-refined PRGs, unacceptable risk was identified at UPR-82 and UPR-86 for the radiological contaminants Cs-137.

The areas within WMA C and surrounding areas have physical features including buildings, parking lots, paved areas, and maintained landscaping that severely reduce potential exposure to soil. In addition, the Site has not been and is not currently managed for ecological purposes (buildings, pavement, use of herbicides to control vegetation). There have been no onsite improvements in the interim which could create a suitable habitat for ecological receptors. As a result, no ecological habitats are known to be associated with the current and future land use for WMA C. Since the soil-based exposure pathways and ecological habitats are largely absent ecological receptors are not expected to be present and their potential risk expected to be low.

Of note, several remedial alternatives such as isolation barriers and/or infiltration barriers are being considered in support of *RCRA Corrective Measure Study Report for Waste Management Area C*. Based on the design of the remedial alternatives, a 4-in. isolation barrier is being considered at each exposure area within WMA C. Due to the presence of elevated radiological contaminants, the remedial alternatives proposed is a 3-ft isolation barrier at each UPR. The presence of an isolation barrier will further serve to eliminate or greatly minimize the direct exposure for the ecological receptor to the contaminated soil. In summary, the analysis does not identify any ecological receptors at risk at these UPRs in WMA C.

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8.0 MODEL CONFIGUREATION MANAGEMENT

All inputs and outputs for this Tier 2 SLERA calculation are committed to the CH2M HILL Plateau Remediation Company's Environmental Risk Management Archive database to maintain and preserve configuration managed models. Inputs include the input files used in the Excel. Basis information (information collected to form the basis for SLERA input parameterization) is also stored in the Environmental Risk Management Archive for traceability purposes.

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9.0 REFERENCES

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ECF-HANFORD-11-0158, 2014, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site,* Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

ENVIRONMENTAL MODEL CALCULATION COVER PAGE

Section 1: Completed by Responsible Manager

RELEASE/ISSUE: 0

Project: Waste Management Area C(WMA C)

Date: 11/17/2016

Calculation Title & Description: Radiological Risk Assessments for Past Leaks and Surface Releases within Waste Management Area C

Section 2: Completed by Preparer

Calculation No.: RPP-CALC-61239 Revision No.: 0

Revision History

Revision No.	Description	Date	Affected Pages
0		11/17/2017	All

Section 3: Completed by Responsible Manager

Document Control

1. Is document intended to be controlled within SmartPlant? ☒ Yes ☐ No
2. Does document contain scientific and technical information intended for public use? ☒ Yes ☐ No
3. Does document contain controlled-use information? ☐ Yes ☒ No

Section 4: Training and Software Installation Approval (Completed Prior to Performing Calculation)

Modeler-Required Training Completed:

Name/Position	Signature	Date
WE Nichols/Principal Engineer — Training Coordinator (Name/Position)	[signature]	17 NOV 2016

Software Installation and Checkout Certified:

Name/Position	Signature	Date
WE Nichols / Principal Engineer — Integration Lead (Name/Position)	[signature]	17 NOV 2016

Section 5: Document Review & Approval

Name/Position	Signature	Date
Doug Evans & S. Lindberg/Sr. Risk Assessor — Preparer (Name/Position)	[signature] Doug Evans	11/17/2016
Mahmudur Rahman/Sr. Risk Assessor — Checker (Name/Position)	[signature] M. Rahman	11/17/2016
Sue Robinson/Sr. Risk Assessor — Senior Reviewer (Name/Position)	[signature]	11/28/2016
Andrea Hopkins/Env. Compliance/WRPS — Responsible Manager (Name/Position)	[signature]	11/28/2016

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Contents

Appendices

Tables

Terms

bgs	below ground surface
BRA	baseline risk assessment
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DSR	dose to source ratio
DQO	Data Quality Objectives
EA	Exposure Area
ELCR	Excess lifetime cancer risk
EMCF	Environmental model calculation file
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
FGR	federal guidance report
K_d	distribution coefficient factor
MTCA	Model Toxics Control Act
OSWER	Office of Solid Waste and Emergency Response
pCi	pico-Curies
PEF	Particulate Emission Factor
RCRA	*Resource Conservation and Recovery Act of 1976*
RESRAD	RESidual RADioactivity computer code
RSR	risk to source ratio
WAC	*Washington Administrative Code*
WMA	Waste Management Area

1 PURPOSE

This environmental model calculation file (EMCF) presents the results of human health risk assessments for the radionuclide soil contamination associated with Waste Management Area (WMA) C past leaks originating from six single-shell tanks (SSTs) (241-C-101, 241-C-104, 241-C-105, 241-C-108, 241-C-110, and 241-C-112). This EMCF also presents the results of human health risk assessments for the radionuclide soil contamination resulting from past discharges to the 216-C-8 French drain and the radiological surface contamination associated with non-specific contaminant migration due to releases and activities within WMA C.

The leaks originating from the WMA C SSTs are estimated to have occurred at depths of at least 20 feet (ft) below ground surface (bgs) (RPP-ENV-33418, *Hanford C-Farm Leak Inventory Assessments Report*). The soil contamination associated with these leaks was therefore evaluated for potential impacts to groundwater in the WMA C baseline risk assessment (BRA) report (RPP-RPT-58329, *Baseline Risk Assessment for Waste Management Area C*) but was not included in the BRA evaluation of potential human health risk via the direct contact pathway. Similarly, no human health risk assessment was performed in the BRA for the soil contamination associated with the 216-C-8 French drain and WMA C surface contamination. The purpose of this EMCF is to supplement the BRA and support the WMA C Corrective Measures Study (*RCRA Corrective Measures Study Report for Waste Management Area C)* by evaluating human health risks associated with the WMA C past tank leaks, 216-C-8 French drain, and WMA C surface contamination.

For the six WMA C past tank leaks, the baseline (assuming no protective cover) cancer risks and radiation dose associated with the exposure to radiological contaminants of potential concern (COPCs) in soil are estimated assuming a construction worker exposure scenario. In addition to the construction worker, risks are also estimated assuming a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) industrial worker exposure scenario with an additional exposure assumption of a 6.1-m (20-ft) soil cover, which represents the conceptual exposure model of the current conditions for the soil contamination associated with the past tank leaks.

For the soil contamination associated with past discharges to the 216-C-8 French drain and the WMA C surface contamination, baseline risks are estimated assuming a CERCLA industrial worker exposure scenario. Additionally, risks are estimated for the soil contamination associated with the 216-C-8 French drain assuming the same CERCLA industrial worker exposure scenario with an additional assumption of a 0.1-m (4-inch) concrete cover, which represents a conceptual exposure model of post-remediation conditions for the waste site.

2 BACKGROUND

The construction worker scenario for radionuclides in vadose zone soil represents an exposure scenario consistent with the anticipated future land use for the Inner Area of the Hanford Site Central Plateau. The Central Plateau Inner Area cleanup principles establish that the construction worker exposure scenario is exclusively applicable to radionuclides (no chemicals), which are located at depths greater than 4.6 m (15 ft) bgs; however, the conceptual site exposure model

takes no credit for the soil layer between the contamination and ground level (i.e., no cover). Therefore, the construction worker exposure scenario is not applicable for radionuclides or chemicals located at depths above 4.6 m (15 ft) bgs.

The CERCLA industrial worker exposure scenario for chemicals and radionuclides in vadose zone soil is one of six CERCLA scenarios selected to represent the range of receptors that could be exposed to COPCs in soil from WMA C and was evaluated as part of the WMA C BRA (RPP-RPT-58329). All exposure scenarios identified for evaluation at WMA C are fully described in RPP-RPT-47479, *Exposure Scenarios for the Waste Management Area C Performance Assessment*. It is noted that following issuance of the BRA, the assigned exposure parameters for all exposure scenarios were updated in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*. However, to be consistent with the BRA, the updated values documented in RPP-ENV-58813 are not used in this EMCF.

Additional details regarding the exposure parameters are presented in Section 4, Assumptions and Inputs.

3 METHODOLOGY

This section summarizes the risk assessment methodology for radionuclides. The methodology calculates an excess lifetime cancer risk (ELCR), which is the incremental increase in the probability of developing cancer during an individual's lifetime in addition to the background probability of developing cancer.

Only radiological contaminants are evaluated for contaminants located at depths greater than 4.6 m (15 ft) bgs at the Hanford Site. Therefore, only a radiological risk assessment was performed for contamination associated with the WMA C past tank leaks.

For surface contamination evaluations, except for nutrients, the only inventory information available for aluminum among all other nonmobile (based upon K_d) constituents. However, the estimated source concentration of aluminum is 0.24 mg/kg, which is well below its corresponding background concentration of 11,800 mg/kg (DOE/RL-92-24, Vol. 1, Revision 4, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*); therefore, non-radiological risk was not evaluated for surface contamination. For the 216-C-8 French drain, inventory information for most of the nonmobile source constituents are not available. When data is available, the estimated concentrations are less than 0.01 mg/kg. Accordingly, only a radiological risk assessment was performed for surface contamination (and for past tank leaks and French drain) as part of this EMCF.

3.1 RADIOLOGICAL RISK ASSESSMENT METHODOLOGY

This section summarizes the methodology used to calculate cumulative ELCRs for radiological contaminants associated with the WMA C past tank leaks, 216-C-8 French drain, and WMA C surface contamination. The same methodology is implemented for both the construction worker and the CERCLA industrial worker exposure scenarios, applying scenario-specific parameters as applicable. The methodology was implemented using the RESidual RADioactivity computer

code (RESRAD) Version 7.0 (ANL, 2014), a noted departure from the BRA, which used RESRAD Version 6.5 (ANL, 2009).

The following steps summarize and document the methodology used to calculate individual and cumulative risks (ELCR) for radiological contamination associated with the WMA C past tank leaks, for a construction worker exposure scenario.

1. Enter the construction worker exposure scenario-applicable user input parameters listed in Table 4-1 into the RESRAD model.
2. Enter a unit concentration of 1 pCi/g and COPC-specific distribution coefficient (K_d) (Table 4-3) for each of the 22 COPCs identified for the WMA C (see Section 4.2) for the source term.
3. Run RESRAD and review the results to identify the year(s) at which peak risk occurs for each COPC.
4. Rerun RESRAD with times for calculation corresponding to the years of peak risk, as identified in Step 2 (only necessary if years of peak risk are identified in addition to the RESRAD-default times for calculation).
5. Open the Health Risk Report and Summary Report and obtain the pathway-specific and cumulative risk to source ratios (RSR) and dose to source ratios (DSR) for each radiological COPC at each calculation time and copy the results into a Microsoft Excel® workbook.
6. Multiply the COPC-specific RSR and DSR by the corresponding past leak-specific source term concentration for each COPC (Table 4-6) to calculate the individual risk.
7. Sum the individual risks to calculate the cumulative ELCR and dose for each calculation time (years of peak risk, as identified in Step 2).
8. Compare the maximum results of the cumulative ELCR and dose with the acceptable risk and dose criteria to identify whether unacceptable risks and dose are present and if so, identify the primary risk contributors.
9. Repeat Step 6 through Step 8 for each WMA C past tank leak, as identified in Table 4-6.

For WMA C past tank leaks, repeat Step 1 through Step 9, substituting the CERCLA industrial worker scenario-applicable user input parameters listed in Table 4-1 in Step 1 to calculate individual and cumulative risks (ELCR only, omit dose calculations) for the CERCLA industrial worker exposure scenario with an additional assumption of a 6.1-m (20-ft) soil cover.

For the surface contamination and the 216-C-8 French drain, repeat Step 1 through Step 8 separately for each, substituting the applicable (surface area contamination-specific or 216-C-8 French drain-specific) user input parameters for baseline conditions listed in Table 4-2 in Step 1 and the applicable (surface area contamination or 216-C-8 French drain) source term concentrations listed in Table 4-6 in Step 6 to calculate individual and cumulative risks for the CERCLA industrial worker exposure scenario.

For the 216-C-8 French drain, repeat Step 1 through Step 8, substituting the 216-C-8 French drain-specific user input parameters listed in Table 4-2 for post-remediation conditions (i.e. 0.1-m [4-in. concrete cover]) in Step 1 and the 216-C-8 French drain-specific COPC source term concentrations listed in Table 4-6 for in Step 6 to calculate individual and cumulative risks for the CERCLA industrial worker exposure scenario with an additional assumption of a 0.1-m (4-in.) concrete cover.

4 ASSUMPTIONS AND INPUTS

This section provides key assumptions and inputs used in calculating cancer risk for the construction worker and the CERCLA industrial worker exposure scenarios. It also documents the process used to identify radiological COPCs and calculate the COPC-specific concentrations.

4.1 EXPOSURE SCENARIO INPUTS AND ASSUMPTIONS

The RESRAD inputs used for WMA C past tank leaks are presented in Table 4-1. The RESRAD inputs used for the WMA C surface area contaminations and the 216-C-8 French drain are presented in Table 4-2. The radionuclide-specific distribution coefficients (K_ds) are presented in Table 4-3. Other key assumptions are as follows:

- The direct contact and inhalation exposure pathways are considered potentially complete for both the construction worker and the industrial worker scenarios. The exposure routes involved with these scenarios are incidental soil ingestion, inhalation of dust, and external gamma exposure.
- The construction worker exposure scenario represents potential exposure from short-term work activities that include soil disturbance from a trench or excavation such as putting in an underground utility line or construction of a building. For the Hanford Site, the receptor is assumed to spend 8 hours per day outdoors where contact with contaminated soil can occur, for 30 days over a one-year timeframe. An incidental soil ingestion rate of 330 mg/day is assumed. The inhalation rate for the receptor is 20 m^3 per day. The receptor could potentially be exposed to deep vadose zone soil (greater than 15 ft bgs).
- The CERCLA industrial worker exposure scenario is a long-term receptor (25-year exposure duration) exposed as a full-time employee working on-site, spending 2 hours outdoors and 6 hours indoor during an 8-hour work day. The receptor is on the site for 250 days per year. An incidental soil ingestion rate of 50 mg/day is assumed. The inhalation rate for the receptor is 20 m^3 per day. The gamma shielding factor is assumed to be 0.4. The receptor could potentially be exposed to shallow vadose zone soil (0 to 15 ft bgs).
- For the WMA C past tank leaks, the area of the contaminated zone is assumed to be 292 m^2, which represents the largest estimated leak area of the six WMA C past tank releases (216-C-105) (RPP-ENV-33418). The area of the contaminated zone for the surface area contamination is assumed to be 55,700 m^2 (see Table 4-5). The area of the contaminated zone for the 216-C-8 French drain is assumed to be 535 m^2 (see Table 4-5).
- Under the 2007 Washington State Model Toxics Control Act (MTCA) (Revised Code of Washington 70.105D, “Hazardous Waste Cleanup — Model Toxics Control Act”) cleanup

regulations (Washington Administrative Code [WAC] 173-340-740, "Unrestricted Land Use Soil Cleanup Standards"), the point of compliance for soil cleanup levels based on the direct contact pathway is defined as the zone extending from the ground surface to 15 ft bgs. Therefore, the thickness of the contaminated zone for the BRA and this EMCF is assumed to be 15 ft or 4.6 m.

- Four (4) inches of a concrete isolation barrier is assumed as cover thickness during the calculation of radiological risk to a CERCLA industrial worker for the 216-C-8 French drain under post-remediation conditions.
- Twenty feet of soil cover is assumed as cover thickness during the calculation of radiological risk to a CERCLA industrial worker for the WMA C past tank leaks under a conceptual exposure model for current conditions.

4.2 CONTAMINANTS OF POTENTIAL CONCERN AND SOURCE TERM CONCENTRATIONS

The COPCs and associated source term concentrations for the WMA C past tank leaks, the surface area contamination, and the 216-C-8 French drain are presented in the following sections.

4.2.1 Identification of Radiological COPCs

Four exclusion criteria were used to identify soil COPCs for the risk assessments presented in this EMCF. Radionuclides that met one or more of the criteria were excluded. Radionuclides that did not meet any of the exclusion criteria were carried forward into the risk assessment. COPCs were identified by applying the exclusion criteria to the list of 46 standard Best Basis Inventory radionuclides presented in the RPP-ENV-33418. The exclusion criteria are described as follows. Application of the exclusion criteria resulted in the identification of 22 COPCs as shown in Table 4-4.

1. Exclusion of Radionuclides Based on Data Quality Objectives

Table 4-11 of RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study* presented primary radionuclide constituents for WMA C. Therefore, all other radionuclides included in RPP-ENV-33418 but not identified as a primary constituent in Table 4-11 of RPP-RPT-38152 are excluded from further consideration.

2. Exclusion of Radionuclides Based on Mobility of Radionuclides

Based on the results of the past leak analysis (RPP-ENV-59197, *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington*), mobile radiological contaminants are not expected to be present within the contaminated zone. Therefore, only non-mobile radiological contaminants are considered during the risk assessments for the WMA C past tank leaks, 216-C-8 French drain, and WMA C surface contamination.

Table 6-11 of RPP-ENV-58782, *Performance Assessment for Waste Management Area C, Hanford Site, Washington* presented the K_d values for various radionuclides for WMA C. These K_d values are documented in Table 4-3 of this EMCF. According to that report, the maximum K_d value that produces an impact to groundwater is approximately 0.15 mL/g (without any gravel correction) within the 1,000-year compliance time frame, and approximately 1.5 mL/g (without any gravel correction) within the 10,000-year compliance time frame. Therefore, radionuclides with K_d value <0.15 mL/g are excluded due to high mobility in the vadose zone.

3. Exclusion of Radionuclides Based on Half-Life

Radionuclides with half-lives of less than 3 years are eliminated from further consideration as soil COPCs. They are either insignificant dose and risk contributors due to decay or their contributions are already accounted for as daughter products of a parent radionuclide.

4. Exclusion of Radionuclides Based on Background

Radionuclides considered to be naturally occurring and not directly related to Hanford Site operations or processes are eliminated from further consideration as soil COPCs.

4.2.2 Radiological COPC Source Term Concentrations

COPC source term concentrations were developed based on radionuclide release inventories for each tank leak and surface release (except the 216-C-8 French drain) presented in RPP-ENV-33418. In RPP-ENV-33418, release inventories are estimated by multiplying leak volume estimates by waste type compositions for waste types assumed to have been released with each leak/release event. Waste type compositions were obtained from the Hanford Defined Waste (HDW) model (RPP-19822, *Hanford Defined Waste Model*). Inventories for the 216-C-8 French drain were obtained from the Soil Inventory Model (SIM) (RPP-26744, *Hanford Soil Inventory Model*). For this EMCF, inventory values were decayed from 1/1/2001 (the decay date for HDW Rev. 5 values) to 1/1/2017 to represent existing radionuclide inventories.

Leak-affected soil volume estimates were developed using the Cs-137 distributions and release volume estimates in RPP-ENV-33418. The Cs-137 distributions are based largely on drywell logging data. Where logging data were not available for C-110 and the 216-C-108 French drain the distributions were assumed to be similar to those for tanks C-104 and C-112 respectively, where dry well data was available, and ratios used to estimate the release volumes for the tanks. Radionuclide soil concentrations were calculated using the following equation and assuming a soil density of 2.13 kg/L, consistent with the effective bulk density value assumed for backfill (gravelly) in the WMA C Performance Assessment (Table 3-5 of RPP-RPT-58949, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA C Performance Assessment and RCRA Closure Analysis*).

$$Soil\ Concentration\left(\frac{Ci}{kg}\right) = \frac{Release\ Inventory\ (Ci)}{Leak\ affected\ Soil\ Volume\ (L)} \times \frac{1}{Soil\ Bulk\ Density\left(\frac{kg}{L}\right)}$$

The radionuclide COPC concentrations developed for the six tank leaks, 216-C-8 French drain, and WMA C surface contamination are provided in Table 4-5. The exposure point

concentrations (EPCs) used in the risk and dose calculations are provided in Table 4-6. The concentrations in Table 4-6 were obtained by converting the concentration units in Table 4-5 from Ci/kg to pCi/g, as follows.

$$Soil\ Concentration\left(\frac{pCi}{g}\right) = Soil\ Concentration\left(\frac{Ci}{kg}\right) \times 10^{-3}\frac{kg}{g} \times 10^{12}\frac{pCi}{Ci}$$

4.3 TOXICITY ASSESSMENT

The toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at WMA C and the likelihood of adverse health effects to potentially exposed populations. The toxicity assessment for radiological COPCs is summarized below.

RESRAD version 6.5, used during the BRA, utilizes Federal Guidance Report (FGR) No. 13 and includes the risk coefficient values for all radionuclides (EPA 402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*). Default DCFPAK 3.02 Morbidity risk factors and DCFPAK 3.02 internal (adult) and external dose libraries within RESRAD version 7.0 were utilized during this risk assessment. The risk coefficient slope factors are presented in units of pCi^{-1} (internal pathways) or (risk/year)/(pCi/g) (external pathways); the dose conversion factors are in units of mrem/pCi (internal pathways) or (mrem/yr)/(pCi/g) (external pathways).

4.4 RISK CHARACTERIZATION

In Title 40, *Code of Federal Regulations*, Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan," the U.S. Environmental Protection Agency (EPA) considers remedial action at a site when cumulative ELCR to any current or future population exceeds a risk range of 10^{-4} to 10^{-6} (i.e., one case of cancer in ten thousand to one case in one million). Excess lifetime cancer risks below 10^{-6} are considered acceptable whereas ELCRs above 10^{-4} are considered unacceptable. Risks between 10^{-4} to 10^{-6} are generally referred to as the "acceptable risk range." Therefore, for radiological COPCs, the ELCRs were compared to the EPA acceptable target risk range of 10^{-4} to 10^{-6}. When the total cumulative ELCR exceeds 10^{-4}, those individual COPCs with a risk greater than 10^{-6} (those analytes that contribute greater than 1% of total cumulative ELCR) are identified as major risk contributors for each release. In addition, cumulative dose values calculated for the construction worker are compared to the 500 mrem/yr dose limit specified under DOE M 435.1-1, *Radioactive Waste Management Manual*.

5 SOFTWARE APPLICATIONS

RESRAD Version 7.0 was used for determining radionuclide specific RSR/DSR values for the construction worker and industrial worker scenarios. All supporting calculations were performed on electronic spreadsheets using Microsoft Excel®. Electronic versions of all spreadsheets are

® Microsoft Excel is a registered product of the Microsoft Corporation.

provided with calculations included to facilitate comparison with hand calculations and checking of logical functions. This approach meets the requirements for "Single Use Software" as described in PRC-PRO-EP-40205, *CHPRC Environmental Calculation Preparation and Issue*. These spreadsheets are listed below in Section 6.

5.1 APPROVED SOFTWARE

RESRAD Version 7.0 is approved for use at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309, *Controlled Software Management*. The installed RESRAD software was tested in accordance with the procedure per CHPRC-00209, *RESRAD Software Management Plan*. RESRAD was registered on the Hanford Information System Inventory (HISI) and identified as approved for use.

5.1.1 Description

The following represent the description of RESRAD software package used in the calculation:

- RESRAD for Windows
- Version 7.0, Created February 24, 2014
- HISI Identification Number: 2102
- Workstation type and property number: Intera-0740, Intera-00474, and Intera-00295 (subcontractor supplied unique property IDs)

5.1.2 Software Installation and Checkout

The software installation and checkout form for RESRAD are provided in Appendix C to this Environmental Calculation.

5.1.3 Statement of Valid Software Application

The following presents the statement that RESRAD is a valid software application.

- RESRAD was developed for the U.S. Department of Energy (DOE) to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material. RESRAD has been used for this purpose in support of previous decision documents developed at the Hanford Site.

- RESRAD as it has been used in this Environmental Calculation has been implemented within the range of its limitations. The parameters used in the modeling (shown in Tables 4-1, 4-2, and 4-3) are included in the modeling input files accompanying this Environmental Calculation, and also in the modeling output files where they are shown alongside the default parameters provided with the model. The modeling input and output files for RESRAD are listed in Section 6.

6 CALCULATION

The following section of the report presents the information about the input and output files associated with the radiological and non-radiological risk assessment calculation. The risk assessment calculations were verified independently by utilizing the methodology, assumptions and inputs described in Sections 3 and 4.

6.1 ORIGINAL RADIOLOGICAL RISK ASSESSMENT CALCULATION

The ELCR results were calculated with RESRAD and Microsoft Excel® using the methodology described in Section 3 and the inputs presented in Section 4. RESRAD input files are listed below.

- File for Identifying Year of Peak Risk for Past Leaks without Cover Under Construction Worker Scenario– CW_PL_WMAC_PKYR.RAD
- File for Identifying Risk per Unit Concentration at Year of Peak Risk for Past Leaks without Cover Under Construction Worker Scenario– CW_PL_WMAC_RSR.RAD
- File for Identifying Year of Peak Risk and Risk per Unit Concentration at Year of Peak Risk for Past Leaks without Cover Under Industrial Worker Scenario– IW_PL_WMAC_PKYR.RAD
- File for Identifying Year of Peak Risk for Surface Contamination without Cover– INDWORKER_SURFACECONT_WMAC.RAD
- File for Identifying Risk per Unit Concentration at Year of Peak Risk for Surface Contamination without Cover– INDWORKER_SURFACECONT_WMAC_PKYEARONLY.RAD
- File for Identifying Year at Peak Risk for 216-C-8 French Drain Contamination without Cover– INDWORKER_216-C-8_WMAC.RAD
- File for Identifying Risk per Unit Concentration at Year of Peak Risk for Surface Contamination without Cover– INDWORKER_216-C-8_WMAC_PKYEARS.RAD
- File for Identifying Year at Peak Risk for 216-C-8 French Drain Contamination with Cover– INDWORKER_216-C-8_WITHCOVER.RAD
- File for Identifying Peak Risk per Unit Concentration at Year of Peak Risk for Surface Contamination with 4 Inches Cover– INDWORKER_216-C-8_WITHCOVERPEAKYEARS.RAD

Appendix A contains the detailed ELCR and maximum dose calculations associated with past tank leaks under the construction worker scenario. Appendix B contains the detailed ELCR calculations associated with surface contamination and the 216-C-8 French drain under the industrial worker scenario. Results of the calculations are summarized in Section 7.

All RESRAD input and output files (*.RAD, *.SUM, and *.INT) and Excel calculations are archived under this EMCF number (RPP-CALC-61239) in the CH2M HILL Plateau Remediation Company's Environmental Risk Management Archive database to maintain and preserve configuration managed models.

6.2 QC REVIEW OF ORIGINAL RISK ASSESSMENT CALCULATION

A QC review was performed independently to verify the results of the original radiological risk assessment.

6.2.1 QC Review of Original Radiological Risk Assessment Calculation

Two types of QC reviews were performed and are described below.

6.2.1.1 Verification of RESRAD Input Values

All RESRAD input values that were entered into the RESRAD input files were compared to the values presented in Tables 4-1, 4-2, and 4-3 to verify that the RESRAD file and input parameters were consistent. When inconsistencies were identified, the reviewer documented the findings and provided them to the EMCF originator. Inconsistencies were corrected by the originator and followed up with a second review. The following parameters were checked:

- Set Pathways - verify all of the active pathways are turned on. For the Construction/Industrial Worker, the active pathways are external gamma, inhalation (without radon), and soil ingestion.
- Contaminated zone
- Cover and contaminated zone hydrological data
- Occupancy, inhalation, and external gamma data
- Ingestion (non-dietary)
- Soil radionuclide concentrations based on a unit concentration of 1 pCi/g, followed by verification of EPCs for each source term
- Calculation times - confirm that all of the relevant years are in the table, including the year of maximum risk if it is not at year 0 or 1,000.

6.2.1.2 Verification of Risk Calculations

Verification of radiological risk calculations was performed independently by using the methodologies presented in Section 3.0. The results of the radiological risk calculations were compared to the original risk calculations to verify accurate transposition of data from the RESRAD health risk report file into the Microsoft Excel® worksheet and to verify the formulas used for each radionuclide-specific risk result for all pathways were not corrupted and correct formulas were used. Below is a step-by-step description of the review process:

- Verify calculation times of year 0, as the maximum risks occurred at year 0.
- Obtain a copy of the RSR/DSR data generated by originator (this will be in Microsoft Excel® format).

- Obtain the RSR/DSR data that was generated by the QC reviewer (note this is found in the Health Risk report).
- Copy and paste the RSR/DSR data from the Health Risk Report generated by the QC reviewer into the same Microsoft Excel® workbook with the RSR data generated by the originator. Perform this step for year 0.
- Insert a column and enter the EPCs for each radiological COPC for each past tank leak, the surface contamination, and the 216-C-8 French drain (included in Table 4-6).
- Insert another column to calculate the total risk for each radiological COPC by entering the formula provided below:

$$\text{Risk} = \text{EPC (pCi/g)} \times \text{RSR (Risk/(pCi/g))}$$

- Compare the originator results to the QC review results and verify the two sets of results are the same.

The results of the first review step did not identify any transposition errors. The results of the second review step did not identify errors associated with formulas used to calculate risk or transcription errors.

7 RESULTS/CONCLUSIONS

The construction worker scenario was considered for the baseline radiological risk assessments of contaminated soils associated with WMA C past leaks originating from six single-shell tanks (241-C-101, 241-C-104, 241-C-105, 241-C-108, 241-C-110, and 241-C-112). The CERCLA industrial worker exposure scenario with the additional assumption of a 20-ft soil cover was considered for a radiological risk assessment for the WMA C past leaks to assess a conceptual exposure model of current conditions.

The CERCLA industrial worker exposure scenario was considered for the baseline radiological risk assessments of contaminated soils associated with the WMA C surface area contamination and the past discharges to the 216-C-8 French drain. The CERLA industrial worker exposure scenario with the additional assumption of a 0.1-m concrete cover was considered for a radiological risk assessment for the 216-C-8 French drain to assess probable post-remediation conditions as well. The following sections summarize the results of the radiological risk assessments.

7.1 RADIOLOGICAL RISK AND DOSE ASSESSMENT FOR PAST TANK LEAKS

The RESRAD code was used to calculate the construction worker ELCR and dose for radionuclide COPCs over a period of 1,000 years. Calculation detail is provided in Appendix A. The peak cancer risk and dose occurs at year 0 for all COPCs except plutonium-241, which peaks at year 54, and uranium-233, which peaks at year 1,000, as a result of contributions from ingrowth daughter products.

Results of the construction worker radiological risk assessment for past tank leaks at WMA C under baseline conditions (no cover) are summarized in Table 7-1. The maximum cumulative ELCR over 1,000 years for each tank leak is compared to the EPA acceptable target risk range of 10^{-4} to 10^{-6}. The results of the assessments showed that at the year of maximum ELCR (year 0), the total cumulative ELCR for all six past tank leaks are greater than EPA's acceptable target risk range of 10^{-4} to 10^{-6} assuming baseline condition (no soil cover).

Results of the construction worker radiological dose assessment are summarized in Table 7-2. The maximum cumulative dose over 1,000 years for each tank leak is compared to a radiation dose limit of 500 mrem/yr, consistent with DOE M 435.1-1, *Radioactive Waste Management Manual*. The results of the assessments showed that the maximum doses for all six past tank leaks are greater than 500 mrem/yr assuming baseline condition (no soil cover).

An additional radiological risk assessment was performed, assuming a CERCLA industrial worker exposure scenario with an additional assumption of a 6.1-m (20-ft) soil cover, which represents the conceptual exposure model of the current conditions for the soil contamination associated with the past tank leaks. Assessment results indicate that, over the 1,000-yr assessment period, the presence of a 6.1-m (20-ft) soil cover eliminates all risk contributions for the external gamma, inhalation, and soil ingestion pathways. Therefore, there will not be any risk associated with the soil contamination due to past tank leaks for the industrial worker scenario.

7.2 RADIOLOGICAL RISK ASSESSMENTS FOR SURFACE AREA CONTAMINATION AND 216-C-8 FRENCH DRAIN

The RESRAD code was used to calculate the industrial worker ELCR for both surface contamination and the 216-C-8 French drain over a period of 1,000 years. Calculation detail is provided in Appendix B. For both areas, the peak cancer risk occurs at year 0 for all COPCs except plutonium-241, which peaks at year 54, and uranium-233 and uranium-234, which peak at year 1,000, as a result of contributions from ingrowth daughter products.

Results of the industrial worker radiological risk assessment for both surface contamination and the 216-C-8 French drain at WMA C under baseline conditions (no cover) are summarized in Table 7-3. The maximum cumulative ELCR over 1,000 years for each area is compared to the EPA acceptable target risk range of 10^{-4} to 10^{-6}. The results of the assessments for surface contamination showed that at the year of maximum ELCR (year 0), the total cumulative ELCR is within EPA's acceptable target risk range of 10^{-4} to 10^{-6} under baseline condition (no soil cover). However, assessment results showed that the total cumulative ELCR for the 216-C-8 French drain is greater than EPA's acceptable target risk range of 10^{-4} to 10^{-6} assuming baseline condition (no soil cover). The results further showed that the total cumulative ELCR for the 216-C-8 French drain is within EPA's acceptable target risk range of 10^{-4} to 10^{-6} assuming post-remediation conditions (Table 7-3).

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Tables

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
Dose and Risk Libraries	Internal (ingestion and inhalation) dose coefficients	mrem/pCi	DCFPAK3.02 (Adult)	DCFPAK3.02 (Adult)	Updated internal dose coefficients based on ICRP Publication 107	ICRP, 2008
	External dose coefficients	mrem/yr per pCi/g	DCFPAK3.02	DCFPAK3.02	Updated external dose coefficients based on ICRP Publication 107	ICRP, 2008
	Risk factors	Risk/pCi, Risk/yr per pCi/g	DCFPAK3.02 Morbidity	DCFPAK3.02 Morbidity	Updated risk coefficients based on ICRP Publication 107	ICRP, 2008
Graphic Parameters	Number of points	NA	32	32	RESRAD default	--
Exposure Pathways	External gamma: Inhalation: Plant ingestion: Meat ingestion: Milk ingestion: Aquatic foods: Drinking water: Soil ingestion: Radon:	NA	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Construction Worker and Industrial Worker Scenarios	--
R011 – Contaminated Zone (CZ)	Area of CZ	m^2	292	292	Largest estimated leak-affected area of 6 C Farm past tank releases (C-105)	RPP-ENV-33418
	Thickness of CZ	m	4.6	4.6	Direct contact exposure applies to the upper 4.6 m (15 ft)	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Length Parallel to Aquifer Flow	m	NA	NA	Not applicable[a]	--
	Does Initial Contamination Penetrate Water Table?	NA	No	No	Not applicable[a]	--
R012 –Principal Radionuclides Concentrations	All radionuclide contaminants of concern	pCi/g	1	1	Unit concentrations are input to obtain radionuclide-specific risk-to-source ratios (risk per pCi/g) at time of peak. For Construction Worker scenario, risk-to-dose ratios (mrem/yr per pCi/g) are also obtained.	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
R013 - Cover and CZ Hydrological Data	Cover Depth	m	0	6.1	Construction Worker scenario: conservatively assumes no cover is present and direct exposure to contamination may occur Industrial Worker scenario: uses minimum estimated release depth of 6 C Farm past tank releases (20 ft ÷ 3.281 ft/m = 6.1 m)	RPP-ENV-33418
	Density of Cover Material	g/cm^3	NA	2.13	--	PNNL-18564, Table 6.2, value for C Tank Farm Bf – backfill
	Cover Erosion Rate	m/yr	NA	0.001	RESRAD default	--
	Density of CZ	g/cm^3	2.13	2.13	--	PNNL-18564, Table 6.2, value for C Tank Farm Bf – backfill
	CZ Erosion Rate	m/yr	0.001	0.001	RESRAD default	--
	CZ Total Porosity	Unitless	0.258	0.258	--	PNNL-18564, Table 6.3, site-wide value for Hg – Hanford formation sandy gravel

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	CZ Field Capacity	Unitless	0.061	0.061	--	PNNL-18564, Table 6.5, best-estimate value for Hg – Hanford formation sandy gravel
	CZ Hydraulic Conductivity	m/yr	176.6	176.6	5.6E-04 cm/s x 86,400 s/day x 365 day/yr x 0.01 m/cm = 176.6 m/yr	PNNL-18564, Table 6.7, value for C Tank Farm Bf – backfill
	CZ b Parameter	Unitless	2.96	2.96	--	PNNL-18564, Table 6.8, value for Hg – Hanford formation sandy gravel)
	Humidity in Air	g/cm^3	8	8	RESRAD default	--
	Evapotranspiration Coefficient	Unitless	0.91	0.91	EPA, Region X guidance	Letter from EPA
	Wind Speed	m/s	3.4	3.4	Hanford Site average	PNNL-15160, Table 5.1
	Precipitation	m/yr	0.177	0.177	Based on 6.98 in. (0.177 m) normal annual rainfall	PNNL-15160, Table 4.1
	Irrigation Rate	m/yr	0	0	No irrigation assumed for the Inner Area of the Central Plateau	--
	Irrigation Mode	NA	Overhead	Overhead	RESRAD default	--
	Runoff Coefficient	Unitless	0.2	0.2	RESRAD default	--
	Watershed Area for Nearby Stream or Pond	m^2	NA	NA	Not applicable[a]	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Accuracy for Water/Soil Computations	Unitless	NA	NA	Not applicable[a]	--
R014 – Saturated Zone (SZ) Hydrological Data	Density of SZ	g/cm^3	NA	NA	Not applicable[a]	--
	SZ Total Porosity	Unitless	NA	NA	Not applicable[a]	--
	SZ Effective Porosity	Unitless	NA	NA	Not applicable[a]	--
	SZ Field Capacity	Unitless	NA	NA	Not applicable[a]	--
	SZ Hydraulic Conductivity	m/yr	NA	NA	Not applicable[a]	--
	SZ Hydraulic Gradient	Unitless	NA	NA	Not applicable[a]	--
	SZ b Parameter	Unitless	NA	NA	Not applicable[a]	--
	Water Table Drop Rate	m/yr	NA	NA	Not applicable[a]	--
	Well Pump Intake Depth	m below water table	NA	NA	Not applicable[a]	--
	Nondispersion (ND) or Mass-Balance (MB)	NA	NA	NA	Not applicable[a]	--
	Well Pumping Rate	m^3/yr	NA	NA	Not applicable[a]	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
R015 - Uncontaminated and Unsaturated Strata Hydrological Data	Number of Unsaturated Strata	NA	NA	NA	Not applicable[a]	--
	Thickness	m	NA	NA	Not applicable[a]	--
	Soil Density	g/cm^3	NA	NA	Not applicable[a]	--
	Total Porosity	Unitless	NA	NA	Not applicable[a]	--
	Effective Porosity	Unitless	NA	NA	Not applicable[a]	--
	Field Capacity	Unitless	NA	NA	Not applicable[a]	--
	Soil-specific b Parameter	Unitless	NA	NA	Not applicable[a]	--
	Hydraulic Conductivity	m/yr	NA	NA	Not applicable[a]	--
R016 - Distribution Coefficients (K_d) and Leach Rates	CZ K_d	cm^3/g	Contaminant-specific (see Table 4-3)	Contaminant-specific (see Table 4-3)	K_d values used are consistent with those used for the WMA C Performance Assessment.	RPP-ENV-58782, Table 6-11 (< 2 mm material)
	Time Since Material Placement	yr	0	0	RESRAD default	--
	Leach Rate	yr^{-1}	NA	NA	Not applicable (K_ds are used for all leaching calculations)	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Solubility Limit	mol/L	NA	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Radiation Dose Limit	mrem/yr	500	NA	DOE recommended dose limit for workers	DOE M 435.1-1
R017 - Inhalation and External Gamma	Inhalation Rate	m^3/yr	20,000	7,300	Construction Worker scenario: 20 m^3/8 hr x 24 hr/day x 365 day/yr = 21,900 m^3/yr (value truncated at RESRAD upper bound input of 20,000 m^3/yr) Industrial Worker scenario: 20 m^3/day x 365 day/yr = 7,300 m^3/yr	OSWER Directive 9285.6-03, Section 3.3
	Mass Loading for Inhalation	g/m^3	7.81E-04	1.37E-08	Construction Worker scenario: derived from subchronic particulate emission factor (PEF_{sc}) using 1/ PEF_{sc} x 1000 g/kg, where PEF_{sc} = 1.28E+06 m^3/kg Industrial Worker scenario: derived from particulate emission factor (PEF) using 1/PEF x 1000 g/kg, where PEF = 7.30E+10 m^3/kg	Construction Worker scenario: ECF-HANFORD-16-0132 Industrial Worker scenario: ECF-HANFORD-11-0033

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Exposure duration	Yr	1	25	Site-specific	Construction Worker scenario: OSWER 9355.4-24, Exhibit 5-1 Industrial Worker scenario: OSWER 9285.6-03
	Indoor Dust Filtration Factor	Unitless	0	0.4	Construction Worker scenario: assumes no time spent indoors Industrial Worker scenario: RESRAD default	--
	External Gamma Shielding Factor	Unitless	0	0.4	Construction Worker scenario: assumes no time spent indoors Industrial Worker scenario: 60 % shielding	EPA/540-R-00-007, Equation 4
	Indoor Time Fraction	Unitless	0	0.17	Construction Worker scenario: assumes no time spent onsite indoors Industrial Worker scenario: (6 hr/d x 250 d/yr) / 8,760 hr/yr = 0.17	OSWER 9355.4-24

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Outdoor Time Fraction	Unitless	0.0274	0.057	Construction Worker scenario: (8 hr/day x 30 days/yr) / 8,760 hr/yr = 0.0274 Industrial Worker scenario: (2 hr/day x 250 days/yr) / 8,760 hr/yr = 0.057	OSWER 9355.4-24
	Shape Factor	NA	Circular	Circular	RESRAD default	--
R018 - Ingestion Pathway Data, Dietary Parameters	Fruits, Vegetables, and Grain Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Leafy Vegetable Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Milk Consumption	L/yr	NA	NA	Incomplete exposure pathway	--
	Meat and Poultry Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Fish Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Other Seafood Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Soil Ingestion	g/yr	120.45	18.25	Construction Worker scenario: (330 mg/day x 365 days/yr) / 1,000 mg/g = 120.45 g/yr Industrial Worker scenario: (50 mg/day x 365 days/yr) / 1,000 mg/g = 18.25 g/yr	Construction Worker scenario: OSWER Publication 9355.4-24, Exhibit 5-1 Industrial Worker scenario: OSWER Directive 9285.6-03
	Drinking Water Intake	L/yr	NA	NA	Incomplete exposure pathway	--
	Drinking Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Household Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Livestock Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Irrigation Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Aquatic Food Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
	Plant Food Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Meat Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Milk Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
R019 - Ingestion Pathway Data, Nondietary	Livestock Fodder Intake for Meat	kg/d	NA	NA	Incomplete exposure pathway	--
	Livestock Fodder Intake for Milk	kg/d	NA	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Meat	L/d	NA	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Milk	L/d	NA	NA	Incomplete exposure pathway	--
	Livestock Intake of Soil	kg/d	NA	NA	Incomplete exposure pathway	--
	Mass Loading for Foliar Deposition	g/m^3	NA	NA	Incomplete exposure pathway	--
	Depth of Soil Mixing Layer	m	0.15	0.15	RESRAD default	--
	Depth of Roots	m	NA	NA	Incomplete exposure pathway	--

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference
R020 – Groundwater Usage	Groundwater Fractional Usage - Drinking Water	Unitless	NA	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Household Usage	Unitless	NA	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Livestock Water	Unitless	NA	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage – Irrigation	Unitless	NA	NA	Incomplete exposure pathway	--
R021 – Radon	Radon parameters are not used; Radon is not a Hanford Site contaminant of potential concern.					--

Notes:

a. Not applicable – the following parameters are not used in the model when drinking water and food ingestion pathways are suppressed: contaminated zone length parallel to aquifer flow; watershed area; accuracy for water/soil computations; saturated zone hydrological data (R014); and uncontaminated, unsaturated strata hydrological data (R015). These parameters are used in the model to estimate migration through soil and transport to groundwater and are not used for the construction worker or industrial worker scenarios.

CZ = contaminated zone.

DOE = U.S. Department of Energy.

ICRP = International Commission on Radiological Protection.

NA = not applicable.

K_d = soil-water distribution coefficient.

PEF = particulate emission factor.

PEF_{sc} = particulate emission factor – subchronic.

RESRAD = RESidual RADioactivity code (ANL, 2014).

SZ = saturated zone.

Table 4-1. RESRAD Input Parameters Used to Calculate Risk and Dose for Six WMA C Past Tank Leaks

RESRAD Category	Parameter	Units	User Input Construction Worker Scenario	User Input Industrial Worker Scenario	Rationale	Reference

ANL, 2014, RESRAD for Windows, Version 7.0.

DOE M 435.1-1, *Radioactive Waste Management Manual*.

EPA/540-R-00-007, *Soil Screening Guidance for Radionuclides: User's Guide*.

HANFORD-16-0132, *Calculation of Soil Radiological Preliminary Remediation Goals for the Construction Worker Scenario*.

HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

ICRP, 2008, *Nuclear Decay Data for Dosimetric Calculations*, ICRP Publication 107, Ann. ICRP 38 (3).

OSWER Directive 9285.6-03, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* Supplemental Guidance *"Standard Default Exposure Factors" Interim Final*.

OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*.

PNNL-15160, *Hanford Site Climatological Summary 2004 With Historical Data*.

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report*.

RPP-ENV-33418, *Hanford C-Farm Leak Inventory Assessments Report.*

RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington.*

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
Dose and Risk Libraries	Internal (ingestion and inhalation) dose coefficients	mrem/pCi	DCFPAK3.02 (Adult)	DCFPAK3.02 (Adult)	Updated internal dose coefficients based on ICRP Publication 107	ICRP, 2008
	External dose coefficients	mrem/yr per pCi/g	DCFPAK3.02	DCFPAK3.02	Updated external dose coefficients based on ICRP Publication 107	ICRP, 2008
	Risk factors	Risk/pCi, Risk/yr per pCi/g	DCFPAK3.02 Morbidity	DCFPAK3.02 Morbidity	Updated risk coefficients based on ICRP Publication 107	ICRP, 2008
Graphic Parameters	Number of points	NA	32	32	RESRAD default	--
Exposure Pathways	External gamma: Inhalation: Plant ingestion: Meat ingestion: Milk ingestion: Aquatic foods: Drinking water: Soil ingestion: Radon:	NA	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Industrial Worker Scenarios	--
R011 – Contaminated Zone (CZ)	Area of CZ	m^2	55,700	535	See Table 4-5	See Table 4-5
	Thickness of CZ	m	4.6	4.6	Direct contact exposure applies to the upper 4.6 m (15 ft)	--
	Length Parallel to Aquifer Flow	m	NA	NA	Not applicable[a]	--
	Does Initial Contamination Penetrate Water Table?	NA	No	No	Not applicable[a]	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
R012 –Principal Radionuclides Concentrations	All radionuclide contaminants of concern	pCi/g	1	1	Unit concentrations are input to obtain radionuclide-specific risk-to-source ratios (risk per pCi/g) at time of peak.	--
R013 - Cover and CZ Hydrological Data	Cover Depth	m	0	0 (baseline) 0.1 (post-remediation)	Surface Area Contamination: no cover assumed 216-C-8: no cover assumed for baseline conditions; 4-in. concrete cover assumed for post-remediation conditions	--
	Density of Cover Material	g/cm^3	NA	2.4	Average Density (Minimum =2.2 and Maximum = 2.6)	Figure 8.1-1, NUREG/CR 6697, Attachment C
	Cover Erosion Rate	m/yr	NA	2.045E-06	Based on maximum erosion rate of 5.6 E-7 cm/day for concrete.	Figure 8.2-1 NUREG/CR 6697, Attachment C
	Density of CZ	g/cm^3	2.13	2.13	--	PNNL-18564, Table 6.2, value for C Tank Farm Bf – backfill
	CZ Erosion Rate	m/yr	0.001	0.001	RESRAD default	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	CZ Total Porosity	Unitless	0.258	0.258	--	PNNL-18564, Table 6.3, site-wide value for Hg – Hanford formation sandy gravel
	CZ Field Capacity	Unitless	0.061	0.061	--	PNNL-18564, Table 6.5, best-estimate value for Hg – Hanford formation sandy gravel
	CZ Hydraulic Conductivity	m/yr	176.6	176.6		PNNL-18564, Table 6.7, value for C Tank Farm Bf – backfill (5.6E-04 cm/s x 86,400 s/day x 365 day/yr x 0.01 m/cm = 176.6 m/yr)
	CZ b Parameter	Unitless	2.96	2.96		PNNL-18564, Table 6.8, value for Hg – Hanford formation sandy gravel)
	Humidity in Air	g/cm^3	8	8	RESRAD default	--
	Evapotranspiration Coefficient	Unitless	0.91	0.91	EPA, Region X guidance	Letter from EPA
	Wind Speed	m/s	3.4	3.4	Hanford Site average	PNNL-15160, Table 5.1
	Precipitation	m/yr	0.177	0.177	Based on 6.98 in. (0.177 m) normal annual rainfall	PNNL-15160, Table 4.1

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	Irrigation Rate	m/yr	0	0	No irrigation assumed for the Inner Area of the Central Plateau	--
	Irrigation Mode	NA	Overhead	Overhead	RESRAD default	--
	Runoff Coefficient	Unitless	0.2	0.2	RESRAD default	--
	Watershed Area for Nearby Stream or Pond	m^2	NA	NA	Not applicable[a]	--
	Accuracy for Water/Soil Computations	Unitless	NA	NA	Not applicable[a]	--
R014 – Saturated Zone (SZ) Hydrological Data	Density of SZ	g/cm^3	NA	NA	Not applicable[a]	--
	SZ Total Porosity	Unitless	NA	NA	Not applicable[a]	--
	SZ Effective Porosity	Unitless	NA	NA	Not applicable[a]	--
	SZ Field Capacity	Unitless	NA	NA	Not applicable[a]	--
	SZ Hydraulic Conductivity	m/yr	NA	NA	Not applicable[a]	--
	SZ Hydraulic Gradient	Unitless	NA	NA	Not applicable[a]	--
	SZ b Parameter	Unitless	NA	NA	Not applicable[a]	--
	Water Table Drop Rate	m/yr	NA	NA	Not applicable[a]	--
	Well Pump Intake Depth	m below water table	NA	NA	Not applicable[a]	--
	Nondispersion (ND) or Mass-Balance (MB)	NA	NA	NA	Not applicable[a]	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	Well Pumping Rate	m^3/yr	NA	NA	Not applicable[a]	--
R015 - Uncontaminated and Unsaturated Strata Hydrological Data	Number of Unsaturated Strata	NA	NA	NA	Not applicable[a]	--
	Thickness	m	NA	NA	Not applicable[a]	--
	Soil Density	g/cm^3	NA	NA	Not applicable[a]	--
	Total Porosity	Unitless	NA	NA	Not applicable[a]	--
	Effective Porosity	Unitless	NA	NA	Not applicable[a]	--
	Field Capacity	Unitless	NA	NA	Not applicable[a]	--
	Soil-specific b Parameter	Unitless	NA	NA	Not applicable[a]	--
	Hydraulic Conductivity	m/yr	NA	NA	Not applicable[a]	--
R016 - Distribution Coefficients (K_d) and Leach Rates	CZ K_d	mL/g	Contaminant-specific (see Table 4-3)	Contaminant-specific (see Table 4-3)	K_d values used are consistent with those used for the WMA C Performance Assessment.	RPP-ENV-58782, Table 6-11 (< 2 mm material)
	Time Since Material Placement	yr	0	0	RESRAD default	--
	Leach Rate	yr^{-1}	NA	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Solubility Limit	mol/L	NA	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Radiation Dose Limit	mrem/yr	25	25	RESRAD default	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
R017 - Inhalation and External Gamma	Inhalation Rate	m^3/yr	7,300	7,300	20 m^3/day x 365 day/yr = 7,300 m^3/yr	OSWER Directive 9285.6-03, Section 3.3
	Mass Loading for Inhalation	g/m^3	1.37E-08	1.37E-08	Derived from particulate emission factor (PEF) using 1/PEF x 1000 g/kg, where PEF = 7.30E+10 m^3/kg	ECF-HANFORD-11-0033
	Exposure duration	Yr	25	25	Site-specific	OSWER 9285.6-03
	Indoor Dust Filtration Factor	Unitless	0.4	0.4	RESRAD default	--
	External Gamma Shielding Factor	Unitless	0.4	0.4	60 % shielding	EPA/540-R-00-007, Equation 4
	Indoor Time Fraction	Unitless	0.17	0.17	(6 hr/d x 250 d/yr) / 8,760 hr/yr = 0.17	OSWER 9355.4-24
	Outdoor Time Fraction	Unitless	0.057	0.057	(2 hr/day x 250 days/yr) / 8,760 hr/yr = 0.057	OSWER 9355.4-24
	Shape Factor	NA	Circular	Circular	RESRAD default	--
R018 - Ingestion Pathway Data, Dietary Parameters	Fruits, Vegetables, and Grain Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Leafy Vegetable Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Milk Consumption	L/yr	NA	NA	Incomplete exposure pathway	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	Meat and Poultry Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Fish Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Other Seafood Consumption	kg/yr	NA	NA	Incomplete exposure pathway	--
	Soil Ingestion	g/yr	18.25	18.25	(50 mg/day x 365 days/yr) / 1,000 mg/g = 18.25 g/yr	OSWER Directive 9285.6-03
	Drinking Water Intake	L/yr	NA	NA	Incomplete exposure pathway	--
	Drinking Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Household Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Livestock Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Irrigation Water Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Aquatic Food Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Plant Food Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
	Meat Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	Milk Contamination Fraction	Unitless	NA	NA	Incomplete exposure pathway	--
R019 - Ingestion Pathway Data, Nondietary	Livestock Fodder Intake for Meat	kg/d	NA	NA	Incomplete exposure pathway	--
	Livestock Fodder Intake for Milk	kg/d	NA	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Meat	L/d	NA	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Milk	L/d	NA	NA	Incomplete exposure pathway	--
	Livestock Intake of Soil	kg/d	NA	NA	Incomplete exposure pathway	--
	Mass Loading for Foliar Deposition	g/m^3	NA	NA	Incomplete exposure pathway	--
	Depth of Soil Mixing Layer	m	0.15	0.15	RESRAD default	--
	Depth of Roots	m	NA	NA	Incomplete exposure pathway	--
R020 – Groundwater Usage	Groundwater Fractional Usage - Drinking Water	Unitless	NA	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Household Usage	Unitless	NA	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Livestock Water	Unitless	NA	NA	Incomplete exposure pathway	--

Table 4-2. RESRAD Input Parameters Used to Calculate Risk for Surface Area Contamination and 216-C-8 French Drain under a CERCLA Industrial Worker Exposure Scenario.

RESRAD Category	Parameter	Units	User Input Surface Area Contamination-Specific	User Input 216-C-8-Specific	Rationale	Reference
	Groundwater Fractional Usage – Irrigation	Unitless	NA	NA	Incomplete exposure pathway	--
R021 – Radon	Radon parameters are not used; Radon is not a Hanford Site contaminant of potential concern.					--

Notes:

a. Not applicable – the following parameters are not used in the model when drinking water and food ingestion pathways are suppressed: contaminated zone length parallel to aquifer flow; watershed area; accuracy for water/soil computations; saturated zone hydrological data (R014); and uncontaminated, unsaturated strata hydrological data (R015). These parameters are used in the model to estimate migration through soil and transport to groundwater and are not used for the construction worker or industrial worker scenarios.

CZ = contaminated zone.

DOE = U.S. Department of Energy.

NA = not applicable.

K_d = soil-water distribution coefficient.

RESRAD = RESidual RADioactivity code (ANL, 2014).

SZ = saturated zone.

ANL, 2014, RESRAD for Windows, Version 7.0.

ANL/EAD-4, *User's Manual for RESRAD Version 6*.

DOE M 435.1-1, *Radioactive Waste Management Manual*.

ICRP, 2008, *Nuclear Decay Data for Dosimetric Calculations*, ICRP Publication 107, Ann. ICRP 38 (3).

OSWER Directive 9285.6-03, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" Interim Final*.

OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*.

PNNL-15160, *Hanford Site Climatological Summary 2004 With Historical Data*.

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report*.

Table 4-3. Radionuclide-Specific Distribution Coefficients (K_d)

Radionuclide COPC	Contaminated Zone Layer (cm^3/g)[a]	Unsaturated Zone and Saturated Zone (cm^3/g)[a]
Am-241	600	600
C-14	1	1
Cm-243	350	350
Cm-244	350	350
Cs-137	100	100
Eu-152	10	10
Eu-154	10	10
Eu-155	10	10
I-129	0.2	0.2
Ni-63	3	3
Np-237	10	10
Pu-238	600	600
Pu-239	600	600
Pu-240	600	600
Pu-241	600	600
Sn-126	0.5	0.5
Sr-90	10	10
U-233	0.6	0.6
U-234	0.6	0.6
U-235	0.6	0.6
U-236	0.6	0.6
U-238	0.6	0.6

Note:

a. RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*, Table 6-11, Distribution Coefficient (K_d) Values Used to Approximate the Transport of the Radionuclides in the Base Case.

COPC = contaminant of potential concern.

Table 4-4. Identification of COPCs in Leak Affected Soil for WMA C Past Tank Leaks and Releases

Radionuclide	Included in DQO?[a]	K_d[b] (mL/g)	Mobile in Soil?[c]	Half Life (yr)	Half-life > 3 years?[d]	COPC?
H-3	Yes	0	Yes	12.32	Yes	No
C-14	Yes	1	No	5715	Yes	Yes
Ni-59	No	3	No	7.6E+04	Yes	No
Co-60	Yes	0	Yes	5.271	Yes	No
Ni-63	Yes	3	No	101	Yes	Yes
Se-79	Yes	0.1	Yes	2.9E+05	Yes	No
Sr-90	Yes	10	No	28.78	Yes	Yes
Y-90	No	--	No	7.31E-03	No	No
Zr-93	No	300	No	1.5E+06	Yes	No
Nb-93m	No	0	Yes	16.1	Yes	No
Tc-99	Yes	0	Yes	2.13E+05	Yes	No
Ru-106	No	--	No	1.020	No	No
Cd-113m	No	--	No	14.1	Yes	No
Sb-125	Yes	--	No	2.758	No	No
Sn-126	Yes	0.5	No	2.3E+05	Yes	Yes
I-129	Yes	0.2	No	1.57E+07	Yes	Yes
Cs-134	No	--	No	2.065	No	No
Cs-137	Yes	100	No	30.07	Yes	Yes
Ba-137m	No	--	No	4.852E-06	No	No
Sm-151	No	10	No	90	Yes	No
Eu-152	Yes	10	No	13.54	Yes	Yes
Eu-154	Yes	10	No	8.593	Yes	Yes
Eu-155	Yes	10	No	4.75	Yes	Yes
Ra-226	No	10	No	1599	Yes	No
Ac-227	No	350	No	21.772	Yes	No
Ra-228	No	10	No	5.76	Yes	No
Th-229	No	300	No	7.3E+03	Yes	No
Pa-231	No	300	No	3.28E+04	Yes	No
Th-232	Yes	300	No	1.40E+10	Yes	No[e]
U-232	No	0.6	No	69.8	Yes	No
U-233	Yes	0.6	No	1.592E+05	Yes	Yes
U-234	Yes	0.6	No	2.46E+05	Yes	Yes
U-235	Yes	0.6	No	7.04E+08	Yes	Yes
U-236	Yes	0.6	No	2.342E+07	Yes	Yes
Np-237	Yes	10	No	2.14E+06	Yes	Yes

Table 4-4. Identification of COPCs in Leak Affected Soil for WMA C Past Tank Leaks and Releases

Radionuclide	Included in DQO?[a]	K_d[b] (mL/g)	Mobile in Soil?[c]	Half Life (yr)	Half-life > 3 years?[d]	COPC?
Pu-238	Yes	600	No	87.7	Yes	Yes
U-238	Yes	0.6	No	4.47E+09	Yes	Yes
Pu-239	Yes	600	No	2.410E+04	Yes	Yes
Pu-240	Yes	600	No	6.56E+03	Yes	Yes
Am-241	Yes	600	No	432.7	Yes	Yes
Pu-241	Yes	600	No	14.4	Yes	Yes
Cm-242	Yes	--	No	4.46E-01	No	No
Pu-242	No	600	No	3.75E+05	Yes	No
Am-243	No	600	No	7.37E+03	Yes	No
Cm-243	Yes	350	No	29.1	Yes	Yes
Cm-244	Yes	350	No	18.1	Yes	Yes

Notes:

a. "Yes" indicates analyte was identified as a primary radionuclide in RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*, Table 4-11, Primary Radiological Parameters.

b. Source = RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*, Table 6-11, Distribution Coefficient (K_d) Values Used to Approximate Transport of Radionuclides in the Base Case.

c. It is assumed that radionuclides with $K_d > 0.15$ mL/g are non-mobile and would be expected to remain in the initial leak affected zone. Mobile radionuclides ($K_d < 0.15$ mL/g) are assumed to have migrated to depth.

d. Radionuclides with half-lives less than three years are eliminated because they are either insignificant risk contributors or their contributions are already included with their parent.

e. Thorium-232 is considered a naturally occurring background radionuclide and is therefore eliminated.

COPC = contaminant of potential concern.
DQO = data quality objectives.
K_d = distribution coefficient.

Table 4-5. Radionuclide COPC Concentrations in Leak Affected Soil for WMA C Past Tank Leaks and Releases[a]

	Units	C-101 release	C-104 release	C-105 leak/release	C-108 release	C-110 release	C-112 release	Surface release	216-C-8 release
Release Waste Type	--	**CWP1/P1**	**CWP1**	**P2**	**CWP1**	**CSR**	**CWP1**	**CWP1**	**Sr-Cs Rec (P2)drain**
Release Area	m^2	15	117	292	117	8	117	55,736	535
C-14	Ci/kg	2.35E-06	4.47E-08	1.66E-07	3.63E-08	3.33E-07	3.45E-08	1.64E-11	0.00E+00
Ni-63	Ci/kg	7.54E-04	1.48E-05	6.44E-06	1.20E-05	5.26E-06	1.14E-05	5.43E-09	0.00E+00
Sr-90	Ci/kg	6.78E-04	1.23E-05	9.39E-05	1.00E-05	1.49E-04	9.52E-06	4.53E-09	5.02E-07
Sn-126	Ci/kg	3.31E-08	7.64E-11	1.26E-07	6.20E-11	1.65E-07	5.90E-11	2.81E-14	0.00E+00
I-129	Ci/kg	4.06E-07	7.97E-09	5.67E-10	6.47E-09	7.46E-09	6.15E-09	2.93E-12	0.00E+00
Cs-134	Ci/kg	1.05E-11	1.63E-14	2.60E-10	1.32E-14	4.99E-12	1.26E-14	5.99E-18	0.00E+00
Eu-152	Ci/kg	1.67E-08	4.73E-11	2.50E-08	3.84E-11	4.26E-08	3.65E-11	1.74E-14	0.00E+00
Eu-154	Ci/kg	7.73E-07	2.14E-09	1.25E-06	1.74E-09	1.98E-06	1.65E-09	7.86E-13	0.00E+00
Eu-155	Ci/kg	1.23E-07	3.28E-10	2.44E-07	2.66E-10	3.21E-07	2.53E-10	1.20E-13	0.00E+00
U-233	Ci/kg	1.76E-13	6.37E-16	8.36E-14	5.17E-16	1.41E-09	4.92E-16	2.34E-19	5.65E-16
U-234	Ci/kg	1.49E-08	2.87E-10	5.90E-10	2.33E-10	9.72E-10	2.21E-10	1.05E-13	3.98E-12
U-235	Ci/kg	6.36E-10	1.22E-11	2.46E-11	9.94E-12	4.06E-11	9.45E-12	4.50E-15	1.67E-13
U-236	Ci/kg	3.40E-10	6.54E-12	1.51E-11	5.31E-12	2.64E-11	5.05E-12	2.40E-15	1.02E-13
Np-237	Ci/kg	1.49E-08	5.43E-11	2.54E-08	4.40E-11	4.13E-08	4.19E-11	1.99E-14	7.45E-12
Pu-238	Ci/kg	1.18E-07	2.25E-09	1.19E-08	1.83E-09	1.67E-08	1.74E-09	8.27E-13	6.01E-11
U-238	Ci/kg	1.53E-08	2.94E-10	5.76E-10	2.39E-10	9.11E-10	2.27E-10	1.08E-13	3.89E-12
Pu-239	Ci/kg	7.52E-06	1.45E-07	2.80E-07	1.17E-07	4.45E-07	1.12E-07	5.32E-11	1.45E-09
Pu-240	Ci/kg	1.56E-06	3.01E-08	6.86E-08	2.44E-08	1.03E-07	2.32E-08	1.11E-11	3.55E-10
Am-241	Ci/kg	9.49E-06	1.83E-07	3.65E-07	1.48E-07	5.78E-07	1.41E-07	6.71E-11	0.00E+00
Pu-241	Ci/kg	3.15E-06	6.06E-08	2.83E-07	4.92E-08	3.97E-07	4.67E-08	2.23E-11	1.27E-09
Cm-242	Ci/kg	1.18E-09	3.27E-12	7.03E-10	2.65E-12	2.06E-09	2.52E-12	1.20E-15	0.00E+00
Cm-243	Ci/kg	1.69E-11	4.52E-14	3.12E-11	3.67E-14	4.63E-11	3.49E-14	1.66E-17	0.00E+00

a. Original calculation provided by WRPS ("RE: UPR Soil Concentration Spreadsheet," email from J. Field, CHPRC to M. Rahman, Intera, 11/3/2016). Radionuclides are decayed to 1/1/2017. Concentrations shown have been modified for a soil density of 2.13 g/cm^3 for consistency with the WMA C Performance Assessment assumption on effective bulk density of backfill (RPP-RPT-58949, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA C Performance Assessment and RCRA Closure Analysis*, Table 3-5, Effective Bulk Density Estimates for Various Hydrostratigraphic Units at Waste Management Area C Used in the Base Case Evaluation of Alternative Geologic Models I and II).

CSR = cesium removal waste.
CWP1 = PUREX cladding waste, aluminum clad fuel (1956-1960).
P1 = PUREX high-level waste supernate (1956-1962).
P2 = PUREX high-level waste supernate (1959-1966).

Table 4-6. Exposure Point Concentrations for Radionuclide COPCs in WMA C Past Tank Leaks and Releases

Radionuclide COPC	Soil Concentration (pCi/g)							
	C-101	**C-104**	**C-105**	**C-108**	**C-110**	**C-112**	**Surface**	**216-C-8**
Am-241	9,490	183	365	148	578	141	0.067	0
C-14	2,347	45	166	36	333	34	0.016	0
Cm-243	0.017	4.52E-05	0.031	3.67E-05	0.046	3.49E-05	1.66E-08	0
Cm-244	0.36	9.34E-04	0.58	7.58E-04	0.92	7.21E-04	3.43E-07	0
Cs-137	6.57E+06	14,865	2.80E+07	12,065	913,680	11,472	5.5	60
Eu-152	17	0.047	25	0.038	43	0.036	1.74E-05	0
Eu-154	773	2.1	1,250	1.7	1,978	1.7	7.86E-04	0
Eu-155	123	0.33	244	0.27	321	0.25	1.20E-04	0
I-129	406	8.0	0.57	6.5	7.5	6.1	0.0029	0
Ni-63	753,741	14,771	6,437	11,989	5,264	11,400	5.4	0
Np-237	15	0.054	25	0.044	41	0.042	1.99E-05	0.0075
Pu-238	118	2.2	12	1.8	17	1.7	8.27E-04	0.060
Pu-239	7,519	145	280	117	445	112	0.053	1.4
Pu-240	1,564	30	69	24	103	23	0.011	0.36
Pu-241	3,146	61	283	49	397	47	0.022	1.3
Sn-126	33	0.076	126	0.062	165	0.059	2.81E-05	0
Sr-90	677,789	12,330	93,943	10,008	148,602	9,516	4.5	502
U-233	1.76E-04	6.37E-07	8.36E-05	5.17E-07	1.4	4.92E-07	2.34E-10	5.65E-07
U-234	15	0.29	0.59	0.23	0.97	0.22	1.05E-04	0.0040
U-235	0.64	0.012	0.025	0.0099	0.041	0.0094	4.50E-06	1.67E-04
U-236	0.34	0.0065	0.015	0.0053	0.026	0.0050	2.40E-06	1.02E-04
U-238	15	0.29	0.58	0.24	0.91	0.23	1.08E-04	0.0039

Table 7-1. Peak Cancer Risks for the CERCLA Construction Worker Scenario at WMA C Past Tank Releases (Assuming No Soil Cover)

Exposure Pathway	C-101	C-104	C-105	C-108	C-110	C-112
External Gamma	3.8E-01	8.7E-04	1.6E+00	7.1E-04	5.4E-02	6.7E-04
Inhalation	7.1E-05	8.8E-07	1.2E-04	7.2E-07	8.2E-06	6.8E-07
Soil Ingestion	3.0E-04	1.7E-06	1.0E-03	1.4E-06	4.6E-05	1.3E-06
Cumulative ELCR	**4E-01**	**9E-04**	**2E+00**	**7E-04**	**5E-02**	**7E-04**

Table 7-2. Maximum Radiological Doses for the CERCLA Construction Worker Scenario at WMA C Past Tank Releases (Assuming No Soil Cover)

Exposure Pathway	C-101	C-104	C-105	C-108	C-110	C-112
External Gamma	481,962	1,101	2,051,178	894	67,459	850
Inhalation	327	6	163	5	25	4
Soil Ingestion	403	2	1,352	2	61	2
Cumulative Dose (mrem/yr)	482,670	1,109	2,052,601	900	67,542	856

Table 7-3. Maximum Risk for Surface Area Contamination and French Drain 216-C-8 under a CERCLA Industrial Worker Exposure Scenario

Exposure Pathway	Surface Contamination	216-C-8 French Drain (Baseline Condition)	216-C-8 French Drain (Post-Remediation Condition)
External Gamma	3.2E-05	3.4E-04	4.1E-05
Inhalation	3.3E-12	7.9E-12	2.6E-12
Soil Ingestion	5.2E-08	2.1E-06	7.0E-07
Cumulative ELCR	3E-05	**3E-04**	4E-05

APPENDIX A

Risk Assessment Calculation Detail for WMA C Past Tank Leaks Under a Construction Worker Scenario

Table A-1. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-101 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	9,490	6.8E-10	1.4E-09	1.3E-10	2.2E-09	6.5E-06	1.3E-05	1.2E-06	2.1E-05	6.2E-10	1.3E-09	1.2E-10	2.0E-09	5.9E-06	1.2E-05	1.1E-06	1.9E-05	1.4E-10	2.8E-10	2.6E-11	4.5E-10	1.3E-06	2.7E-06	2.5E-07	4.2E-06
C-14	2,347	1.0E-13	3.6E-12	1.0E-12	4.7E-12	2.4E-10	8.4E-09	2.4E-09	1.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.017	1.0E-08	1.3E-09	1.2E-10	1.2E-08	1.7E-10	2.3E-11	2.0E-12	2.0E-10	2.8E-09	3.7E-10	3.3E-11	3.2E-09	4.7E-11	6.3E-12	5.6E-13	5.4E-11	1.4E-13	2.4E-12	2.0E-13	2.8E-12	2.3E-15	4.1E-14	3.3E-15	4.7E-14
Cm-244	0.36	3.4E-12	1.3E-09	1.0E-10	1.4E-09	1.2E-12	4.6E-10	3.6E-11	5.0E-10	4.3E-13	1.7E-10	1.3E-11	1.8E-10	1.5E-13	6.0E-11	4.7E-12	6.5E-11	4.8E-15	5.1E-12	4.2E-13	5.5E-12	1.7E-15	1.8E-12	1.5E-13	2.0E-12
Cs-137	6.57E+06	5.8E-08	4.1E-12	3.6E-11	5.8E-08	3.8E-01	2.7E-05	2.3E-04	3.8E-01	1.7E-08	1.2E-12	1.0E-11	1.7E-08	1.1E-01	7.9E-06	6.8E-05	1.1E-01	6.0E-18	4.3E-22	3.7E-21	6.0E-18	4.0E-11	2.8E-15	2.4E-14	4.0E-11
Eu-152	17	1.2E-07	6.9E-12	7.8E-12	1.2E-07	2.0E-06	1.2E-10	1.3E-10	2.0E-06	7.7E-09	4.3E-13	4.9E-13	7.7E-09	1.3E-07	7.2E-12	8.2E-12	1.3E-07	6.2E-30	1.2E-23	1.3E-24	1.3E-23	1.0E-28	2.0E-22	2.2E-23	2.2E-22
Eu-154	773	1.3E-07	7.3E-12	1.3E-11	1.3E-07	1.0E-04	5.7E-09	1.0E-08	1.0E-04	1.7E-09	9.4E-14	1.7E-13	1.7E-09	1.3E-06	7.2E-11	1.3E-10	1.3E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	123	2.8E-09	6.6E-13	2.5E-12	2.8E-09	3.5E-07	8.2E-11	3.1E-10	3.5E-07	1.1E-12	2.5E-16	9.7E-16	1.1E-12	1.3E-10	3.1E-14	1.2E-13	1.3E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	406	1.5E-10	6.1E-12	1.9E-10	3.5E-10	6.2E-08	2.5E-09	7.7E-08	1.4E-07	1.1E-10	4.5E-12	1.4E-10	2.6E-10	4.6E-08	1.8E-09	5.7E-08	1.1E-07	7.0E-13	2.8E-14	8.7E-13	1.6E-12	2.8E-10	1.1E-11	3.5E-10	6.5E-10
Ni-63	753,741	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	1.6E-07	7.0E-07	8.7E-07	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	1.1E-07	4.7E-07	5.8E-07	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	1.0E-10	4.5E-10	5.5E-10
Np-237	15	2.1E-08	1.1E-09	8.9E-11	2.2E-08	3.1E-07	1.6E-08	1.3E-09	3.2E-07	2.0E-08	1.1E-09	8.8E-11	2.2E-08	3.0E-07	1.6E-08	1.3E-09	3.2E-07	1.8E-08	9.4E-10	7.8E-11	1.9E-08	2.7E-07	1.4E-08	1.2E-09	2.8E-07
Pu-238	118	1.9E-12	1.9E-09	1.6E-10	2.1E-09	2.2E-10	2.3E-07	1.9E-08	2.5E-07	1.2E-12	1.3E-09	1.1E-10	1.4E-09	1.4E-10	1.5E-07	1.2E-08	1.6E-07	5.6E-14	7.8E-13	6.7E-14	9.0E-13	6.6E-12	9.2E-11	7.9E-12	1.1E-10
Pu-239	7,519	5.2E-12	2.1E-09	1.7E-10	2.2E-09	3.9E-08	1.5E-05	1.3E-06	1.7E-05	5.2E-12	2.1E-09	1.7E-10	2.2E-09	3.9E-08	1.5E-05	1.3E-06	1.7E-05	5.0E-12	2.0E-09	1.6E-10	2.2E-09	3.8E-08	1.5E-05	1.2E-06	1.6E-05
Pu-240	1,564	1.9E-12	2.1E-09	1.7E-10	2.2E-09	3.0E-09	3.2E-06	2.6E-07	3.5E-06	1.9E-12	2.0E-09	1.7E-10	2.2E-09	3.0E-09	3.2E-06	2.6E-07	3.5E-06	1.7E-12	1.8E-09	1.5E-10	2.0E-09	2.7E-09	2.9E-06	2.4E-07	3.1E-06
Pu-241	3,146	8.5E-13	3.2E-11	2.2E-12	3.6E-11	2.7E-09	1.0E-07	7.1E-09	1.1E-07	2.0E-11	4.3E-11	3.9E-12	6.7E-11	6.2E-08	1.3E-07	1.2E-08	2.1E-07	4.8E-12	9.6E-12	8.9E-13	1.5E-11	1.5E-08	3.0E-08	2.8E-09	4.8E-08
Sn-126	33	2.0E-07	1.6E-11	3.9E-11	2.0E-07	6.8E-06	5.2E-10	1.3E-09	6.8E-06	1.8E-07	1.4E-11	3.4E-11	1.8E-07	5.9E-06	4.6E-10	1.1E-09	5.9E-06	1.8E-08	1.4E-12	3.5E-12	1.8E-08	6.1E-07	4.7E-11	1.2E-10	6.1E-07
Sr-90	677,789	4.5E-10	1.6E-11	9.1E-11	5.6E-10	3.0E-04	1.1E-05	6.2E-05	3.8E-04	1.2E-10	4.3E-12	2.5E-11	1.5E-10	8.2E-05	2.9E-06	1.7E-05	1.0E-04	1.4E-20	4.9E-22	2.8E-21	1.7E-20	9.3E-15	3.3E-16	1.9E-15	1.2E-14
U-233	1.76E-04	1.9E-11	1.0E-09	9.3E-11	1.2E-09	3.3E-15	1.8E-13	1.6E-14	2.0E-13	1.5E-10	9.8E-10	8.7E-11	1.2E-09	2.6E-14	1.7E-13	1.5E-14	2.1E-13	1.0E-09	4.6E-10	3.8E-11	1.5E-09	1.8E-13	8.1E-14	6.8E-15	2.7E-13
U-234	15	6.9E-12	1.0E-09	9.2E-11	1.1E-09	1.0E-10	1.5E-08	1.4E-09	1.7E-08	7.3E-12	9.2E-10	8.2E-11	1.0E-09	1.1E-10	1.4E-08	1.2E-09	1.5E-08	1.9E-10	1.4E-10	1.6E-11	3.4E-10	2.8E-09	2.1E-09	2.4E-10	5.1E-09
U-235	0.64	1.4E-08	9.3E-10	9.4E-11	1.5E-08	8.9E-09	5.9E-10	6.0E-11	9.5E-09	1.3E-08	8.4E-10	8.5E-11	1.3E-08	8.0E-09	5.3E-10	5.4E-11	8.6E-09	2.2E-09	2.2E-10	2.0E-11	2.4E-09	1.4E-09	1.4E-10	1.3E-11	1.6E-09
U-236	0.34	3.4E-12	9.5E-10	8.7E-11	1.0E-09	1.1E-12	3.2E-10	2.9E-11	3.5E-10	3.0E-12	8.5E-10	7.8E-11	9.3E-10	1.0E-12	2.9E-10	2.6E-11	3.2E-10	4.5E-13	1.3E-10	1.1E-11	1.4E-10	1.5E-13	4.3E-11	3.9E-12	4.7E-11
U-238	15	2.8E-09	8.8E-10	1.2E-10	3.8E-09	4.3E-08	1.3E-08	1.8E-09	5.8E-08	2.5E-09	7.8E-10	1.0E-10	3.4E-09	3.8E-08	1.2E-08	1.6E-09	5.2E-08	3.7E-10	1.2E-10	1.5E-11	5.0E-10	5.6E-09	1.8E-09	2.3E-10	7.6E-09
		Cumulative ELCR				**3.8E-01**	7.1E-05	3.0E-04	**3.8E-01**	**Cumulative ELCR**				**1.1E-01**	4.2E-05	8.7E-05	**1.1E-01**	**Cumulative ELCR**				**2.3E-06**	2.1E-05	1.7E-06	**2.5E-05**

Table A-2. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-104 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	183	6.8E-10	1.4E-09	1.3E-10	2.2E-09	1.2E-07	2.6E-07	2.4E-08	4.0E-07	6.2E-10	1.3E-09	1.2E-10	2.0E-09	1.1E-07	2.3E-07	2.2E-08	3.7E-07	1.4E-10	2.8E-10	2.6E-11	4.5E-10	2.5E-08	5.1E-08	4.7E-09	8.1E-08
C-14	45	1.0E-13	3.6E-12	1.0E-12	4.7E-12	4.5E-12	1.6E-10	4.6E-11	2.1E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	4.52E-05	1.0E-08	1.3E-09	1.2E-10	1.2E-08	4.5E-13	6.1E-14	5.3E-15	5.2E-13	2.8E-09	3.7E-10	3.3E-11	3.2E-09	1.3E-13	1.7E-14	1.5E-15	1.4E-13	1.4E-13	2.4E-12	2.0E-13	2.8E-12	6.2E-18	1.1E-16	8.9E-18	1.2E-16
Cm-244	9.34E-04	3.4E-12	1.3E-09	1.0E-10	1.4E-09	3.2E-15	1.2E-12	9.5E-14	1.3E-12	4.3E-13	1.7E-10	1.3E-11	1.8E-10	4.0E-16	1.6E-13	1.2E-14	1.7E-13	4.8E-15	5.1E-12	4.2E-13	5.5E-12	4.5E-18	4.8E-15	3.9E-16	5.2E-15
Cs-137	14,865	5.8E-08	4.1E-12	3.6E-11	5.8E-08	8.7E-04	6.2E-08	5.3E-07	8.7E-04	1.7E-08	1.2E-12	1.0E-11	1.7E-08	2.5E-04	1.8E-08	1.5E-07	2.5E-04	6.0E-18	4.3E-22	3.7E-21	6.0E-18	9.0E-14	6.4E-18	5.5E-17	9.0E-14
Eu-152	0.047	1.2E-07	6.9E-12	7.8E-12	1.2E-07	5.8E-09	3.3E-13	3.7E-13	5.8E-09	7.7E-09	4.3E-13	4.9E-13	7.7E-09	3.6E-10	2.0E-14	2.3E-14	3.6E-10	6.2E-30	1.2E-23	1.3E-24	1.3E-23	2.9E-31	5.6E-25	6.1E-26	6.2E-25
Eu-154	2.1	1.3E-07	7.3E-12	1.3E-11	1.3E-07	2.8E-07	1.6E-11	2.8E-11	2.8E-07	1.7E-09	9.4E-14	1.7E-13	1.7E-09	3.6E-09	2.0E-13	3.6E-13	3.6E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.33	2.8E-09	6.6E-13	2.5E-12	2.8E-09	9.3E-10	2.2E-13	8.3E-13	9.3E-10	1.1E-12	2.5E-16	9.7E-16	1.1E-12	3.5E-13	8.3E-17	3.2E-16	3.5E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	8.0	1.5E-10	6.1E-12	1.9E-10	3.5E-10	1.2E-09	4.8E-11	1.5E-09	2.8E-09	1.1E-10	4.5E-12	1.4E-10	2.6E-10	9.0E-10	3.6E-11	1.1E-09	2.1E-09	7.0E-13	2.8E-14	8.7E-13	1.6E-12	5.5E-12	2.2E-13	6.9E-12	1.3E-11
Ni-63	14,771	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	3.2E-09	1.4E-08	1.7E-08	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	2.2E-09	9.2E-09	1.1E-08	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	2.1E-12	8.8E-12	1.1E-11
Np-237	0.054	2.1E-08	1.1E-09	8.9E-11	2.2E-08	1.1E-09	5.8E-11	4.8E-12	1.2E-09	2.0E-08	1.1E-09	8.8E-11	2.2E-08	1.1E-09	5.7E-11	4.8E-12	1.2E-09	1.8E-08	9.4E-10	7.8E-11	1.9E-08	9.8E-10	5.1E-11	4.2E-12	1.0E-09
Pu-238	2.2	1.9E-12	1.9E-09	1.6E-10	2.1E-09	4.2E-12	4.3E-09	3.6E-10	4.7E-09	1.2E-12	1.3E-09	1.1E-10	1.4E-09	2.8E-12	2.8E-09	2.4E-10	3.1E-09	5.6E-14	7.8E-13	6.7E-14	9.0E-13	1.3E-13	1.8E-12	1.5E-13	2.0E-12
Pu-239	145	5.2E-12	2.1E-09	1.7E-10	2.2E-09	7.5E-10	3.0E-07	2.4E-08	3.2E-07	5.2E-12	2.1E-09	1.7E-10	2.2E-09	7.5E-10	3.0E-07	2.4E-08	3.2E-07	5.0E-12	2.0E-09	1.6E-10	2.2E-09	7.2E-10	2.9E-07	2.4E-08	3.1E-07
Pu-240	30	1.9E-12	2.1E-09	1.7E-10	2.2E-09	5.8E-11	6.2E-08	5.1E-09	6.7E-08	1.9E-12	2.0E-09	1.7E-10	2.2E-09	5.8E-11	6.2E-08	5.0E-09	6.7E-08	1.7E-12	1.8E-09	1.5E-10	2.0E-09	5.2E-11	5.6E-08	4.5E-09	6.0E-08
Pu-241	61	8.5E-13	3.2E-11	2.2E-12	3.6E-11	5.1E-11	2.0E-09	1.4E-10	2.2E-09	2.0E-11	4.3E-11	3.9E-12	6.7E-11	1.2E-09	2.6E-09	2.4E-10	4.0E-09	4.8E-12	9.6E-12	8.9E-13	1.5E-11	2.9E-10	5.8E-10	5.4E-11	9.3E-10
Sn-126	0.076	2.0E-07	1.6E-11	3.9E-11	2.0E-07	1.6E-08	1.2E-12	2.9E-12	1.6E-08	1.8E-07	1.4E-11	3.4E-11	1.8E-07	1.4E-08	1.1E-12	2.6E-12	1.4E-08	1.8E-08	1.4E-12	3.5E-12	1.8E-08	1.4E-09	1.1E-13	2.7E-13	1.4E-09
Sr-90	12,330	4.5E-10	1.6E-11	9.1E-11	5.6E-10	5.5E-06	2.0E-07	1.1E-06	6.8E-06	1.2E-10	4.3E-12	2.5E-11	1.5E-10	1.5E-06	5.3E-08	3.0E-07	1.9E-06	1.4E-20	4.9E-22	2.8E-21	1.7E-20	1.7E-16	6.0E-18	3.4E-17	2.1E-16
U-233	6.37E-07	1.9E-11	1.0E-09	9.3E-11	1.2E-09	1.2E-17	6.7E-16	5.9E-17	7.4E-16	1.5E-10	9.8E-10	8.7E-11	1.2E-09	9.3E-17	6.3E-16	5.5E-17	7.7E-16	1.0E-09	4.6E-10	3.8E-11	1.5E-09	6.5E-16	2.9E-16	2.5E-17	9.7E-16
U-234	0.29	6.9E-12	1.0E-09	9.2E-11	1.1E-09	2.0E-12	3.0E-10	2.6E-11	3.2E-10	7.3E-12	9.2E-10	8.2E-11	1.0E-09	2.1E-12	2.6E-10	2.4E-11	2.9E-10	1.9E-10	1.4E-10	1.6E-11	3.4E-10	5.3E-11	4.1E-11	4.6E-12	9.9E-11
U-235	0.012	1.4E-08	9.3E-10	9.4E-11	1.5E-08	1.7E-10	1.1E-11	1.1E-12	1.8E-10	1.3E-08	8.4E-10	8.5E-11	1.3E-08	1.5E-10	1.0E-11	1.0E-12	1.6E-10	2.2E-09	2.2E-10	2.0E-11	2.4E-09	2.7E-11	2.6E-12	2.4E-13	3.0E-11
U-236	0.0065	3.4E-12	9.5E-10	8.7E-11	1.0E-09	2.2E-14	6.2E-12	5.7E-13	6.8E-12	3.0E-12	8.5E-10	7.8E-11	9.3E-10	2.0E-14	5.6E-12	5.1E-13	6.1E-12	4.5E-13	1.3E-10	1.1E-11	1.4E-10	2.9E-15	8.2E-13	7.5E-14	9.0E-13
U-238	0.29	2.8E-09	8.8E-10	1.2E-10	3.8E-09	8.2E-10	2.6E-10	3.4E-11	1.1E-09	2.5E-09	7.8E-10	1.0E-10	3.4E-09	7.4E-10	2.3E-10	3.1E-11	1.0E-09	3.7E-10	1.2E-10	1.5E-11	5.0E-10	1.1E-10	3.4E-11	4.5E-12	1.5E-10
		Cumulative ELCR				**8.7E-04**	8.8E-07	1.7E-06	**8.8E-04**	**Cumulative ELCR**				**2.5E-04**	6.7E-07	5.2E-07	**2.5E-04**	**Cumulative ELCR**				**2.9E-08**	4.0E-07	3.3E-08	**4.6E-07**

Table A-3. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-105 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	365	6.8E-10	1.4E-09	1.3E-10	2.2E-09	2.5E-07	5.1E-07	4.7E-08	8.1E-07	6.2E-10	1.3E-09	1.2E-10	2.0E-09	2.3E-07	4.7E-07	4.3E-08	7.4E-07	1.4E-10	2.8E-10	2.6E-11	4.5E-10	5.1E-08	1.0E-07	9.5E-09	1.6E-07
C-14	166	1.0E-13	3.6E-12	1.0E-12	4.7E-12	1.7E-11	5.9E-10	1.7E-10	7.8E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.031	1.0E-08	1.3E-09	1.2E-10	1.2E-08	3.1E-10	4.2E-11	3.7E-12	3.6E-10	2.8E-09	3.7E-10	3.3E-11	3.2E-09	8.6E-11	1.2E-11	1.0E-12	9.9E-11	1.4E-13	2.4E-12	2.0E-13	2.8E-12	4.3E-15	7.5E-14	6.1E-15	8.6E-14
Cm-244	0.58	3.4E-12	1.3E-09	1.0E-10	1.4E-09	2.0E-12	7.5E-10	5.9E-11	8.1E-10	4.3E-13	1.7E-10	1.3E-11	1.8E-10	2.5E-13	9.8E-11	7.7E-12	1.1E-10	4.8E-15	5.1E-12	4.2E-13	5.5E-12	2.8E-15	3.0E-12	2.4E-13	3.2E-12
Cs-137	2.80E+07	5.8E-08	4.1E-12	3.6E-11	5.8E-08	1.6E+00	1.2E-04	1.0E-03	1.6E+00	1.7E-08	1.2E-12	1.0E-11	1.7E-08	4.7E-01	3.4E-05	2.9E-04	4.7E-01	6.0E-18	4.3E-22	3.7E-21	6.0E-18	1.7E-10	1.2E-14	1.0E-13	1.7E-10
Eu-152	25	1.2E-07	6.9E-12	7.8E-12	1.2E-07	3.1E-06	1.7E-10	2.0E-10	3.1E-06	7.7E-09	4.3E-13	4.9E-13	7.7E-09	1.9E-07	1.1E-11	1.2E-11	1.9E-07	6.2E-30	1.2E-23	1.3E-24	1.3E-23	1.6E-28	2.9E-22	3.2E-23	3.3E-22
Eu-154	1,250	1.3E-07	7.3E-12	1.3E-11	1.3E-07	1.6E-04	9.2E-09	1.6E-08	1.6E-04	1.7E-09	9.4E-14	1.7E-13	1.7E-09	2.1E-06	1.2E-10	2.1E-10	2.1E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	244	2.8E-09	6.6E-13	2.5E-12	2.8E-09	6.9E-07	1.6E-10	6.2E-10	6.9E-07	1.1E-12	2.5E-16	9.7E-16	1.1E-12	2.6E-10	6.2E-14	2.4E-13	2.6E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	0.57	1.5E-10	6.1E-12	1.9E-10	3.5E-10	8.6E-11	3.4E-12	1.1E-10	2.0E-10	1.1E-10	4.5E-12	1.4E-10	2.6E-10	6.4E-11	2.6E-12	8.0E-11	1.5E-10	7.0E-13	2.8E-14	8.7E-13	1.6E-12	3.9E-13	1.6E-14	4.9E-13	9.0E-13
Ni-63	6,437	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	1.4E-09	6.0E-09	7.4E-09	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	9.4E-10	4.0E-09	5.0E-09	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	9.0E-13	3.8E-12	4.7E-12
Np-237	25	2.1E-08	1.1E-09	8.9E-11	2.2E-08	5.2E-07	2.7E-08	2.3E-09	5.5E-07	2.0E-08	1.1E-09	8.8E-11	2.2E-08	5.2E-07	2.7E-08	2.2E-09	5.5E-07	1.8E-08	9.4E-10	7.8E-11	1.9E-08	4.6E-07	2.4E-08	2.0E-09	4.9E-07
Pu-238	12	1.9E-12	1.9E-09	1.6E-10	2.1E-09	2.2E-11	2.3E-08	1.9E-09	2.5E-08	1.2E-12	1.3E-09	1.1E-10	1.4E-09	1.5E-11	1.5E-08	1.3E-09	1.6E-08	5.6E-14	7.8E-13	6.7E-14	9.0E-13	6.7E-13	9.2E-12	7.9E-13	1.1E-11
Pu-239	280	5.2E-12	2.1E-09	1.7E-10	2.2E-09	1.4E-09	5.8E-07	4.7E-08	6.3E-07	5.2E-12	2.1E-09	1.7E-10	2.2E-09	1.4E-09	5.8E-07	4.7E-08	6.2E-07	5.0E-12	2.0E-09	1.6E-10	2.2E-09	1.4E-09	5.6E-07	4.6E-08	6.1E-07
Pu-240	69	1.9E-12	2.1E-09	1.7E-10	2.2E-09	1.3E-10	1.4E-07	1.2E-08	1.5E-07	1.9E-12	2.0E-09	1.7E-10	2.2E-09	1.3E-10	1.4E-07	1.1E-08	1.5E-07	1.7E-12	1.8E-09	1.5E-10	2.0E-09	1.2E-10	1.3E-07	1.0E-08	1.4E-07
Pu-241	283	8.5E-13	3.2E-11	2.2E-12	3.6E-11	2.4E-10	9.2E-09	6.4E-10	1.0E-08	2.0E-11	4.3E-11	3.9E-12	6.7E-11	5.6E-09	1.2E-08	1.1E-09	1.9E-08	4.8E-12	9.6E-12	8.9E-13	1.5E-11	1.4E-09	2.7E-09	2.5E-10	4.3E-09
Sn-126	126	2.0E-07	1.6E-11	3.9E-11	2.0E-07	2.6E-05	2.0E-09	4.9E-09	2.6E-05	1.8E-07	1.4E-11	3.4E-11	1.8E-07	2.3E-05	1.7E-09	4.3E-09	2.3E-05	1.8E-08	1.4E-12	3.5E-12	1.8E-08	2.3E-06	1.8E-10	4.4E-10	2.3E-06
Sr-90	93,943	4.5E-10	1.6E-11	9.1E-11	5.6E-10	4.2E-05	1.5E-06	8.5E-06	5.2E-05	1.2E-10	4.3E-12	2.5E-11	1.5E-10	1.1E-05	4.0E-07	2.3E-06	1.4E-05	1.4E-20	4.9E-22	2.8E-21	1.7E-20	1.3E-15	4.6E-17	2.6E-16	1.6E-15
U-233	8.36E-05	1.9E-11	1.0E-09	9.3E-11	1.2E-09	1.6E-15	8.8E-14	7.8E-15	9.7E-14	1.5E-10	9.8E-10	8.7E-11	1.2E-09	1.2E-14	8.2E-14	7.3E-15	1.0E-13	1.0E-09	4.6E-10	3.8E-11	1.5E-09	8.6E-14	3.9E-14	3.2E-15	1.3E-13
U-234	0.59	6.9E-12	1.0E-09	9.2E-11	1.1E-09	4.1E-12	6.1E-10	5.4E-11	6.7E-10	7.3E-12	9.2E-10	8.2E-11	1.0E-09	4.3E-12	5.4E-10	4.9E-11	6.0E-10	1.9E-10	1.4E-10	1.6E-11	3.4E-10	1.1E-10	8.4E-11	9.4E-12	2.0E-10
U-235	0.025	1.4E-08	9.3E-10	9.4E-11	1.5E-08	3.4E-10	2.3E-11	2.3E-12	3.7E-10	1.3E-08	8.4E-10	8.5E-11	1.3E-08	3.1E-10	2.1E-11	2.1E-12	3.3E-10	2.2E-09	2.2E-10	2.0E-11	2.4E-09	5.4E-11	5.3E-12	4.9E-13	6.0E-11
U-236	0.015	3.4E-12	9.5E-10	8.7E-11	1.0E-09	5.1E-14	1.4E-11	1.3E-12	1.6E-11	3.0E-12	8.5E-10	7.8E-11	9.3E-10	4.6E-14	1.3E-11	1.2E-12	1.4E-11	4.5E-13	1.3E-10	1.1E-11	1.4E-10	6.8E-15	1.9E-12	1.7E-13	2.1E-12
U-238	0.58	2.8E-09	8.8E-10	1.2E-10	3.8E-09	1.6E-09	5.0E-10	6.7E-11	2.2E-09	2.5E-09	7.8E-10	1.0E-10	3.4E-09	1.4E-09	4.5E-10	6.0E-11	2.0E-09	3.7E-10	1.2E-10	1.5E-11	5.0E-10	2.1E-10	6.7E-11	8.8E-12	2.9E-10
		Cumulative ELCR				**1.6E+00**	1.2E-04	1.0E-03	**1.6E+00**	**Cumulative ELCR**				**4.7E-01**	3.5E-05	2.9E-04	**4.7E-01**	**Cumulative ELCR**				**2.8E-06**	8.2E-07	6.8E-08	**3.7E-06**

Table A-4. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-108 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	**EPC (pCi/g)**	**RSR (1/(pCi/g)**				**Risk (unitless)**				**RSR (1/(pCi/g)**				**Risk (unitless)**				**RSR (1/(pCi/g)**				**Risk (unitless)**			
		Ground	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**
Am-241	148	6.8E-10	1.4E-09	1.3E-10	2.2E-09	1.0E-07	2.1E-07	1.9E-08	3.3E-07	6.2E-10	1.3E-09	1.2E-10	2.0E-09	9.2E-08	1.9E-07	1.8E-08	3.0E-07	1.4E-10	2.8E-10	2.6E-11	4.5E-10	2.1E-08	4.2E-08	3.8E-09	6.6E-08
C-14	36	1.0E-13	3.6E-12	1.0E-12	4.7E-12	3.7E-12	1.3E-10	3.7E-11	1.7E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	3.67E-05	1.0E-08	1.3E-09	1.2E-10	1.2E-08	3.7E-13	4.9E-14	4.3E-15	4.2E-13	2.8E-09	3.7E-10	3.3E-11	3.2E-09	1.0E-13	1.4E-14	1.2E-15	1.2E-13	1.4E-13	2.4E-12	2.0E-13	2.8E-12	5.0E-18	8.9E-17	7.2E-18	1.0E-16
Cm-244	7.58E-04	3.4E-12	1.3E-09	1.0E-10	1.4E-09	2.6E-15	9.8E-13	7.7E-14	1.1E-12	4.3E-13	1.7E-10	1.3E-11	1.8E-10	3.3E-16	1.3E-13	1.0E-14	1.4E-13	4.8E-15	5.1E-12	4.2E-13	5.5E-12	3.6E-18	3.9E-15	3.2E-16	4.2E-15
Cs-137	12,065	5.8E-08	4.1E-12	3.6E-11	5.8E-08	7.0E-04	5.0E-08	4.3E-07	7.0E-04	1.7E-08	1.2E-12	1.0E-11	1.7E-08	2.0E-04	1.4E-08	1.2E-07	2.0E-04	6.0E-18	4.3E-22	3.7E-21	6.0E-18	7.3E-14	5.2E-18	4.5E-17	7.3E-14
Eu-152	0.038	1.2E-07	6.9E-12	7.8E-12	1.2E-07	4.7E-09	2.6E-13	3.0E-13	4.7E-09	7.7E-09	4.3E-13	4.9E-13	7.7E-09	2.9E-10	1.7E-14	1.9E-14	2.9E-10	6.2E-30	1.2E-23	1.3E-24	1.3E-23	2.4E-31	4.5E-25	5.0E-26	5.0E-25
Eu-154	1.7	1.3E-07	7.3E-12	1.3E-11	1.3E-07	2.3E-07	1.3E-11	2.3E-11	2.3E-07	1.7E-09	9.4E-14	1.7E-13	1.7E-09	2.9E-09	1.6E-13	2.9E-13	2.9E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.27	2.8E-09	6.6E-13	2.5E-12	2.8E-09	7.5E-10	1.8E-13	6.8E-13	7.5E-10	1.1E-12	2.5E-16	9.7E-16	1.1E-12	2.9E-13	6.7E-17	2.6E-16	2.9E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	6.5	1.5E-10	6.1E-12	1.9E-10	3.5E-10	9.8E-10	3.9E-11	1.2E-09	2.2E-09	1.1E-10	4.5E-12	1.4E-10	2.6E-10	7.3E-10	2.9E-11	9.2E-10	1.7E-09	7.0E-13	2.8E-14	8.7E-13	1.6E-12	4.5E-12	1.8E-13	5.6E-12	1.0E-11
Ni-63	11,989	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	2.6E-09	1.1E-08	1.4E-08	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	1.8E-09	7.5E-09	9.3E-09	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	1.7E-12	7.2E-12	8.8E-12
Np-237	0.044	2.1E-08	1.1E-09	8.9E-11	2.2E-08	9.1E-10	4.7E-11	3.9E-12	9.6E-10	2.0E-08	1.1E-09	8.8E-11	2.2E-08	9.0E-10	4.7E-11	3.9E-12	9.5E-10	1.8E-08	9.4E-10	7.8E-11	1.9E-08	8.0E-10	4.1E-11	3.4E-12	8.4E-10
Pu-238	1.8	1.9E-12	1.9E-09	1.6E-10	2.1E-09	3.4E-12	3.5E-09	3.0E-10	3.8E-09	1.2E-12	1.3E-09	1.1E-10	1.4E-09	2.2E-12	2.3E-09	1.9E-10	2.5E-09	5.6E-14	7.8E-13	6.7E-14	9.0E-13	1.0E-13	1.4E-12	1.2E-13	1.6E-12
Pu-239	117	5.2E-12	2.1E-09	1.7E-10	2.2E-09	6.1E-10	2.4E-07	2.0E-08	2.6E-07	5.2E-12	2.1E-09	1.7E-10	2.2E-09	6.0E-10	2.4E-07	2.0E-08	2.6E-07	5.0E-12	2.0E-09	1.6E-10	2.2E-09	5.9E-10	2.3E-07	1.9E-08	2.5E-07
Pu-240	24	1.9E-12	2.1E-09	1.7E-10	2.2E-09	4.7E-11	5.0E-08	4.1E-09	5.4E-08	1.9E-12	2.0E-09	1.7E-10	2.2E-09	4.7E-11	5.0E-08	4.1E-09	5.4E-08	1.7E-12	1.8E-09	1.5E-10	2.0E-09	4.2E-11	4.5E-08	3.7E-09	4.9E-08
Pu-241	49	8.5E-13	3.2E-11	2.2E-12	3.6E-11	4.2E-11	1.6E-09	1.1E-10	1.7E-09	2.0E-11	4.3E-11	3.9E-12	6.7E-11	9.7E-10	2.1E-09	1.9E-10	3.3E-09	4.8E-12	9.6E-12	8.9E-13	1.5E-11	2.4E-10	4.7E-10	4.4E-11	7.5E-10
Sn-126	0.062	2.0E-07	1.6E-11	3.9E-11	2.0E-07	1.3E-08	9.7E-13	2.4E-12	1.3E-08	1.8E-07	1.4E-11	3.4E-11	1.8E-07	1.1E-08	8.6E-13	2.1E-12	1.1E-08	1.8E-08	1.4E-12	3.5E-12	1.8E-08	1.1E-09	8.8E-14	2.2E-13	1.1E-09
Sr-90	10,008	4.5E-10	1.6E-11	9.1E-11	5.6E-10	4.5E-06	1.6E-07	9.1E-07	5.6E-06	1.2E-10	4.3E-12	2.5E-11	1.5E-10	1.2E-06	4.3E-08	2.5E-07	1.5E-06	1.4E-20	4.9E-22	2.8E-21	1.7E-20	1.4E-16	4.9E-18	2.8E-17	1.7E-16
U-233	5.17E-07	1.9E-11	1.0E-09	9.3E-11	1.2E-09	9.6E-18	5.4E-16	4.8E-17	6.0E-16	1.5E-10	9.8E-10	8.7E-11	1.2E-09	7.6E-17	5.1E-16	4.5E-17	6.3E-16	1.0E-09	4.6E-10	3.8E-11	1.5E-09	5.3E-16	2.4E-16	2.0E-17	7.9E-16
U-234	0.23	6.9E-12	1.0E-09	9.2E-11	1.1E-09	1.6E-12	2.4E-10	2.1E-11	2.6E-10	7.3E-12	9.2E-10	8.2E-11	1.0E-09	1.7E-12	2.2E-10	1.9E-11	2.4E-10	1.9E-10	1.4E-10	1.6E-11	3.4E-10	4.3E-11	3.3E-11	3.7E-12	8.0E-11
U-235	0.0099	1.4E-08	9.3E-10	9.4E-11	1.5E-08	1.4E-10	9.2E-12	9.3E-13	1.5E-10	1.3E-08	8.4E-10	8.5E-11	1.3E-08	1.2E-10	8.3E-12	8.4E-13	1.3E-10	2.2E-09	2.2E-10	2.0E-11	2.4E-09	2.2E-11	2.1E-12	2.0E-13	2.4E-11
U-236	0.0053	3.4E-12	9.5E-10	8.7E-11	1.0E-09	1.8E-14	5.1E-12	4.6E-13	5.5E-12	3.0E-12	8.5E-10	7.8E-11	9.3E-10	1.6E-14	4.5E-12	4.1E-13	5.0E-12	4.5E-13	1.3E-10	1.1E-11	1.4E-10	2.4E-15	6.7E-13	6.1E-14	7.3E-13
U-238	0.24	2.8E-09	8.8E-10	1.2E-10	3.8E-09	6.7E-10	2.1E-10	2.8E-11	9.0E-10	2.5E-09	7.8E-10	1.0E-10	3.4E-09	6.0E-10	1.9E-10	2.5E-11	8.1E-10	3.7E-10	1.2E-10	1.5E-11	5.0E-10	8.8E-11	2.8E-11	3.7E-12	1.2E-10
		Cumulative ELCR				**7.1E-04**	7.2E-07	1.4E-06	**7.1E-04**	**Cumulative ELCR**				**2.0E-04**	5.5E-07	4.2E-07	**2.1E-04**	**Cumulative ELCR**				**2.4E-08**	3.2E-07	2.7E-08	**3.7E-07**

Table A-5. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-110 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	578	6.8E-10	1.4E-09	1.3E-10	2.2E-09	3.9E-07	8.1E-07	7.5E-08	1.3E-06	6.2E-10	1.3E-09	1.2E-10	2.0E-09	3.6E-07	7.4E-07	6.8E-08	1.2E-06	1.4E-10	2.8E-10	2.6E-11	4.5E-10	8.1E-08	1.6E-07	1.5E-08	2.6E-07
C-14	333	1.0E-13	3.6E-12	1.0E-12	4.7E-12	3.4E-11	1.2E-09	3.4E-10	1.6E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.046	1.0E-08	1.3E-09	1.2E-10	1.2E-08	4.6E-10	6.2E-11	5.5E-12	5.3E-10	2.8E-09	3.7E-10	3.3E-11	3.2E-09	1.3E-10	1.7E-11	1.5E-12	1.5E-10	1.4E-13	2.4E-12	2.0E-13	2.8E-12	6.4E-15	1.1E-13	9.1E-15	1.3E-13
Cm-244	0.92	3.4E-12	1.3E-09	1.0E-10	1.4E-09	3.1E-12	1.2E-09	9.4E-11	1.3E-09	4.3E-13	1.7E-10	1.3E-11	1.8E-10	4.0E-13	1.5E-10	1.2E-11	1.7E-10	4.8E-15	5.1E-12	4.2E-13	5.5E-12	4.4E-15	4.7E-12	3.8E-13	5.1E-12
Cs-137	913,680	5.8E-08	4.1E-12	3.6E-11	5.8E-08	5.3E-02	3.8E-06	3.3E-05	5.3E-02	1.7E-08	1.2E-12	1.0E-11	1.7E-08	1.5E-02	1.1E-06	9.4E-06	1.5E-02	6.0E-18	4.3E-22	3.7E-21	6.0E-18	5.5E-12	3.9E-16	3.4E-15	5.5E-12
Eu-152	43	1.2E-07	6.9E-12	7.8E-12	1.2E-07	5.2E-06	2.9E-10	3.3E-10	5.2E-06	7.7E-09	4.3E-13	4.9E-13	7.7E-09	3.3E-07	1.8E-11	2.1E-11	3.3E-07	6.2E-30	1.2E-23	1.3E-24	1.3E-23	2.6E-28	5.0E-22	5.5E-23	5.6E-22
Eu-154	1,978	1.3E-07	7.3E-12	1.3E-11	1.3E-07	2.6E-04	1.5E-08	2.6E-08	2.6E-04	1.7E-09	9.4E-14	1.7E-13	1.7E-09	3.3E-06	1.8E-10	3.3E-10	3.3E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	321	2.8E-09	6.6E-13	2.5E-12	2.8E-09	9.1E-07	2.1E-10	8.2E-10	9.1E-07	1.1E-12	2.5E-16	9.7E-16	1.1E-12	3.5E-10	8.1E-14	3.1E-13	3.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	7.5	1.5E-10	6.1E-12	1.9E-10	3.5E-10	1.1E-09	4.5E-11	1.4E-09	2.6E-09	1.1E-10	4.5E-12	1.4E-10	2.6E-10	8.5E-10	3.4E-11	1.1E-09	1.9E-09	7.0E-13	2.8E-14	8.7E-13	1.6E-12	5.2E-12	2.1E-13	6.5E-12	1.2E-11
Ni-63	5,264	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	1.1E-09	4.9E-09	6.0E-09	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	7.7E-10	3.3E-09	4.1E-09	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	7.3E-13	3.1E-12	3.9E-12
Np-237	41	2.1E-08	1.1E-09	8.9E-11	2.2E-08	8.5E-07	4.4E-08	3.7E-09	9.0E-07	2.0E-08	1.1E-09	8.8E-11	2.2E-08	8.4E-07	4.4E-08	3.6E-09	8.9E-07	1.8E-08	9.4E-10	7.8E-11	1.9E-08	7.5E-07	3.9E-08	3.2E-09	7.9E-07
Pu-238	17	1.9E-12	1.9E-09	1.6E-10	2.1E-09	3.1E-11	3.2E-08	2.7E-09	3.5E-08	1.2E-12	1.3E-09	1.1E-10	1.4E-09	2.1E-11	2.1E-08	1.8E-09	2.3E-08	5.6E-14	7.8E-13	6.7E-14	9.0E-13	9.4E-13	1.3E-11	1.1E-12	1.5E-11
Pu-239	445	5.2E-12	2.1E-09	1.7E-10	2.2E-09	2.3E-09	9.2E-07	7.5E-08	9.9E-07	5.2E-12	2.1E-09	1.7E-10	2.2E-09	2.3E-09	9.1E-07	7.4E-08	9.9E-07	5.0E-12	2.0E-09	1.6E-10	2.2E-09	2.2E-09	8.9E-07	7.2E-08	9.6E-07
Pu-240	103	1.9E-12	2.1E-09	1.7E-10	2.2E-09	2.0E-10	2.1E-07	1.7E-08	2.3E-07	1.9E-12	2.0E-09	1.7E-10	2.2E-09	2.0E-10	2.1E-07	1.7E-08	2.3E-07	1.7E-12	1.8E-09	1.5E-10	2.0E-09	1.8E-10	1.9E-07	1.5E-08	2.1E-07
Pu-241	397	8.5E-13	3.2E-11	2.2E-12	3.6E-11	3.4E-10	1.3E-08	8.9E-10	1.4E-08	2.0E-11	4.3E-11	3.9E-12	6.7E-11	7.9E-09	1.7E-08	1.6E-09	2.6E-08	4.8E-12	9.6E-12	8.9E-13	1.5E-11	1.9E-09	3.8E-09	3.5E-10	6.1E-09
Sn-126	165	2.0E-07	1.6E-11	3.9E-11	2.0E-07	3.4E-05	2.6E-09	6.4E-09	3.4E-05	1.8E-07	1.4E-11	3.4E-11	1.8E-07	3.0E-05	2.3E-09	5.6E-09	3.0E-05	1.8E-08	1.4E-12	3.5E-12	1.8E-08	3.0E-06	2.3E-10	5.7E-10	3.0E-06
Sr-90	148,602	4.5E-10	1.6E-11	9.1E-11	5.6E-10	6.7E-05	2.4E-06	1.3E-05	8.3E-05	1.2E-10	4.3E-12	2.5E-11	1.5E-10	1.8E-05	6.4E-07	3.6E-06	2.2E-05	1.4E-20	4.9E-22	2.8E-21	1.7E-20	2.0E-15	7.3E-17	4.1E-16	2.5E-15
U-233	1.4	1.9E-11	1.0E-09	9.3E-11	1.2E-09	2.6E-11	1.5E-09	1.3E-10	1.6E-09	1.5E-10	9.8E-10	8.7E-11	1.2E-09	2.1E-10	1.4E-09	1.2E-10	1.7E-09	1.0E-09	4.6E-10	3.8E-11	1.5E-09	1.5E-09	6.5E-10	5.4E-11	2.2E-09
U-234	0.97	6.9E-12	1.0E-09	9.2E-11	1.1E-09	6.7E-12	1.0E-09	8.9E-11	1.1E-09	7.3E-12	9.2E-10	8.2E-11	1.0E-09	7.1E-12	9.0E-10	8.0E-11	9.8E-10	1.9E-10	1.4E-10	1.6E-11	3.4E-10	1.8E-10	1.4E-10	1.6E-11	3.4E-10
U-235	0.041	1.4E-08	9.3E-10	9.4E-11	1.5E-08	5.7E-10	3.8E-11	3.8E-12	6.1E-10	1.3E-08	8.4E-10	8.5E-11	1.3E-08	5.1E-10	3.4E-11	3.4E-12	5.5E-10	2.2E-09	2.2E-10	2.0E-11	2.4E-09	8.9E-11	8.8E-12	8.0E-13	9.9E-11
U-236	0.026	3.4E-12	9.5E-10	8.7E-11	1.0E-09	8.9E-14	2.5E-11	2.3E-12	2.7E-11	3.0E-12	8.5E-10	7.8E-11	9.3E-10	8.0E-14	2.2E-11	2.0E-12	2.5E-11	4.5E-13	1.3E-10	1.1E-11	1.4E-10	1.2E-14	3.3E-12	3.0E-13	3.6E-12
U-238	0.91	2.8E-09	8.8E-10	1.2E-10	3.8E-09	2.5E-09	8.0E-10	1.1E-10	3.4E-09	2.5E-09	7.8E-10	1.0E-10	3.4E-09	2.3E-09	7.2E-10	9.5E-11	3.1E-09	3.7E-10	1.2E-10	1.5E-11	5.0E-10	3.3E-10	1.1E-10	1.4E-11	4.5E-10
		Cumulative ELCR				**5.4E-02**	8.2E-06	4.6E-05	**5.4E-02**	Cumulative ELCR				**1.5E-02**	3.7E-06	1.3E-05	**1.5E-02**	Cumulative ELCR				**3.9E-06**	1.3E-06	1.1E-07	**5.3E-06**

Table A-6. Radiological Risk Assessment Results for CERCLA Construction Worker Scenario at C-112 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPC	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	141	6.8E-10	1.4E-09	1.3E-10	2.2E-09	9.6E-08	2.0E-07	1.8E-08	3.1E-07	6.2E-10	1.3E-09	1.2E-10	2.0E-09	8.8E-08	1.8E-07	1.7E-08	2.8E-07	1.4E-10	2.8E-10	2.6E-11	4.5E-10	2.0E-08	4.0E-08	3.7E-09	6.3E-08
C-14	34	1.0E-13	3.6E-12	1.0E-12	4.7E-12	3.5E-12	1.2E-10	3.5E-11	1.6E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	3.49E-05	1.0E-08	1.3E-09	1.2E-10	1.2E-08	3.5E-13	4.7E-14	4.1E-15	4.0E-13	2.8E-09	3.7E-10	3.3E-11	3.2E-09	9.7E-14	1.3E-14	1.1E-15	1.1E-13	1.4E-13	2.4E-12	2.0E-13	2.8E-12	4.8E-18	8.4E-17	6.9E-18	9.6E-17
Cm-244	7.21E-04	3.4E-12	1.3E-09	1.0E-10	1.4E-09	2.4E-15	9.3E-13	7.4E-14	1.0E-12	4.3E-13	1.7E-10	1.3E-11	1.8E-10	3.1E-16	1.2E-13	9.6E-15	1.3E-13	4.8E-15	5.1E-12	4.2E-13	5.5E-12	3.5E-18	3.7E-15	3.0E-16	4.0E-15
Cs-137	11,472	5.8E-08	4.1E-12	3.6E-11	5.8E-08	6.7E-04	4.8E-08	4.1E-07	6.7E-04	1.7E-08	1.2E-12	1.0E-11	1.7E-08	1.9E-04	1.4E-08	1.2E-07	1.9E-04	6.0E-18	4.3E-22	3.7E-21	6.0E-18	6.9E-14	4.9E-18	4.2E-17	6.9E-14
Eu-152	0.036	1.2E-07	6.9E-12	7.8E-12	1.2E-07	4.5E-09	2.5E-13	2.9E-13	4.5E-09	7.7E-09	4.3E-13	4.9E-13	7.7E-09	2.8E-10	1.6E-14	1.8E-14	2.8E-10	6.2E-30	1.2E-23	1.3E-24	1.3E-23	2.3E-31	4.3E-25	4.7E-26	4.8E-25
Eu-154	1.7	1.3E-07	7.3E-12	1.3E-11	1.3E-07	2.2E-07	1.2E-11	2.2E-11	2.2E-07	1.7E-09	9.4E-14	1.7E-13	1.7E-09	2.8E-09	1.5E-13	2.8E-13	2.8E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.25	2.8E-09	6.6E-13	2.5E-12	2.8E-09	7.2E-10	1.7E-13	6.4E-13	7.2E-10	1.1E-12	2.5E-16	9.7E-16	1.1E-12	2.7E-13	6.4E-17	2.5E-16	2.7E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	6.1	1.5E-10	6.1E-12	1.9E-10	3.5E-10	9.3E-10	3.7E-11	1.2E-09	2.1E-09	1.1E-10	4.5E-12	1.4E-10	2.6E-10	7.0E-10	2.8E-11	8.7E-10	1.6E-09	7.0E-13	2.8E-14	8.7E-13	1.6E-12	4.3E-12	1.7E-13	5.3E-12	9.8E-12
Ni-63	11,400	0.0E+00	2.2E-13	9.3E-13	1.1E-12	0.0E+00	2.5E-09	1.1E-08	1.3E-08	0.0E+00	1.5E-13	6.3E-13	7.7E-13	0.0E+00	1.7E-09	7.1E-09	8.8E-09	0.0E+00	1.4E-16	6.0E-16	7.4E-16	0.0E+00	1.6E-12	6.8E-12	8.4E-12
Np-237	0.042	2.1E-08	1.1E-09	8.9E-11	2.2E-08	8.6E-10	4.5E-11	3.7E-12	9.1E-10	2.0E-08	1.1E-09	8.8E-11	2.2E-08	8.6E-10	4.4E-11	3.7E-12	9.0E-10	1.8E-08	9.4E-10	7.8E-11	1.9E-08	7.6E-10	3.9E-11	3.3E-12	8.0E-10
Pu-238	1.7	1.9E-12	1.9E-09	1.6E-10	2.1E-09	3.3E-12	3.3E-09	2.8E-10	3.6E-09	1.2E-12	1.3E-09	1.1E-10	1.4E-09	2.1E-12	2.2E-09	1.8E-10	2.4E-09	5.6E-14	7.8E-13	6.7E-14	9.0E-13	9.8E-14	1.4E-12	1.2E-13	1.6E-12
Pu-239	112	5.2E-12	2.1E-09	1.7E-10	2.2E-09	5.8E-10	2.3E-07	1.9E-08	2.5E-07	5.2E-12	2.1E-09	1.7E-10	2.2E-09	5.8E-10	2.3E-07	1.9E-08	2.5E-07	5.0E-12	2.0E-09	1.6E-10	2.2E-09	5.6E-10	2.2E-07	1.8E-08	2.4E-07
Pu-240	23	1.9E-12	2.1E-09	1.7E-10	2.2E-09	4.5E-11	4.8E-08	3.9E-09	5.2E-08	1.9E-12	2.0E-09	1.7E-10	2.2E-09	4.5E-11	4.8E-08	3.9E-09	5.1E-08	1.7E-12	1.8E-09	1.5E-10	2.0E-09	4.0E-11	4.3E-08	3.5E-09	4.6E-08
Pu-241	47	8.5E-13	3.2E-11	2.2E-12	3.6E-11	4.0E-11	1.5E-09	1.1E-10	1.7E-09	2.0E-11	4.3E-11	3.9E-12	6.7E-11	9.2E-10	2.0E-09	1.8E-10	3.1E-09	4.8E-12	9.6E-12	8.9E-13	1.5E-11	2.2E-10	4.5E-10	4.2E-11	7.2E-10
Sn-126	0.059	2.0E-07	1.6E-11	3.9E-11	2.0E-07	1.2E-08	9.3E-13	2.3E-12	1.2E-08	1.8E-07	1.4E-11	3.4E-11	1.8E-07	1.1E-08	8.1E-13	2.0E-12	1.1E-08	1.8E-08	1.4E-12	3.5E-12	1.8E-08	1.1E-09	8.4E-14	2.1E-13	1.1E-09
Sr-90	9,516	4.5E-10	1.6E-11	9.1E-11	5.6E-10	4.3E-06	1.5E-07	8.6E-07	5.3E-06	1.2E-10	4.3E-12	2.5E-11	1.5E-10	1.2E-06	4.1E-08	2.3E-07	1.4E-06	1.4E-20	4.9E-22	2.8E-21	1.7E-20	1.3E-16	4.7E-18	2.7E-17	1.6E-16
U-233	4.92E-07	1.9E-11	1.0E-09	9.3E-11	1.2E-09	9.1E-18	5.2E-16	4.6E-17	5.7E-16	1.5E-10	9.8E-10	8.7E-11	1.2E-09	7.2E-17	4.8E-16	4.3E-17	6.0E-16	1.0E-09	4.6E-10	3.8E-11	1.5E-09	5.0E-16	2.3E-16	1.9E-17	7.5E-16
U-234	0.22	6.9E-12	1.0E-09	9.2E-11	1.1E-09	1.5E-12	2.3E-10	2.0E-11	2.5E-10	7.3E-12	9.2E-10	8.2E-11	1.0E-09	1.6E-12	2.0E-10	1.8E-11	2.2E-10	1.9E-10	1.4E-10	1.6E-11	3.4E-10	4.1E-11	3.1E-11	3.5E-12	7.6E-11
U-235	0.0094	1.4E-08	9.3E-10	9.4E-11	1.5E-08	1.3E-10	8.8E-12	8.9E-13	1.4E-10	1.3E-08	8.4E-10	8.5E-11	1.3E-08	1.2E-10	7.9E-12	8.0E-13	1.3E-10	2.2E-09	2.2E-10	2.0E-11	2.4E-09	2.1E-11	2.0E-12	1.9E-13	2.3E-11
U-236	0.0050	3.4E-12	9.5E-10	8.7E-11	1.0E-09	1.7E-14	4.8E-12	4.4E-13	5.3E-12	3.0E-12	8.5E-10	7.8E-11	9.3E-10	1.5E-14	4.3E-12	3.9E-13	4.7E-12	4.5E-13	1.3E-10	1.1E-11	1.4E-10	2.3E-15	6.3E-13	5.8E-14	6.9E-13
U-238	0.23	2.8E-09	8.8E-10	1.2E-10	3.8E-09	6.3E-10	2.0E-10	2.6E-11	8.6E-10	2.5E-09	7.8E-10	1.0E-10	3.4E-09	5.7E-10	1.8E-10	2.4E-11	7.7E-10	3.7E-10	1.2E-10	1.5E-11	5.0E-10	8.4E-11	2.6E-11	3.5E-12	1.1E-10
				Cumulative ELCR		**6.7E-04**	6.8E-07	1.3E-06	**6.8E-04**			**Cumulative ELCR**		**1.9E-04**	5.2E-07	4.0E-07	**2.0E-04**			**Cumulative ELCR**		**2.2E-08**	3.1E-07	2.5E-08	**3.5E-07**

Table A-7. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-101 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPCs	EPC (pCi/g)	DSR (mrem/yr per pCi/g)				Dose (mrem/yr)				RSR (1/(pCi/g)				Risk (unitless)				DSR (mrem/yr per pCi/g)				Dose (mrem/yr)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
A	9,490	9.1E-04	1.3E-02	7.3E-04	1.5E-02	8.7E+00	1.3E+02	6.9E+00	1.4E+02	8.4E-04	1.2E-02	6.7E-04	1.4E-02	7.9E+00	1.2E+02	6.3E+00	1.3E+02	1.9E-04	2.7E-03	1.5E-04	3.0E-03	1.8E+00	2.5E+01	1.4E+00	2.8E+01
C-14	2,347	1.4E-07	4.2E-06	1.1E-06	5.4E-06	3.3E-04	9.8E-03	2.6E-03	1.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.017	1.3E-02	9.5E-03	5.3E-04	2.3E-02	2.2E-04	1.6E-04	9.0E-06	3.9E-04	3.5E-03	2.6E-03	1.5E-04	6.3E-03	6.0E-05	4.5E-05	2.5E-06	1.1E-04	1.8E-07	1.9E-05	1.1E-06	2.0E-05	3.0E-09	3.3E-07	1.8E-08	3.5E-07
Cm-244	0.36	4.8E-06	7.7E-03	4.3E-04	8.1E-03	1.7E-06	2.7E-03	1.5E-04	2.9E-03	6.2E-07	1.0E-03	5.7E-05	1.1E-03	2.2E-07	3.6E-04	2.0E-05	3.8E-04	7.6E-09	4.1E-05	2.2E-06	4.3E-05	2.7E-09	1.4E-05	7.9E-07	1.5E-05
Cs-137	6.57E+06	7.3E-02	5.4E-06	4.8E-05	7.3E-02	4.8E+05	3.5E+01	3.1E+02	4.8E+05	2.1E-02	1.5E-06	1.4E-05	2.1E-02	1.4E+05	1.0E+01	9.1E+01	1.4E+05	7.6E-12	5.5E-16	5.0E-15	7.6E-12	5.0E-05	3.6E-09	3.3E-08	5.0E-05
Eu-152	17	1.5E-01	1.2E-05	4.7E-06	1.5E-01	2.6E+00	2.1E-04	7.8E-05	2.6E+00	9.5E-03	7.8E-07	2.9E-07	9.5E-03	1.6E-01	1.3E-05	4.9E-06	1.6E-01	7.8E-24	9.1E-17	5.1E-18	9.6E-17	1.3E-22	1.5E-15	8.5E-17	1.6E-15
Eu-154	773	1.6E-01	1.4E-05	6.7E-06	1.6E-01	1.3E+02	1.1E-02	5.2E-03	1.3E+02	2.1E-03	1.8E-07	8.6E-08	2.1E-03	1.6E+00	1.4E-04	6.6E-05	1.6E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	123	3.7E-03	1.6E-06	1.1E-06	3.7E-03	4.6E-01	2.0E-04	1.4E-04	4.6E-01	1.4E-06	6.1E-10	4.2E-10	1.4E-06	1.7E-04	7.5E-08	5.2E-08	1.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	406	2.4E-04	1.3E-05	3.8E-04	6.4E-04	9.7E-02	5.5E-03	1.6E-01	2.6E-01	1.8E-04	1.0E-05	2.9E-04	4.8E-04	7.2E-02	4.1E-03	1.2E-01	1.9E-01	1.1E-06	6.2E-08	1.8E-06	2.9E-06	4.4E-04	2.5E-05	7.2E-04	1.2E-03
Ni-63	753,741	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	2.1E-01	4.2E-01	6.2E-01	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	1.4E-01	2.8E-01	4.2E-01	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	1.3E-04	2.7E-04	4.0E-04
Np-237	15	2.6E-02	6.8E-03	3.9E-04	3.3E-02	3.9E-01	1.0E-01	5.7E-03	5.0E-01	2.6E-02	6.8E-03	3.8E-04	3.3E-02	3.9E-01	1.0E-01	5.7E-03	4.9E-01	2.3E-02	6.0E-03	3.4E-04	2.9E-02	3.4E-01	8.9E-02	5.0E-03	4.4E-01
Pu-238	118	3.0E-06	1.5E-02	8.1E-04	1.6E-02	3.6E-04	1.7E+00	9.5E-02	1.8E+00	2.0E-06	9.6E-03	5.3E-04	1.0E-02	2.3E-04	1.1E+00	6.2E-02	1.2E+00	7.1E-08	5.5E-06	3.1E-07	5.9E-06	8.3E-06	6.5E-04	3.7E-05	7.0E-04
Pu-239	7,519	6.8E-06	1.6E-02	9.0E-04	1.7E-02	5.1E-02	1.2E+02	6.7E+00	1.3E+02	6.8E-06	1.6E-02	8.9E-04	1.7E-02	5.1E-02	1.2E+02	6.7E+00	1.3E+02	6.6E-06	1.6E-02	8.7E-04	1.7E-02	5.0E-02	1.2E+02	6.5E+00	1.3E+02
Pu-240	1,564	3.1E-06	1.6E-02	9.0E-04	1.7E-02	4.8E-03	2.6E+01	1.4E+00	2.7E+01	3.0E-06	1.6E-02	8.9E-04	1.7E-02	4.8E-03	2.5E+01	1.4E+00	2.7E+01	2.7E-06	1.5E-02	8.0E-04	1.5E-02	4.3E-03	2.3E+01	1.3E+00	2.4E+01
Pu-241	3,146	1.1E-06	3.2E-04	1.7E-05	3.3E-04	3.5E-03	1.0E+00	5.4E-02	1.1E+00	2.7E-05	4.1E-04	2.2E-05	4.6E-04	8.3E-02	1.3E+00	7.0E-02	1.4E+00	6.4E-06	9.1E-05	5.0E-06	1.0E-04	2.0E-02	2.9E-01	1.6E-02	3.2E-01
Sn-126	33	2.6E-01	2.2E-05	1.9E-05	2.6E-01	8.5E+00	7.2E-04	6.2E-04	8.5E+00	2.3E-01	1.9E-05	1.6E-05	2.3E-01	7.5E+00	6.3E-04	5.4E-04	7.5E+00	2.3E-02	2.0E-06	1.7E-06	2.3E-02	7.7E-01	6.5E-05	5.6E-05	7.7E-01
Sr-90	677,789	9.4E-04	2.1E-05	1.1E-04	1.1E-03	6.4E+02	1.5E+01	7.2E+01	7.2E+02	2.5E-04	5.8E-06	2.9E-05	2.9E-04	1.7E+02	3.9E+00	2.0E+01	2.0E+02	2.9E-14	6.6E-16	3.3E-15	3.3E-14	2.0E-08	4.5E-10	2.2E-09	2.2E-08
U-233	1.76E-04	2.4E-05	1.3E-03	1.8E-04	1.5E-03	4.2E-09	2.3E-07	3.2E-08	2.7E-07	1.9E-04	1.3E-03	1.7E-04	1.7E-03	3.3E-08	2.4E-07	3.1E-08	3.0E-07	1.3E-03	1.5E-03	1.1E-04	2.9E-03	2.3E-07	2.6E-07	1.9E-08	5.1E-07
U-234	15	9.4E-06	1.3E-03	1.8E-04	1.5E-03	1.4E-04	1.9E-02	2.6E-03	2.2E-02	9.8E-06	1.2E-03	1.6E-04	1.3E-03	1.5E-04	1.7E-02	2.4E-03	2.0E-02	2.3E-04	2.3E-04	3.3E-05	4.9E-04	3.5E-03	3.4E-03	5.0E-04	7.3E-03
U-235	0.64	1.8E-02	1.2E-03	1.7E-04	1.9E-02	1.1E-02	7.4E-04	1.1E-04	1.2E-02	1.6E-02	1.1E-03	1.5E-04	1.7E-02	1.0E-02	6.9E-04	9.7E-05	1.1E-02	2.8E-03	6.4E-04	5.1E-05	3.5E-03	1.8E-03	4.1E-04	3.2E-05	2.2E-03
U-236	0.34	4.8E-06	1.2E-03	1.7E-04	1.4E-03	1.6E-06	4.0E-04	5.6E-05	4.6E-04	4.3E-06	1.1E-03	1.5E-04	1.2E-03	1.5E-06	3.6E-04	5.0E-05	4.1E-04	6.4E-07	1.6E-04	2.2E-05	1.8E-04	2.2E-07	5.3E-05	7.4E-06	6.1E-05
U-238	15	3.8E-03	1.1E-03	1.7E-04	5.1E-03	5.8E-02	1.7E-02	2.6E-03	7.8E-02	3.4E-03	9.9E-04	1.5E-04	4.5E-03	5.2E-02	1.5E-02	2.3E-03	7.0E-02	5.0E-04	1.5E-04	2.3E-05	6.7E-04	7.7E-03	2.2E-03	3.5E-04	1.0E-02
		Cumulative Dose				**4.8E+05**	3.3E+02	4.0E+02	**4.8E+05**	**Cumulative Dose**				**1.4E+05**	2.8E+02	1.3E+02	**1.4E+05**	**Cumulative Dose**				**3.0E+00**	1.7E+02	9.2E+00	**1.8E+02**

Table A-8. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-104 (No Soil Cover)

		T=0 Year								**T=54 Year**								**T=1000 Year**							
COPCs	**EPC (pCi/g)**	**DSR (mrem/yr per pCi/g)**				**Dose (mrem/yr)**				**RSR (1/(pCi/g)**				**Risk (unitless)**				**DSR (mrem/yr per pCi/g)**				**Dose (mrem/yr)**			
		Ground	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**	**Ground**	**Inhalation**	**Soil**	**Total**
Am-241	183	9.1E-04	1.3E-02	7.3E-04	1.5E-02	1.7E-01	2.4E+00	1.3E-01	2.7E+00	8.4E-04	1.2E-02	6.7E-04	1.4E-02	1.5E-01	2.2E+00	1.2E-01	2.5E+00	1.9E-04	2.7E-03	1.5E-04	3.0E-03	3.4E-02	4.8E-01	2.7E-02	5.5E-01
C-14	45	1.4E-07	4.2E-06	1.1E-06	5.4E-06	6.3E-06	1.9E-04	4.9E-05	2.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	4.52E-05	1.3E-02	9.5E-03	5.3E-04	2.3E-02	5.8E-07	4.3E-07	2.4E-08	1.0E-06	3.5E-03	2.6E-03	1.5E-04	6.3E-03	1.6E-07	1.2E-07	6.6E-09	2.9E-07	1.8E-07	1.9E-05	1.1E-06	2.0E-05	8.0E-12	8.7E-10	4.8E-11	9.2E-10
Cm-244	9.34E-04	4.8E-06	7.7E-03	4.3E-04	8.1E-03	4.5E-09	7.2E-06	4.0E-07	7.6E-06	6.2E-07	1.0E-03	5.7E-05	1.1E-03	5.8E-10	9.4E-07	5.3E-08	1.0E-06	7.6E-09	4.1E-05	2.2E-06	4.3E-05	7.1E-12	3.8E-08	2.1E-09	4.0E-08
Cs-137	14,865	7.3E-02	5.4E-06	4.8E-05	7.3E-02	1.1E+03	8.0E-02	7.1E-01	1.1E+03	2.1E-02	1.5E-06	1.4E-05	2.1E-02	3.1E+02	2.3E-02	2.1E-01	3.1E+02	7.6E-12	5.5E-16	5.0E-15	7.6E-12	1.1E-07	8.2E-12	7.4E-11	1.1E-07
Eu-152	0.047	1.5E-01	1.2E-05	4.7E-06	1.5E-01	7.2E-03	5.9E-07	2.2E-07	7.2E-03	9.5E-03	7.8E-07	2.9E-07	9.5E-03	4.5E-04	3.7E-08	1.4E-08	4.5E-04	7.8E-24	9.1E-17	5.1E-18	9.6E-17	3.7E-25	4.3E-18	2.4E-19	4.5E-18
Eu-154	2.1	1.6E-01	1.4E-05	6.7E-06	1.6E-01	3.5E-01	3.0E-05	1.4E-05	3.5E-01	2.1E-03	1.8E-07	8.6E-08	2.1E-03	4.4E-03	3.8E-07	1.8E-07	4.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.33	3.7E-03	1.6E-06	1.1E-06	3.7E-03	1.2E-03	5.2E-07	3.6E-07	1.2E-03	1.4E-06	6.1E-10	4.2E-10	1.4E-06	4.6E-07	2.0E-10	1.4E-10	4.6E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	8.0	2.4E-04	1.3E-05	3.8E-04	6.4E-04	1.9E-03	1.1E-04	3.1E-03	5.1E-03	1.8E-04	1.0E-05	2.9E-04	4.8E-04	1.4E-03	8.0E-05	2.3E-03	3.8E-03	1.1E-06	6.2E-08	1.8E-06	2.9E-06	8.7E-06	4.9E-07	1.4E-05	2.3E-05
Ni-63	14,771	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	4.0E-03	8.1E-03	1.2E-02	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	2.7E-03	5.5E-03	8.2E-03	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	2.6E-06	5.2E-06	7.8E-06
Np-237	0.054	2.6E-02	6.8E-03	3.9E-04	3.3E-02	1.4E-03	3.7E-04	2.1E-05	1.8E-03	2.6E-02	6.8E-03	3.8E-04	3.3E-02	1.4E-03	3.7E-04	2.1E-05	1.8E-03	2.3E-02	6.0E-03	3.4E-04	2.9E-02	1.2E-03	3.3E-04	1.8E-05	1.6E-03
Pu-238	2.2	3.0E-06	1.5E-02	8.1E-04	1.6E-02	6.8E-06	3.3E-02	1.8E-03	3.5E-02	2.0E-06	9.6E-03	5.3E-04	1.0E-02	4.4E-06	2.2E-02	1.2E-03	2.3E-02	7.1E-08	5.5E-06	3.1E-07	5.9E-06	1.6E-07	1.2E-05	7.0E-07	1.3E-05
Pu-239	145	6.8E-06	1.6E-02	9.0E-04	1.7E-02	9.9E-04	2.4E+00	1.3E-01	2.5E+00	6.8E-06	1.6E-02	8.9E-04	1.7E-02	9.9E-04	2.4E+00	1.3E-01	2.5E+00	6.6E-06	1.6E-02	8.7E-04	1.7E-02	9.6E-04	2.3E+00	1.3E-01	2.4E+00
Pu-240	30	3.1E-06	1.6E-02	9.0E-04	1.7E-02	9.2E-05	4.9E-01	2.7E-02	5.2E-01	3.0E-06	1.6E-02	8.9E-04	1.7E-02	9.2E-05	4.9E-01	2.7E-02	5.2E-01	2.7E-06	1.5E-02	8.0E-04	1.5E-02	8.3E-05	4.4E-01	2.4E-02	4.7E-01
Pu-241	61	1.1E-06	3.2E-04	1.7E-05	3.3E-04	6.8E-05	1.9E-02	1.0E-03	2.0E-02	2.7E-05	4.1E-04	2.2E-05	4.6E-04	1.6E-03	2.5E-02	1.4E-03	2.8E-02	6.4E-06	9.1E-05	5.0E-06	1.0E-04	3.9E-04	5.5E-03	3.0E-04	6.2E-03
Sn-126	0.076	2.6E-01	2.2E-05	1.9E-05	2.6E-01	2.0E-02	1.7E-06	1.4E-06	2.0E-02	2.3E-01	1.9E-05	1.6E-05	2.3E-01	1.7E-02	1.5E-06	1.2E-06	1.7E-02	2.3E-02	2.0E-06	1.7E-06	2.3E-02	1.8E-03	1.5E-07	1.3E-07	1.8E-03
Sr-90	12,330	9.4E-04	2.1E-05	1.1E-04	1.1E-03	1.2E+01	2.6E-01	1.3E+00	1.3E+01	2.5E-04	5.8E-06	2.9E-05	2.9E-04	3.1E+00	7.1E-02	3.6E-01	3.6E+00	2.9E-14	6.6E-16	3.3E-15	3.3E-14	3.6E-10	8.1E-12	4.0E-11	4.0E-10
U-233	6.37E-07	2.4E-05	1.3E-03	1.8E-04	1.5E-03	1.5E-11	8.4E-10	1.2E-10	9.7E-10	1.9E-04	1.3E-03	1.7E-04	1.7E-03	1.2E-10	8.6E-10	1.1E-10	1.1E-09	1.3E-03	1.5E-03	1.1E-04	2.9E-03	8.3E-10	9.6E-10	7.0E-11	1.9E-09
U-234	0.29	9.4E-06	1.3E-03	1.8E-04	1.5E-03	2.7E-06	3.7E-04	5.1E-05	4.2E-04	9.8E-06	1.2E-03	1.6E-04	1.3E-03	2.8E-06	3.3E-04	4.5E-05	3.8E-04	2.3E-04	2.3E-04	3.3E-05	4.9E-04	6.7E-05	6.5E-05	9.5E-06	1.4E-04
U-235	0.012	1.8E-02	1.2E-03	1.7E-04	1.9E-02	2.2E-04	1.4E-05	2.1E-06	2.3E-04	1.6E-02	1.1E-03	1.5E-04	1.7E-02	2.0E-04	1.3E-05	1.9E-06	2.1E-04	2.8E-03	6.4E-04	5.1E-05	3.5E-03	3.4E-05	7.8E-06	6.2E-07	4.3E-05
U-236	0.0065	4.8E-06	1.2E-03	1.7E-04	1.4E-03	3.1E-08	7.8E-06	1.1E-06	8.9E-06	4.3E-06	1.1E-03	1.5E-04	1.2E-03	2.8E-08	7.0E-06	9.7E-07	8.0E-06	6.4E-07	1.6E-04	2.2E-05	1.8E-04	4.2E-09	1.0E-06	1.4E-07	1.2E-06
U-238	0.29	3.8E-03	1.1E-03	1.7E-04	5.1E-03	1.1E-03	3.2E-04	5.0E-05	1.5E-03	3.4E-03	9.9E-04	1.5E-04	4.5E-03	1.0E-03	2.9E-04	4.5E-05	1.3E-03	5.0E-04	1.5E-04	2.3E-05	6.7E-04	1.5E-04	4.3E-05	6.6E-06	2.0E-04
					Cumulative Dose	**1.1E+03**	5.7E+00	2.3E+00	**1.1E+03**				**Cumulative Dose**	**3.2.E+02**	5.2.E+00	8.5.E-01	**3.2.E+02**				**Cumulative Dose**	**3.9.E-02**	3.2.E+00	1.8.E-01	**3.4.E+00**

Table A-9. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-105 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
		DSR (mrem/yr per pCi/g)				Dose (mrem/yr)				RSR (1/(pCi/g)				Risk (unitless)				DSR (mrem/yr per pCi/g)				Dose (mrem/yr)			
COPCs	EPC (pCi/g)	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	365	9.1E-04	1.3E-02	7.3E-04	1.5E-02	3.3E-01	4.8E+00	2.7E-01	5.4E+00	8.4E-04	1.2E-02	6.7E-04	1.4E-02	3.1E-01	4.4E+00	2.4E-01	5.0E+00	1.9E-04	2.7E-03	1.5E-04	3.0E-03	6.8E-02	9.7E-01	5.3E-02	1.1E+00
C-14	166	1.4E-07	4.2E-06	1.1E-06	5.4E-06	2.4E-05	6.9E-04	1.8E-04	9.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.031	1.3E-02	9.5E-03	5.3E-04	2.3E-02	4.0E-04	3.0E-04	1.6E-05	7.1E-04	3.5E-03	2.6E-03	1.5E-04	6.3E-03	1.1E-04	8.2E-05	4.6E-06	2.0E-04	1.8E-07	1.9E-05	1.1E-06	2.0E-05	5.5E-09	6.0E-07	3.3E-08	6.4E-07
Cm-244	0.58	4.8E-06	7.7E-03	4.3E-04	8.1E-03	2.8E-06	4.4E-03	2.5E-04	4.7E-03	6.2E-07	1.0E-03	5.7E-05	1.1E-03	3.6E-07	5.9E-04	3.3E-05	6.2E-04	7.6E-09	4.1E-05	2.2E-06	4.3E-05	4.4E-09	2.4E-05	1.3E-06	2.5E-05
Cs-137	2.80E+07	7.3E-02	5.4E-06	4.8E-05	7.3E-02	2.1E+06	1.5E+02	1.3E+03	2.1E+06	2.1E-02	1.5E-06	1.4E-05	2.1E-02	5.9E+05	4.3E+01	3.9E+02	5.9E+05	7.6E-12	5.5E-16	5.0E-15	7.6E-12	2.1E-04	1.6E-08	1.4E-07	2.1E-04
Eu-152	25	1.5E-01	1.2E-05	4.7E-06	1.5E-01	3.8E+00	3.1E-04	1.2E-04	3.8E+00	9.5E-03	7.8E-07	2.9E-07	9.5E-03	2.4E-01	2.0E-05	7.3E-06	2.4E-01	7.8E-24	9.1E-17	5.1E-18	9.6E-17	1.9E-22	2.3E-15	1.3E-16	2.4E-15
Eu-154	1,250	1.6E-01	1.4E-05	6.7E-06	1.6E-01	2.0E+02	1.8E-02	8.4E-03	2.0E+02	2.1E-03	1.8E-07	8.6E-08	2.1E-03	2.6E+00	2.2E-04	1.1E-04	2.6E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	244	3.7E-03	1.6E-06	1.1E-06	3.7E-03	9.0E-01	3.9E-04	2.7E-04	9.0E-01	1.4E-06	6.1E-10	4.2E-10	1.4E-06	3.4E-04	1.5E-07	1.0E-07	3.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	0.57	2.4E-04	1.3E-05	3.8E-04	6.4E-04	1.3E-04	7.6E-06	2.2E-04	3.6E-04	1.8E-04	1.0E-05	2.9E-04	4.8E-04	1.0E-04	5.7E-06	1.6E-04	2.7E-04	1.1E-06	6.2E-08	1.8E-06	2.9E-06	6.2E-07	3.5E-08	1.0E-06	1.7E-06
Ni-63	6,437	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	1.8E-03	3.5E-03	5.3E-03	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	1.2E-03	2.4E-03	3.6E-03	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	1.1E-06	2.3E-06	3.4E-06
Np-237	25	2.6E-02	6.8E-03	3.9E-04	3.3E-02	6.6E-01	1.7E-01	9.8E-03	8.5E-01	2.6E-02	6.8E-03	3.8E-04	3.3E-02	6.6E-01	1.7E-01	9.7E-03	8.4E-01	2.3E-02	6.0E-03	3.4E-04	2.9E-02	5.8E-01	1.5E-01	8.6E-03	7.5E-01
Pu-238	12	3.0E-06	1.5E-02	8.1E-04	1.6E-02	3.6E-05	1.8E-01	9.6E-03	1.9E-01	2.0E-06	9.6E-03	5.3E-04	1.0E-02	2.3E-05	1.1E-01	6.3E-03	1.2E-01	7.1E-08	5.5E-06	3.1E-07	5.9E-06	8.4E-07	6.6E-05	3.7E-06	7.0E-05
Pu-239	280	6.8E-06	1.6E-02	9.0E-04	1.7E-02	1.9E-03	4.6E+00	2.5E-01	4.8E+00	6.8E-06	1.6E-02	8.9E-04	1.7E-02	1.9E-03	4.6E+00	2.5E-01	4.8E+00	6.6E-06	1.6E-02	8.7E-04	1.7E-02	1.9E-03	4.4E+00	2.4E-01	4.7E+00
Pu-240	69	3.1E-06	1.6E-02	9.0E-04	1.7E-02	2.1E-04	1.1E+00	6.1E-02	1.2E+00	3.0E-06	1.6E-02	8.9E-04	1.7E-02	2.1E-04	1.1E+00	6.1E-02	1.2E+00	2.7E-06	1.5E-02	8.0E-04	1.5E-02	1.9E-04	1.0E+00	5.5E-02	1.1E+00
Pu-241	283	1.1E-06	3.2E-04	1.7E-05	3.3E-04	3.2E-04	9.0E-02	4.8E-03	9.5E-02	2.7E-05	4.1E-04	2.2E-05	4.6E-04	7.5E-03	1.2E-01	6.3E-03	1.3E-01	6.4E-06	9.1E-05	5.0E-06	1.0E-04	1.8E-03	2.6E-02	1.4E-03	2.9E-02
Sn-126	126	2.6E-01	2.2E-05	1.9E-05	2.6E-01	3.2E+01	2.8E-03	2.3E-03	3.2E+01	2.3E-01	1.9E-05	1.6E-05	2.3E-01	2.8E+01	2.4E-03	2.1E-03	2.8E+01	2.3E-02	2.0E-06	1.7E-06	2.3E-02	2.9E+00	2.5E-04	2.1E-04	2.9E+00
Sr-90	93,943	9.4E-04	2.1E-05	1.1E-04	1.1E-03	8.8E+01	2.0E+00	1.0E+01	1.0E+02	2.5E-04	5.8E-06	2.9E-05	2.9E-04	2.4E+01	5.4E-01	2.7E+00	2.7E+01	2.9E-14	6.6E-16	3.3E-15	3.3E-14	2.7E-09	6.2E-11	3.1E-10	3.1E-09
U-233	8.36E-05	2.4E-05	1.3E-03	1.8E-04	1.5E-03	2.0E-09	1.1E-07	1.5E-08	1.3E-07	1.9E-04	1.3E-03	1.7E-04	1.7E-03	1.6E-08	1.1E-07	1.5E-08	1.4E-07	1.3E-03	1.5E-03	1.1E-04	2.9E-03	1.1E-07	1.3E-07	9.2E-09	2.4E-07
U-234	0.59	9.4E-06	1.3E-03	1.8E-04	1.5E-03	5.6E-06	7.6E-04	1.0E-04	8.7E-04	9.8E-06	1.2E-03	1.6E-04	1.3E-03	5.8E-06	6.9E-04	9.3E-05	7.8E-04	2.3E-04	2.3E-04	3.3E-05	4.9E-04	1.4E-04	1.3E-04	2.0E-05	2.9E-04
U-235	0.025	1.8E-02	1.2E-03	1.7E-04	1.9E-02	4.4E-04	2.9E-05	4.1E-06	4.7E-04	1.6E-02	1.1E-03	1.5E-04	1.7E-02	3.9E-04	2.7E-05	3.8E-06	4.2E-04	2.8E-03	6.4E-04	5.1E-05	3.5E-03	6.9E-05	1.6E-05	1.2E-06	8.6E-05
U-236	0.015	4.8E-06	1.2E-03	1.7E-04	1.4E-03	7.2E-08	1.8E-05	2.5E-06	2.1E-05	4.3E-06	1.1E-03	1.5E-04	1.2E-03	6.5E-08	1.6E-05	2.2E-06	1.8E-05	6.4E-07	1.6E-04	2.2E-05	1.8E-04	9.6E-09	2.4E-06	3.3E-07	2.7E-06
U-238	0.58	3.8E-03	1.1E-03	1.7E-04	5.1E-03	2.2E-03	6.3E-04	9.8E-05	2.9E-03	3.4E-03	9.9E-04	1.5E-04	4.5E-03	2.0E-03	5.7E-04	8.8E-05	2.6E-03	5.0E-04	1.5E-04	2.3E-05	6.7E-04	2.9E-04	8.4E-05	1.3E-05	3.9E-04
		Cumulative Dose				**2.1E+06**	1.6E+02	1.4E+03	**2.1E+06**	**Cumulative Dose**				**5.9E+05**	5.4E+01	3.9E+02	**5.9E+05**	**Cumulative Dose**				**3.6E+00**	6.6E+00	3.6E-01	**1.1E+01**

Table A-10. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-108 (No Soil Cover)

COPCs	EPC (pCi/g)	T=0 Year								T=54 Year								T=1000 Year							
		DSR (mrem/yr per pCi/g)				Dose (mrem/yr)				RSR (1/(pCi/g))				Risk (unitless)				DSR (mrem/yr per pCi/g)				Dose (mrem/yr)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	148	9.1E-04	1.3E-02	7.3E-04	1.5E-02	1.4E-01	2.0E+00	1.1E-01	2.2E+00	8.4E-04	1.2E-02	6.7E-04	1.4E-02	1.2E-01	1.8E+00	9.9E-02	2.0E+00	1.9E-04	2.7E-03	1.5E-04	3.0E-03	2.8E-02	3.9E-01	2.2E-02	4.4E-01
C-14	36	1.4E-07	4.2E-06	1.1E-06	5.4E-06	5.1E-06	1.5E-04	4.0E-05	2.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	3.67E-05	1.3E-02	9.5E-03	5.3E-04	2.3E-02	4.7E-07	3.5E-07	1.9E-08	8.4E-07	3.5E-03	2.6E-03	1.5E-04	6.3E-03	1.3E-07	9.7E-08	5.4E-09	2.3E-07	1.8E-07	1.9E-05	1.1E-06	2.0E-05	6.5E-12	7.1E-10	3.9E-11	7.5E-10
Cm-244	7.58E-04	4.8E-06	7.7E-03	4.3E-04	8.1E-03	3.7E-09	5.8E-06	3.3E-07	6.2E-06	6.2E-07	1.0E-03	5.7E-05	1.1E-03	4.7E-10	7.7E-07	4.3E-08	8.1E-07	7.6E-09	4.1E-05	2.2E-06	4.3E-05	5.8E-12	3.1E-08	1.7E-09	3.2E-08
Cs-137	12,065	7.3E-02	5.4E-06	4.8E-05	7.3E-02	8.8E+02	6.5E-02	5.8E-01	8.8E+02	2.1E-02	1.5E-06	1.4E-05	2.1E-02	2.6E+02	1.9E-02	1.7E-01	2.6E+02	7.6E-12	5.5E-16	5.0E-15	7.6E-12	9.2E-08	6.7E-12	6.0E-11	9.2E-08
Eu-152	0.038	1.5E-01	1.2E-05	4.7E-06	1.5E-01	5.9E-03	4.8E-07	1.8E-07	5.9E-03	9.5E-03	7.8E-07	2.9E-07	9.5E-03	3.7E-04	3.0E-08	1.1E-08	3.7E-04	7.8E-24	9.1E-17	5.1E-18	9.6E-17	3.0E-25	3.5E-18	2.0E-19	3.7E-18
Eu-154	1.7	1.6E-01	1.4E-05	6.7E-06	1.6E-01	2.8E-01	2.4E-05	1.2E-05	2.8E-01	2.1E-03	1.8E-07	8.6E-08	2.1E-03	3.6E-03	3.1E-07	1.5E-07	3.6E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.27	3.7E-03	1.6E-06	1.1E-06	3.7E-03	9.8E-04	4.2E-07	2.9E-07	9.8E-04	1.4E-06	6.1E-10	4.2E-10	1.4E-06	3.8E-07	1.6E-10	1.1E-10	3.8E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	6.5	2.4E-04	1.3E-05	3.8E-04	6.4E-04	1.5E-03	8.7E-05	2.5E-03	4.1E-03	1.8E-04	1.0E-05	2.9E-04	4.8E-04	1.2E-03	6.5E-05	1.9E-03	3.1E-03	1.1E-06	6.2E-08	1.8E-06	2.9E-06	7.1E-06	4.0E-07	1.1E-05	1.9E-05
Ni-63	11,989	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	3.3E-03	6.6E-03	9.9E-03	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	2.2E-03	4.4E-03	6.6E-03	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	2.1E-06	4.2E-06	6.3E-06
Np-237	0.044	2.6E-02	6.8E-03	3.9E-04	3.3E-02	1.2E-03	3.0E-04	1.7E-05	1.5E-03	2.6E-02	6.8E-03	3.8E-04	3.3E-02	1.1E-03	3.0E-04	1.7E-05	1.5E-03	2.3E-02	6.0E-03	3.4E-04	2.9E-02	1.0E-03	2.6E-04	1.5E-05	1.3E-03
Pu-238	1.8	3.0E-06	1.5E-02	8.1E-04	1.6E-02	5.5E-06	2.7E-02	1.5E-03	2.8E-02	2.0E-06	9.6E-03	5.3E-04	1.0E-02	3.6E-06	1.8E-02	9.7E-04	1.9E-02	7.1E-08	5.5E-06	3.1E-07	5.9E-06	1.3E-07	1.0E-05	5.7E-07	1.1E-05
Pu-239	117	6.8E-06	1.6E-02	9.0E-04	1.7E-02	8.0E-04	1.9E+00	1.1E-01	2.0E+00	6.8E-06	1.6E-02	8.9E-04	1.7E-02	8.0E-04	1.9E+00	1.0E-01	2.0E+00	6.6E-06	1.6E-02	8.7E-04	1.7E-02	7.8E-04	1.9E+00	1.0E-01	2.0E+00
Pu-240	24	3.1E-06	1.6E-02	9.0E-04	1.7E-02	7.5E-05	4.0E-01	2.2E-02	4.2E-01	3.0E-06	1.6E-02	8.9E-04	1.7E-02	7.4E-05	4.0E-01	2.2E-02	4.2E-01	2.7E-06	1.5E-02	8.0E-04	1.5E-02	6.7E-05	3.6E-01	2.0E-02	3.8E-01
Pu-241	49	1.1E-06	3.2E-04	1.7E-05	3.3E-04	5.5E-05	1.6E-02	8.4E-04	1.6E-02	2.7E-05	4.1E-04	2.2E-05	4.6E-04	1.3E-03	2.0E-02	1.1E-03	2.2E-02	6.4E-06	9.1E-05	5.0E-06	1.0E-04	3.2E-04	4.5E-03	2.5E-04	5.0E-03
Sn-126	0.062	2.6E-01	2.2E-05	1.9E-05	2.6E-01	1.6E-02	1.4E-06	1.2E-06	1.6E-02	2.3E-01	1.9E-05	1.6E-05	2.3E-01	1.4E-02	1.2E-06	1.0E-06	1.4E-02	2.3E-02	2.0E-06	1.7E-06	2.3E-02	1.4E-03	1.2E-07	1.0E-07	1.4E-03
Sr-90	10,008	9.4E-04	2.1E-05	1.1E-04	1.1E-03	9.4E+00	2.1E-01	1.1E+00	1.1E+01	2.5E-04	5.8E-06	2.9E-05	2.9E-04	2.5E+00	5.8E-02	2.9E-01	2.9E+00	2.9E-14	6.6E-16	3.3E-15	3.3E-14	2.9E-10	6.6E-12	3.3E-11	3.3E-10
U-233	5.17E-07	2.4E-05	1.3E-03	1.8E-04	1.5E-03	1.2E-11	6.8E-10	9.4E-11	7.9E-10	1.9E-04	1.3E-03	1.7E-04	1.7E-03	9.6E-11	7.0E-10	9.0E-11	8.8E-10	1.3E-03	1.5E-03	1.1E-04	2.9E-03	6.7E-10	7.8E-10	5.7E-11	1.5E-09
U-234	0.23	9.4E-06	1.3E-03	1.8E-04	1.5E-03	2.2E-06	3.0E-04	4.1E-05	3.4E-04	9.8E-06	1.2E-03	1.6E-04	1.3E-03	2.3E-06	2.7E-04	3.7E-05	3.1E-04	2.3E-04	2.3E-04	3.3E-05	4.9E-04	5.4E-05	5.3E-05	7.7E-06	1.1E-04
U-235	0.0099	1.8E-02	1.2E-03	1.7E-04	1.9E-02	1.8E-04	1.2E-05	1.7E-06	1.9E-04	1.6E-02	1.1E-03	1.5E-04	1.7E-02	1.6E-04	1.1E-05	1.5E-06	1.7E-04	2.8E-03	6.4E-04	5.1E-05	3.5E-03	2.8E-05	6.3E-06	5.0E-07	3.5E-05
U-236	0.0053	4.8E-06	1.2E-03	1.7E-04	1.4E-03	2.5E-08	6.3E-06	8.8E-07	7.2E-06	4.3E-06	1.1E-03	1.5E-04	1.2E-03	2.3E-08	5.7E-06	7.9E-07	6.5E-06	6.4E-07	1.6E-04	2.2E-05	1.8E-04	3.4E-09	8.3E-07	1.2E-07	9.5E-07
U-238	0.24	3.8E-03	1.1E-03	1.7E-04	5.1E-03	9.1E-04	2.6E-04	4.1E-05	1.2E-03	3.4E-03	9.9E-04	1.5E-04	4.5E-03	8.1E-04	2.4E-04	3.7E-05	1.1E-03	5.0E-04	1.5E-04	2.3E-05	6.7E-04	1.2E-04	3.5E-05	5.4E-06	1.6E-04
		Cumulative Dose				**8.9E+02**	4.6E+00	1.9E+00	**9.0E+02**	**Cumulative Dose**				**2.6E+02**	4.2E+00	6.9E-01	**2.6E+02**	**Cumulative Dose**				**3.2E-02**	2.6E+00	1.4E-01	**2.8E+00**

Table A-11. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-110 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPCs	EPC (pCi/g)	DSR (mrem/yr per pCi/g)				Dose (mrem/yr)				RSR (1/(pCi/g))				Risk (unitless)				DSR (mrem/yr per pCi/g)				Dose (mrem/yr)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	578	9.1E-04	1.3E-02	7.3E-04	1.5E-02	5.3E-01	7.6E+00	4.2E-01	8.6E+00	8.4E-04	1.2E-02	6.7E-04	1.4E-02	4.8E-01	7.0E+00	3.9E-01	7.9E+00	1.9E-04	2.7E-03	1.5E-04	3.0E-03	1.1E-01	1.5E+00	8.4E-02	1.7E+00
C-14	333	1.4E-07	4.2E-06	1.1E-06	5.4E-06	4.7E-05	1.4E-03	3.6E-04	1.8E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	0.046	1.3E-02	9.5E-03	5.3E-04	2.3E-02	5.9E-04	4.4E-04	2.4E-05	1.1E-03	3.5E-03	2.6E-03	1.5E-04	6.3E-03	1.6E-04	1.2E-04	6.8E-06	2.9E-04	1.8E-07	1.9E-05	1.1E-06	2.0E-05	8.2E-09	8.9E-07	4.9E-08	9.5E-07
Cm-244	0.92	4.8E-06	7.7E-03	4.3E-04	8.1E-03	4.4E-06	7.0E-03	3.9E-04	7.4E-03	6.2E-07	1.0E-03	5.7E-05	1.1E-03	5.7E-07	9.3E-04	5.2E-05	9.8E-04	7.6E-09	4.1E-05	2.2E-06	4.3E-05	7.0E-09	3.7E-05	2.0E-06	3.9E-05
Cs-137	913,680	7.3E-02	5.4E-06	4.8E-05	7.3E-02	6.7E+04	4.9E+00	4.4E+01	6.7E+04	2.1E-02	1.5E-06	1.4E-05	2.1E-02	1.9E+04	1.4E+00	1.3E+01	1.9E+04	7.6E-12	5.5E-16	5.0E-15	7.6E-12	6.9E-06	5.1E-10	4.5E-09	6.9E-06
Eu-152	43	1.5E-01	1.2E-05	4.7E-06	1.5E-01	6.5E+00	5.3E-04	2.0E-04	6.5E+00	9.5E-03	7.8E-07	2.9E-07	9.5E-03	4.1E-01	3.3E-05	1.2E-05	4.1E-01	7.8E-24	9.1E-17	5.1E-18	9.6E-17	3.3E-22	3.9E-15	2.2E-16	4.1E-15
Eu-154	1,978	1.6E-01	1.4E-05	6.7E-06	1.6E-01	3.2E+02	2.8E-02	1.3E-02	3.2E+02	2.1E-03	1.8E-07	8.6E-08	2.1E-03	4.1E+00	3.5E-04	1.7E-04	4.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	321	3.7E-03	1.6E-06	1.1E-06	3.7E-03	1.2E+00	5.1E-04	3.5E-04	1.2E+00	1.4E-06	6.1E-10	4.2E-10	1.4E-06	4.5E-04	2.0E-07	1.4E-07	4.5E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	7.5	2.4E-04	1.3E-05	3.8E-04	6.4E-04	1.8E-03	1.0E-04	2.9E-03	4.7E-03	1.8E-04	1.0E-05	2.9E-04	4.8E-04	1.3E-03	7.5E-05	2.1E-03	3.5E-03	1.1E-06	6.2E-08	1.8E-06	2.9E-06	8.1E-06	4.6E-07	1.3E-05	2.2E-05
Ni-63	5,264	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	1.4E-03	2.9E-03	4.3E-03	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	9.7E-04	2.0E-03	2.9E-03	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	9.2E-07	1.9E-06	2.8E-06
Np-237	41	2.6E-02	6.8E-03	3.9E-04	3.3E-02	1.1E+00	2.8E-01	1.6E-02	1.4E+00	2.6E-02	6.8E-03	3.8E-04	3.3E-02	1.1E+00	2.8E-01	1.6E-02	1.4E+00	2.3E-02	6.0E-03	3.4E-04	2.9E-02	9.5E-01	2.5E-01	1.4E-02	1.2E+00
Pu-238	17	3.0E-06	1.5E-02	8.1E-04	1.6E-02	5.1E-05	2.5E-01	1.4E-02	2.6E-01	2.0E-06	9.6E-03	5.3E-04	1.0E-02	3.3E-05	1.6E-01	8.9E-03	1.7E-01	7.1E-08	5.5E-06	3.1E-07	5.9E-06	1.2E-06	9.3E-05	5.2E-06	9.9E-05
Pu-239	445	6.8E-06	1.6E-02	9.0E-04	1.7E-02	3.0E-03	7.3E+00	4.0E-01	7.7E+00	6.8E-06	1.6E-02	8.9E-04	1.7E-02	3.0E-03	7.3E+00	4.0E-01	7.7E+00	6.6E-06	1.6E-02	8.7E-04	1.7E-02	2.9E-03	7.1E+00	3.9E-01	7.4E+00
Pu-240	103	3.1E-06	1.6E-02	9.0E-04	1.7E-02	3.1E-04	1.7E+00	9.2E-02	1.8E+00	3.0E-06	1.6E-02	8.9E-04	1.7E-02	3.1E-04	1.7E+00	9.1E-02	1.8E+00	2.7E-06	1.5E-02	8.0E-04	1.5E-02	2.8E-04	1.5E+00	8.3E-02	1.6E+00
Pu-241	397	1.1E-06	3.2E-04	1.7E-05	3.3E-04	4.5E-04	1.3E-01	6.8E-03	1.3E-01	2.7E-05	4.1E-04	2.2E-05	4.6E-04	1.1E-02	1.6E-01	8.9E-03	1.8E-01	6.4E-06	9.1E-05	5.0E-06	1.0E-04	2.5E-03	3.6E-02	2.0E-03	4.1E-02
Sn-126	165	2.6E-01	2.2E-05	1.9E-05	2.6E-01	4.2E+01	3.6E-03	3.1E-03	4.2E+01	2.3E-01	1.9E-05	1.6E-05	2.3E-01	3.7E+01	3.2E-03	2.7E-03	3.7E+01	2.3E-02	2.0E-06	1.7E-06	2.3E-02	3.8E+00	3.2E-04	2.8E-04	3.8E+00
Sr-90	148,602	9.4E-04	2.1E-05	1.1E-04	1.1E-03	1.4E+02	3.2E+00	1.6E+01	1.6E+02	2.5E-04	5.8E-06	2.9E-05	2.9E-04	3.8E+01	8.6E-01	4.3E+00	4.3E+01	2.9E-14	6.6E-16	3.3E-15	3.3E-14	4.3E-09	9.8E-11	4.9E-10	4.9E-09
U-233	1.4	2.4E-05	1.3E-03	1.8E-04	1.5E-03	3.4E-05	1.9E-03	2.6E-04	2.2E-03	1.9E-04	1.3E-03	1.7E-04	1.7E-03	2.6E-04	1.9E-03	2.5E-04	2.4E-03	1.3E-03	1.5E-03	1.1E-04	2.9E-03	1.8E-03	2.1E-03	1.6E-04	4.1E-03
U-234	0.97	9.4E-06	1.3E-03	1.8E-04	1.5E-03	9.2E-06	1.3E-03	1.7E-04	1.4E-03	9.8E-06	1.2E-03	1.6E-04	1.3E-03	9.6E-06	1.1E-03	1.5E-04	1.3E-03	2.3E-04	2.3E-04	3.3E-05	4.9E-04	2.3E-04	2.2E-04	3.2E-05	4.8E-04
U-235	0.041	1.8E-02	1.2E-03	1.7E-04	1.9E-02	7.2E-04	4.7E-05	6.8E-06	7.8E-04	1.6E-02	1.1E-03	1.5E-04	1.7E-02	6.5E-04	4.4E-05	6.2E-06	7.0E-04	2.8E-03	6.4E-04	5.1E-05	3.5E-03	1.1E-04	2.6E-05	2.0E-06	1.4E-04
U-236	0.026	4.8E-06	1.2E-03	1.7E-04	1.4E-03	1.3E-07	3.1E-05	4.4E-06	3.6E-05	4.3E-06	1.1E-03	1.5E-04	1.2E-03	1.1E-07	2.8E-05	3.9E-06	3.2E-05	6.4E-07	1.6E-04	2.2E-05	1.8E-04	1.7E-08	4.1E-06	5.7E-07	4.7E-06
U-238	0.91	3.8E-03	1.1E-03	1.7E-04	5.1E-03	3.5E-03	1.0E-03	1.6E-04	4.6E-03	3.4E-03	9.9E-04	1.5E-04	4.5E-03	3.1E-03	9.0E-04	1.4E-04	4.1E-03	5.0E-04	1.5E-04	2.3E-05	6.7E-04	4.6E-04	1.3E-04	2.1E-05	6.1E-04
		Cumulative Dose				**6.7E+04**	2.5E+01	6.1E+01	**6.8E+04**	**Cumulative Dose**				**1.9E+04**	1.9E+01	1.8E+01	**1.9E+04**	**Cumulative Dose**				**4.9E+00**	1.0E+01	5.7E-01	**1.6E+01**

Table A-12. Radiological Dose Assessment Results for CERCLA Construction Worker Scenario at C-112 (No Soil Cover)

		T=0 Year								T=54 Year								T=1000 Year							
COPCs	EPC (pCi/g)	DSR (mrem/yr per pCi/g)				Dose (mrem/yr)				RSR (1/(pCi/g)				Risk (unitless)				DSR (mrem/yr per pCi/g)				Dose (mrem/yr)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	141	9.1E-04	1.3E-02	7.3E-04	1.5E-02	1.3E-01	1.9E+00	1.0E-01	2.1E+00	8.4E-04	1.2E-02	6.7E-04	1.4E-02	1.2E-01	1.7E+00	9.4E-02	1.9E+00	1.9E-04	2.7E-03	1.5E-04	3.0E-03	2.6E-02	3.7E-01	2.1E-02	4.2E-01
C-14	34	1.4E-07	4.2E-06	1.1E-06	5.4E-06	4.9E-06	1.4E-04	3.8E-05	1.9E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-243	3.49E-05	1.3E-02	9.5E-03	5.3E-04	2.3E-02	4.5E-07	3.3E-07	1.8E-08	8.0E-07	3.5E-03	2.6E-03	1.5E-04	6.3E-03	1.2E-07	9.2E-08	5.1E-09	2.2E-07	1.8E-07	1.9E-05	1.1E-06	2.0E-05	6.1E-12	6.7E-10	3.7E-11	7.1E-10
Cm-244	7.21E-04	4.8E-06	7.7E-03	4.3E-04	8.1E-03	3.5E-09	5.5E-06	3.1E-07	5.8E-06	6.2E-07	1.0E-03	5.7E-05	1.1E-03	4.5E-10	7.3E-07	4.1E-08	7.7E-07	7.6E-09	4.1E-05	2.2E-06	4.3E-05	5.5E-12	2.9E-08	1.6E-09	3.1E-08
Cs-137	11,472	7.3E-02	5.4E-06	4.8E-05	7.3E-02	8.4E+02	6.1E-02	5.5E-01	8.4E+02	2.1E-02	1.5E-06	1.4E-05	2.1E-02	2.4E+02	1.8E-02	1.6E-01	2.4E+02	7.6E-12	5.5E-16	5.0E-15	7.6E-12	8.7E-08	6.4E-12	5.7E-11	8.7E-08
Eu-152	0.036	1.5E-01	1.2E-05	4.7E-06	1.5E-01	5.6E-03	4.5E-07	1.7E-07	5.6E-03	9.5E-03	7.8E-07	2.9E-07	9.5E-03	3.5E-04	2.8E-08	1.1E-08	3.5E-04	7.8E-24	9.1E-17	5.1E-18	9.6E-17	2.8E-25	3.3E-18	1.9E-19	3.5E-18
Eu-154	1.7	1.6E-01	1.4E-05	6.7E-06	1.6E-01	2.7E-01	2.3E-05	1.1E-05	2.7E-01	2.1E-03	1.8E-07	8.6E-08	2.1E-03	3.4E-03	3.0E-07	1.4E-07	3.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.25	3.7E-03	1.6E-06	1.1E-06	3.7E-03	9.3E-04	4.0E-07	2.8E-07	9.3E-04	1.4E-06	6.1E-10	4.2E-10	1.4E-06	3.6E-07	1.5E-10	1.1E-10	3.6E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	6.1	2.4E-04	1.3E-05	3.8E-04	6.4E-04	1.5E-03	8.3E-05	2.4E-03	3.9E-03	1.8E-04	1.0E-05	2.9E-04	4.8E-04	1.1E-03	6.2E-05	1.8E-03	2.9E-03	1.1E-06	6.2E-08	1.8E-06	2.9E-06	6.7E-06	3.8E-07	1.1E-05	1.8E-05
Ni-63	11,400	0.0E+00	2.7E-07	5.5E-07	8.2E-07	0.0E+00	3.1E-03	6.3E-03	9.4E-03	0.0E+00	1.8E-07	3.7E-07	5.5E-07	0.0E+00	2.1E-03	4.2E-03	6.3E-03	0.0E+00	1.8E-10	3.5E-10	5.3E-10	0.0E+00	2.0E-06	4.0E-06	6.0E-06
Np-237	0.042	2.6E-02	6.8E-03	3.9E-04	3.3E-02	1.1E-03	2.9E-04	1.6E-05	1.4E-03	2.6E-02	6.8E-03	3.8E-04	3.3E-02	1.1E-03	2.8E-04	1.6E-05	1.4E-03	2.3E-02	6.0E-03	3.4E-04	2.9E-02	9.6E-04	2.5E-04	1.4E-05	1.2E-03
Pu-238	1.7	3.0E-06	1.5E-02	8.1E-04	1.6E-02	5.2E-06	2.6E-02	1.4E-03	2.7E-02	2.0E-06	9.6E-03	5.3E-04	1.0E-02	3.4E-06	1.7E-02	9.2E-04	1.8E-02	7.1E-08	5.5E-06	3.1E-07	5.9E-06	1.2E-07	9.6E-06	5.4E-07	1.0E-05
Pu-239	112	6.8E-06	1.6E-02	9.0E-04	1.7E-02	7.6E-04	1.8E+00	1.0E-01	1.9E+00	6.8E-06	1.6E-02	8.9E-04	1.7E-02	7.6E-04	1.8E+00	1.0E-01	1.9E+00	6.6E-06	1.6E-02	8.7E-04	1.7E-02	7.4E-04	1.8E+00	9.7E-02	1.9E+00
Pu-240	23	3.1E-06	1.6E-02	9.0E-04	1.7E-02	7.1E-05	3.8E-01	2.1E-02	4.0E-01	3.0E-06	1.6E-02	8.9E-04	1.7E-02	7.1E-05	3.8E-01	2.1E-02	4.0E-01	2.7E-06	1.5E-02	8.0E-04	1.5E-02	6.4E-05	3.4E-01	1.9E-02	3.6E-01
Pu-241	47	1.1E-06	3.2E-04	1.7E-05	3.3E-04	5.2E-05	1.5E-02	8.0E-04	1.6E-02	2.7E-05	4.1E-04	2.2E-05	4.6E-04	1.2E-03	1.9E-02	1.0E-03	2.1E-02	6.4E-06	9.1E-05	5.0E-06	1.0E-04	3.0E-04	4.3E-03	2.3E-04	4.8E-03
Sn-126	0.059	2.6E-01	2.2E-05	1.9E-05	2.6E-01	1.5E-02	1.3E-06	1.1E-06	1.5E-02	2.3E-01	1.9E-05	1.6E-05	2.3E-01	1.3E-02	1.1E-06	9.6E-07	1.3E-02	2.3E-02	2.0E-06	1.7E-06	2.3E-02	1.4E-03	1.2E-07	9.9E-08	1.4E-03
Sr-90	9,516	9.4E-04	2.1E-05	1.1E-04	1.1E-03	8.9E+00	2.0E-01	1.0E+00	1.0E+01	2.5E-04	5.8E-06	2.9E-05	2.9E-04	2.4E+00	5.5E-02	2.7E-01	2.7E+00	2.9E-14	6.6E-16	3.3E-15	3.3E-14	2.7E-10	6.3E-12	3.1E-11	3.1E-10
U-233	4.92E-07	2.4E-05	1.3E-03	1.8E-04	1.5E-03	1.2E-11	6.5E-10	9.0E-11	7.5E-10	1.9E-04	1.3E-03	1.7E-04	1.7E-03	9.2E-11	6.6E-10	8.6E-11	8.4E-10	1.3E-03	1.5E-03	1.1E-04	2.9E-03	6.4E-10	7.4E-10	5.4E-11	1.4E-09
U-234	0.22	9.4E-06	1.3E-03	1.8E-04	1.5E-03	2.1E-06	2.9E-04	3.9E-05	3.3E-04	9.8E-06	1.2E-03	1.6E-04	1.3E-03	2.2E-06	2.6E-04	3.5E-05	2.9E-04	2.3E-04	2.3E-04	3.3E-05	4.9E-04	5.2E-05	5.0E-05	7.4E-06	1.1E-04
U-235	0.0094	1.8E-02	1.2E-03	1.7E-04	1.9E-02	1.7E-04	1.1E-05	1.6E-06	1.8E-04	1.6E-02	1.1E-03	1.5E-04	1.7E-02	1.5E-04	1.0E-05	1.4E-06	1.6E-04	2.8E-03	6.4E-04	5.1E-05	3.5E-03	2.7E-05	6.0E-06	4.8E-07	3.3E-05
U-236	0.0050	4.8E-06	1.2E-03	1.7E-04	1.4E-03	2.4E-08	6.0E-06	8.4E-07	6.9E-06	4.3E-06	1.1E-03	1.5E-04	1.2E-03	2.2E-08	5.4E-06	7.5E-07	6.2E-06	6.4E-07	1.6E-04	2.2E-05	1.8E-04	3.2E-09	7.9E-07	1.1E-07	9.0E-07
U-238	0.23	3.8E-03	1.1E-03	1.7E-04	5.1E-03	8.6E-04	2.5E-04	3.9E-05	1.2E-03	3.4E-03	9.9E-04	1.5E-04	4.5E-03	7.7E-04	2.2E-04	3.5E-05	1.0E-03	5.0E-04	1.5E-04	2.3E-05	6.7E-04	1.1E-04	3.3E-05	5.1E-06	1.5E-04
		Cumulative Dose				**8.5E+02**	4.4E+00	1.8E+00	**8.6E+02**	Cumulative Dose				**2.5E+02**	4.0E+00	6.6E-01	**2.5E+02**	Cumulative Dose				**3.0E-02**	2.5E+00	1.4E-01	**2.7E+00**

APPENDIX B

Risk Assessment Calculation Detail for WMA C Surface Area Contamination and 216-C-8 French Drain Under a CERCLA Industrial Worker Scenario

Table B-1. Radiological Risk Assessment Results for Surface Contamination Under CERCLA Industrial Worker Scenario (No Cover)

COPCs	EPC (pCi/g)	T=0 Year								T=53.8 Year								T=1000 Year							
		RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0.067	8E-08	2E-12	1E-08	1E-07	6E-09	1E-13	9E-10	7E-09	8E-08	2E-12	1E-08	9E-08	5E-09	1E-13	8E-10	6E-09	2E-08	3E-13	3E-09	2E-08	1E-09	2E-14	2E-10	1E-09
C-14	0.016	7E-13	2E-10	6E-12	2E-10	1E-14	3E-12	9E-14	3E-12	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	1.66E-08	1E-06	1E-12	1E-08	1E-06	2E-14	2E-20	2E-16	2E-14	3E-07	4E-13	3E-09	3E-07	4E-15	6E-21	4E-17	4E-15	2E-11	3E-15	2E-11	4E-11	3E-19	5E-23	4E-19	6E-19
Cm-244	3.43E-07	3E-10	1E-12	7E-09	7E-09	9E-17	4E-19	2E-15	3E-15	4E-11	1E-13	1E-09	1E-09	1E-17	5E-20	3E-16	3E-16	6E-13	6E-15	4E-11	5E-11	2E-19	2E-21	2E-17	2E-17
Cs-137	5.5	6E-06	4E-15	3E-09	6E-06	3E-05	2E-14	2E-08	3E-05	2E-06	1E-15	9E-10	2E-06	9E-06	6E-15	5E-09	9E-06	6E-16	4E-25	3E-19	6E-16	3E-15	2E-24	2E-18	3E-15
Eu-152	1.74E-05	9E-06	5E-15	5E-10	9E-06	2E-10	9E-20	8E-15	2E-10	6E-07	3E-16	3E-11	6E-07	1E-11	6E-21	5E-16	1E-11	5E-28	1E-26	1E-22	1E-22	8E-33	3E-31	2E-27	2E-27
Eu-154	7.86E-04	8E-06	4E-15	6E-10	8E-06	6E-09	3E-18	5E-13	6E-09	1E-07	5E-17	8E-12	1E-07	8E-11	4E-20	6E-15	8E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Eu-155	1.20E-04	1E-07	2E-16	8E-11	1E-07	1E-11	3E-20	9E-15	1E-11	4E-11	9E-20	3E-14	4E-11	5E-15	1E-23	4E-18	5E-15	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0.0029	2E-08	7E-15	2E-08	4E-08	5E-11	2E-17	6E-11	1E-10	1E-08	5E-15	1E-08	3E-08	4E-11	2E-17	4E-11	8E-11	8E-11	3E-17	9E-11	2E-10	2E-13	1E-19	3E-13	5E-13
Ni-63	5.4	0E+00	3E-16	9E-11	9E-11	0E+00	1E-15	5E-10	5E-10	0E+00	2E-16	6E-11	6E-11	0E+00	9E-16	3E-10	3E-10	0E+00	2E-19	6E-14	6E-14	0E+00	9E-19	3E-13	3E-13
Np-237	1.99E-05	3E-06	1E-12	9E-09	3E-06	5E-11	3E-17	2E-13	5E-11	3E-06	1E-12	9E-09	3E-06	5E-11	3E-17	2E-13	5E-11	2E-06	1E-12	8E-09	2E-06	5E-11	2E-17	2E-13	5E-11
Pu-238	8.27E-04	2E-10	2E-12	2E-08	2E-08	2E-13	2E-15	1E-11	1E-11	1E-10	1E-12	1E-08	1E-08	1E-13	1E-15	9E-12	9E-12	7E-12	9E-16	7E-12	1E-11	6E-15	7E-19	5E-15	1E-14
Pu-239	0.053	6E-10	3E-12	2E-08	2E-08	3E-11	1E-13	1E-09	1E-09	6E-10	3E-12	2E-08	2E-08	3E-11	1E-13	1E-09	1E-09	6E-10	3E-12	2E-08	2E-08	3E-11	1E-13	9E-10	1E-09
Pu-240	0.011	2E-10	3E-12	2E-08	2E-08	2E-12	3E-14	2E-10	2E-10	2E-10	3E-12	2E-08	2E-08	2E-12	3E-14	2E-10	2E-10	2E-10	2E-12	2E-08	2E-08	2E-12	3E-14	2E-10	2E-10
Pu-241	0.022	1E-09	5E-14	3E-10	2E-09	3E-11	1E-15	7E-12	3E-11	3E-09	5E-14	4E-10	3E-09	6E-11	1E-15	9E-12	7E-11	6E-10	1E-14	9E-11	7E-10	1E-11	3E-16	2E-12	2E-11
Sn-126	2.81E-05	3E-05	2E-14	4E-09	3E-05	7E-10	5E-19	1E-13	7E-10	2E-05	2E-14	4E-09	2E-05	6E-10	5E-19	1E-13	6E-10	2E-06	2E-15	4E-10	2E-06	7E-11	5E-20	1E-14	7E-11
Sr-90	4.5	4E-08	2E-14	7E-09	5E-08	2E-07	7E-14	3E-08	2E-07	1E-08	4E-15	2E-09	1E-08	5E-08	2E-14	9E-09	6E-08	1E-18	5E-25	2E-19	2E-18	6E-18	2E-24	1E-18	7E-18
U-233	2.34E-10	6E-09	1E-12	1E-08	2E-08	1E-18	3E-22	2E-18	4E-18	2E-08	1E-12	9E-09	3E-08	5E-18	3E-22	2E-18	7E-18	1E-07	6E-13	4E-09	1E-07	3E-17	1E-22	1E-18	3E-17
U-234	1.05E-04	8E-10	1E-12	1E-08	1E-08	8E-14	1E-16	1E-12	1E-12	9E-10	1E-12	9E-09	1E-08	1E-13	1E-16	9E-13	1E-12	2E-08	2E-13	2E-09	3E-08	3E-12	2E-17	2E-13	3E-12
U-235	4.50E-06	2E-06	1E-12	1E-08	2E-06	8E-12	5E-18	4E-14	8E-12	2E-06	1E-12	9E-09	2E-06	7E-12	5E-18	4E-14	7E-12	3E-07	3E-13	2E-09	3E-07	1E-12	1E-18	9E-15	1E-12
U-236	2.40E-06	4E-10	1E-12	9E-09	9E-09	9E-16	3E-18	2E-14	2E-14	3E-10	1E-12	8E-09	8E-09	8E-16	3E-18	2E-14	2E-14	5E-11	2E-13	1E-09	1E-09	1E-16	4E-19	3E-15	3E-15
U-238	1.08E-04	4E-07	1E-12	1E-08	4E-07	4E-11	1E-16	1E-12	4E-11	3E-07	1E-12	1E-08	3E-07	3E-11	1E-16	1E-12	4E-11	5E-08	1E-13	2E-09	5E-08	5E-12	2E-17	2E-13	5E-12
		Cumulative ELCR				**3E-05**	3E-12	5E-08	**3E-05**	**Cumulative ELCR**				9E-06	3E-13	2E-08	9E-06	**Cumulative ELCR**				1E-09	2E-13	1E-09	3E-09

Table B-2. Radiological Risk Assessment Results for CERCLA Industrial Worker Scenario at 216-C-8 (No Cover)

T=0 Year

COPCs	EPC (pCi/g)	RSR (1/(pCi/g)) Ground	RSR Inhalation	RSR Soil	RSR Total	Risk (unitless) Ground	Risk Inhalation	Risk Soil	Risk Total
Am-241	0	7.8E-08	1.1E-12	7.3E-09	8.6E-08	0E+00	0E+00	0E+00	0E+00
C-14	0	6.2E-13	1.7E-11	3.1E-12	2.1E-11	0E+00	0E+00	0E+00	0E+00
Cm-243	0	9.0E-07	8.0E-13	5.2E-09	9.0E-07	0E+00	0E+00	0E+00	0E+00
Cm-244	0	2.6E-10	6.6E-13	3.9E-09	4.1E-09	0E+00	0E+00	0E+00	0E+00
Cs-137	60	5.3E-06	2.5E-15	1.6E-09	5.3E-06	3E-04	1E-13	1E-07	3E-04
Eu-152	0	8.3E-06	3.1E-15	2.6E-10	8.3E-06	0E+00	0E+00	0E+00	0E+00
Eu-154	0	6.9E-06	2.6E-15	3.4E-10	6.9E-06	0E+00	0E+00	0E+00	0E+00
Eu-155	0	9.5E-08	1.5E-16	4.2E-11	9.5E-08	0E+00	0E+00	0E+00	0E+00
I-129	0	1.7E-08	4.4E-15	1.0E-08	2.7E-08	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0.0E+00	1.6E-16	4.9E-11	4.9E-11	0E+00	0E+00	0E+00	0E+00
Np-237	0.0075	2.4E-06	8.3E-13	5.1E-09	2.4E-06	2E-08	6E-15	4E-11	2E-08
Pu-238	0.060	2.0E-10	1.4E-12	8.5E-09	8.7E-09	1E-11	8E-14	5E-10	5E-10
Pu-239	1.4	6.0E-10	1.6E-12	9.6E-09	1.0E-08	9E-10	2E-12	1E-08	1E-08
Pu-240	0.36	2.2E-10	1.6E-12	9.6E-09	9.9E-09	8E-11	6E-13	3E-09	3E-09
Pu-241	1.3	1.1E-09	2.9E-14	1.8E-10	1.3E-09	1E-09	4E-14	2E-10	2E-09
Sn-126	0	2.3E-05	1.2E-14	2.2E-09	2.3E-05	0E+00	0E+00	0E+00	0E+00
Sr-90	502	4.0E-08	9.4E-15	4.0E-09	4.4E-08	2E-05	5E-12	2E-06	2E-05
U-233	5.65E-07	5.6E-09	8.0E-13	5.3E-09	1.1E-08	3E-15	5E-19	3E-15	6E-15
U-234	0.0040	7.8E-10	7.8E-13	5.2E-09	5.9E-09	3E-12	3E-15	2E-11	2E-11
U-235	1.67E-04	1.6E-06	7.1E-13	5.3E-09	1.6E-06	3E-10	1E-16	9E-13	3E-10
U-236	1.02E-04	3.8E-10	7.2E-13	4.9E-09	5.2E-09	4E-14	7E-17	5E-13	5E-13
U-238	0.0039	3.2E-07	6.7E-13	6.5E-09	3.3E-07	1E-09	3E-15	3E-11	1E-09
				Cumulative ELCR		**3E-04**	8E-12	2E-06	**3E-04**

T=53.8 Year

COPCs	RSR (1/(pCi/g)) Ground	RSR Inhalation	RSR Soil	RSR Total	Risk (unitless) Ground	Risk Inhalation	Risk Soil	Risk Total
Am-241	7.2E-08	9.8E-13	6.7E-09	7.9E-08	0E+00	0E+00	0E+00	0E+00
C-14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	2.5E-07	2.2E-13	1.4E-09	2.5E-07	0E+00	0E+00	0E+00	0E+00
Cm-244	3.4E-11	8.8E-14	5.1E-10	5.5E-10	0E+00	0E+00	0E+00	0E+00
Cs-137	1.5E-06	7.2E-16	4.6E-10	1.5E-06	9E-05	4E-14	3E-08	9E-05
Eu-152	5.2E-07	2.0E-16	1.6E-11	5.2E-07	0E+00	0E+00	0E+00	0E+00
Eu-154	8.9E-08	3.3E-17	4.4E-12	8.9E-08	0E+00	0E+00	0E+00	0E+00
Eu-155	3.7E-11	5.8E-20	1.7E-14	3.7E-11	0E+00	0E+00	0E+00	0E+00
I-129	1.2E-08	3.3E-15	7.6E-09	2.0E-08	0E+00	0E+00	0E+00	0E+00
Ni-63	0.0E+00	1.0E-16	3.3E-11	3.3E-11	0E+00	0E+00	0E+00	0E+00
Np-237	2.4E-06	8.2E-13	5.0E-09	2.4E-06	2E-08	6E-15	4E-11	2E-08
Pu-238	1.3E-10	8.9E-13	5.6E-09	5.7E-09	8E-12	5E-14	3E-10	3E-10
Pu-239	6.0E-10	1.6E-12	9.6E-09	1.0E-08	9E-10	2E-12	1E-08	1E-08
Pu-240	2.2E-10	1.6E-12	9.6E-09	9.8E-09	8E-11	6E-13	3E-09	3E-09
Pu-241	2.4E-09	3.3E-14	2.2E-10	2.6E-09	3E-09	4E-14	3E-10	3E-09
Sn-126	2.0E-05	1.0E-14	1.9E-09	2.0E-05	0E+00	0E+00	0E+00	0E+00
Sr-90	1.1E-08	2.6E-15	1.1E-09	1.2E-08	5E-06	1E-12	5E-07	6E-06
U-233	2.0E-08	7.5E-13	4.9E-09	2.5E-08	1E-14	4E-19	3E-15	1E-14
U-234	8.8E-10	7.0E-13	4.6E-09	5.5E-09	4E-12	3E-15	2E-11	2E-11
U-235	1.4E-06	6.4E-13	4.8E-09	1.4E-06	2E-10	1E-16	8E-13	2E-10
U-236	3.4E-10	6.5E-13	4.4E-09	4.7E-09	3E-14	7E-17	4E-13	5E-13
U-238	2.9E-07	6.0E-13	5.8E-09	2.9E-07	1E-09	2E-15	2E-11	1E-09
			Cumulative ELCR		1E-04	4E-12	6E-07	1E-04

T=1000 Year

COPCs	RSR (1/(pCi/g)) Ground	RSR Inhalation	RSR Soil	RSR Total	Risk (unitless) Ground	Risk Inhalation	Risk Soil	Risk Total
Am-241	1.6E-08	2.1E-13	1.5E-09	1.8E-08	0E+00	0E+00	0E+00	0E+00
C-14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	1.6E-11	1.9E-15	1.1E-11	2.7E-11	0E+00	0E+00	0E+00	0E+00
Cm-244	5.5E-13	4.0E-15	2.4E-11	2.4E-11	0E+00	0E+00	0E+00	0E+00
Cs-137	5.5E-16	2.6E-25	1.6E-19	5.5E-16	3E-14	2E-23	1E-17	3E-14
Eu-152	4.2E-28	9.2E-27	7.4E-23	7.4E-23	0E+00	0E+00	0E+00	0E+00
Eu-154	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
Eu-155	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0E+00	0E+00	0E+00	0E+00
I-129	7.7E-11	2.0E-17	4.7E-11	1.2E-10	0E+00	0E+00	0E+00	0E+00
Ni-63	0.0E+00	1.0E-19	3.1E-14	3.1E-14	0E+00	0E+00	0E+00	0E+00
Np-237	2.1E-06	7.3E-13	4.5E-09	2.1E-06	2E-08	5E-15	3E-11	2E-08
Pu-238	6.7E-12	5.6E-16	3.5E-12	1.0E-11	4E-13	3E-17	2E-13	6E-13
Pu-239	5.8E-10	1.6E-12	9.3E-09	9.9E-09	8E-10	2E-12	1E-08	1E-08
Pu-240	2.0E-10	1.4E-12	8.6E-09	8.8E-09	7E-11	5E-13	3E-09	3E-09
Pu-241	5.5E-10	7.4E-15	5.0E-11	6.0E-10	7E-10	9E-15	6E-11	8E-10
Sn-126	2.1E-06	1.1E-15	1.9E-10	2.1E-06	0E+00	0E+00	0E+00	0E+00
Sr-90	1.2E-18	2.9E-25	1.2E-19	1.4E-18	6E-16	1E-22	6E-17	7E-16
U-233	1.2E-07	3.6E-13	2.2E-09	1.2E-07	7E-14	2E-19	1E-15	7E-14
U-234	2.2E-08	1.1E-13	9.1E-10	2.3E-08	9E-11	4E-16	4E-12	9E-11
U-235	2.5E-07	1.7E-13	1.1E-09	2.5E-07	4E-11	3E-17	2E-13	4E-11
U-236	5.0E-11	9.5E-14	6.4E-10	6.9E-10	5E-15	1E-17	7E-14	7E-14
U-238	4.2E-08	8.8E-14	8.6E-10	4.3E-08	2E-10	3E-16	3E-12	2E-10
			Cumulative ELCR		2E-08	3E-12	2E-08	3E-08

Table B-3. Radiological Risk Assessment Results for CERCLA Industrial Worker Scenario at 216-C-8 (4" of Concrete Cover)

		T=0 Year								T=53.8 Year								T=1000 Year							
COPCs	EPC (pCi/g)	RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)				RSR (1/(pCi/g)				Risk (unitless)			
		Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total	Ground	Inhalation	Soil	Total
Am-241	0	4E-11	4E-13	2E-09	2E-09	0E+00	0E+00	0E+00	0E+00	4E-11	3E-13	2E-09	2E-09	0E+00	0E+00	0E+00	0E+00	3E-11	7E-14	5E-10	5E-10	0E+00	0E+00	0E+00	0E+00
C-14	0	6E-16	2E-11	2E-12	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Cm-243	0	3E-08	3E-13	2E-09	4E-08	0E+00	0E+00	0E+00	0E+00	9E-09	7E-14	5E-10	1E-08	0E+00	0E+00	0E+00	0E+00	5E-13	7E-16	4E-12	4E-12	0E+00	0E+00	0E+00	0E+00
Cm-244	0	2E-11	2E-13	1E-09	1E-09	0E+00	0E+00	0E+00	0E+00	3E-12	3E-14	2E-10	2E-10	0E+00	0E+00	0E+00	0E+00	5E-15	1E-15	8E-12	8E-12	0E+00	0E+00	0E+00	0E+00
Cs-137	60	7E-07	8E-16	5E-10	7E-07	4E-05	5E-14	3E-08	4E-05	2E-07	2E-16	2E-10	2E-07	1E-05	1E-14	9E-09	1E-05	7E-17	9E-26	6E-20	7E-17	4E-15	5E-24	3E-18	4E-15
Eu-152	0	1E-06	1E-15	9E-11	1E-06	0E+00	0E+00	0E+00	0E+00	8E-08	7E-17	5E-12	8E-08	0E+00	0E+00	0E+00	0E+00	6E-29	3E-27	3E-23	3E-23	0E+00	0E+00	0E+00	0E+00
Eu-154	0	1E-06	9E-16	1E-10	1E-06	0E+00	0E+00	0E+00	0E+00	1E-08	1E-17	1E-12	1E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
Eu-155	0	8E-10	5E-17	1E-11	8E-10	0E+00	0E+00	0E+00	0E+00	3E-13	2E-20	6E-15	3E-13	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
I-129	0	2E-19	1E-15	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	1E-19	1E-15	3E-09	3E-09	0E+00	0E+00	0E+00	0E+00	1E-21	7E-18	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00
Ni-63	0	0E+00	5E-17	2E-11	2E-11	0E+00	0E+00	0E+00	0E+00	0E+00	3E-17	1E-11	1E-11	0E+00	0E+00	0E+00	0E+00	0E+00	3E-20	1E-14	1E-14	0E+00	0E+00	0E+00	0E+00
Np-237	0.0075	1E-07	3E-13	2E-09	1E-07	1E-09	2E-15	1E-11	1E-09	1E-07	3E-13	2E-09	1E-07	1E-09	2E-15	1E-11	1E-09	1E-07	3E-13	2E-09	1E-07	9E-10	2E-15	1E-11	9E-10
Pu-238	0.060	6E-13	5E-13	3E-09	3E-09	3E-14	3E-14	2E-10	2E-10	4E-13	3E-13	2E-09	2E-09	2E-14	2E-14	1E-10	1E-10	1E-12	2E-16	1E-12	2E-12	7E-14	1E-17	7E-14	1E-13
Pu-239	1.4	2E-11	5E-13	3E-09	3E-09	3E-11	8E-13	5E-09	5E-09	2E-11	5E-13	3E-09	3E-09	3E-11	8E-13	5E-09	5E-09	2E-11	5E-13	3E-09	3E-09	3E-11	8E-13	5E-09	5E-09
Pu-240	0.36	2E-12	5E-13	3E-09	3E-09	7E-13	2E-13	1E-09	1E-09	2E-12	5E-13	3E-09	3E-09	7E-13	2E-13	1E-09	1E-09	2E-12	5E-13	3E-09	3E-09	6E-13	2E-13	1E-09	1E-09
Pu-241	1.3	1E-12	1E-14	6E-11	6E-11	1E-12	1E-14	7E-11	8E-11	1E-12	1E-14	7E-11	8E-11	2E-12	1E-14	9E-11	1E-10	1E-12	3E-15	2E-11	2E-11	1E-12	3E-15	2E-11	2E-11
Sn-126	0	3E-06	4E-15	7E-10	3E-06	0E+00	0E+00	0E+00	0E+00	3E-06	3E-15	6E-10	3E-06	0E+00	0E+00	0E+00	0E+00	3E-07	4E-16	7E-11	3E-07	0E+00	0E+00	0E+00	0E+00
Sr-90	502	2E-09	3E-15	1E-09	3E-09	8E-07	2E-12	7E-07	2E-06	5E-10	9E-16	4E-10	8E-10	2E-07	4E-13	2E-07	4E-07	5E-20	1E-25	4E-20	1E-19	3E-17	5E-23	2E-17	5E-17
U-233	5.65E-07	4E-10	3E-13	2E-09	2E-09	2E-16	2E-19	1E-15	1E-15	2E-09	3E-13	2E-09	3E-09	1E-15	1E-19	9E-16	2E-15	1E-08	1E-13	8E-10	1E-08	6E-15	7E-20	4E-16	7E-15
U-234	0.0040	7E-12	3E-13	2E-09	2E-09	3E-14	1E-15	7E-12	7E-12	4E-11	2E-13	2E-09	2E-09	2E-13	9E-16	6E-12	6E-12	4E-09	4E-14	3E-10	4E-09	2E-11	1E-16	1E-12	2E-11
U-235	1.67E-04	5E-08	2E-13	2E-09	6E-08	9E-12	4E-17	3E-13	9E-12	5E-08	2E-13	2E-09	5E-08	8E-12	4E-17	3E-13	8E-12	1E-08	6E-14	4E-10	1E-08	2E-12	1E-17	6E-14	2E-12
U-236	1.02E-04	2E-12	2E-13	2E-09	2E-09	2E-16	2E-17	2E-13	2E-13	2E-12	2E-13	1E-09	1E-09	2E-16	2E-17	1E-13	1E-13	4E-13	3E-14	2E-10	2E-10	4E-17	3E-18	2E-14	2E-14
U-238	0.0039	4E-08	2E-13	2E-09	4E-08	1E-10	9E-16	8E-12	1E-10	3E-08	2E-13	2E-09	3E-08	1E-10	8E-16	8E-12	1E-10	5E-09	3E-14	3E-10	5E-09	2E-11	1E-16	1E-12	2E-11
				Cumulative ELCR		**4E-05**	3E-12	7E-07	**4E-05**			**Cumulative ELCR**		1E-05	1E-12	2E-07	1E-05			**Cumulative ELCR**		1E-09	1E-12	6E-09	7E-09

APPENDIX C

Software Installation and Checkout Forms for RESRAD

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.876 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   INTERA-0740
7. Operating System (include version number):
   Windows 8.1
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 0, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    PASS
16. Test Performed By: M Rahman
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Passed; Installation added to HISI Entry

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD   Software Version No.: 7.0

Prepared By:

19.	WE Nichols	
Software Owner (Signature)	Print	Date

20. Test Personnel:

Sign	Print	Date
M. Rahman	M RAHMAN	11-16-15

Approved By:

21.	N/R per SMP	
Software SME (Signature)	Print	Date

A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.852 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   Intera-00474
7. Operating System (include version number):
   Windows 10 Pro
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 2, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    Test results matched expected results; pass.
16. Test Performed By: SL Lindberg
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Approved; installation added to HISI entry software user list.

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD — Software Version No.: 7.0

Prepared By:

19.	____ Software Owner (Signature)	WE Nichols — Print	____ Date
20. Test Personnel:	[signature] Sign	SL Lindberg — Print	08/03/2016 — Date
	____ Sign	____ Print	____ Date
	____ Sign	____ Print	____ Date

Approved By:

21.	____ Software SME (Signature)	N/R per SMP — Print	____ Date

 A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

3. Executable Size (bytes): 1.876 MB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Compiled by Vendor (ANL)
5. Operating System (include version number):
   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   Intera-00295
7. Operating System (include version number):
   Windows 7 Professional Service Pack 1
8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

10. Procedure(s):
    per CHPRC-00210 Rev 2, RESRAD Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    Created in RESRAD per installation test instruction
13. Output Files:
    SUMMARY.REP
14. Test Cases:
    RESRAD-ITC-1
15. Test Case Results:
    Test results matched expected results; pass.
16. Test Performed By: RD Evans
17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory
18. Disposition (include HISI update):
    Installation accepted; computer and user added to HISI entry for RESRAD software.

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD Software Version No.: 7.0

Prepared By:

19. [signature] — Software Owner (Signature) | WE Nichols — Print | 30 April 2015 — Date

20. Test Personnel:

Sign	Print	Date
[signature]	RD Evans	4/30/2015

Approved By:

21. ______ — Software SME (Signature) | N/R per SMP — Print | ______ — Date

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APPENDIX C

SUPPORT MATERIAL FOR TECHNOLOGIES SCREENING

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LIST OF TABLES

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Table C-1. Remedial Technologies Screened for Further Consideration. (3 sheets)

General Response Category	Technology	Technical Maturity	Applicable to WMA C	Effectiveness at WMA C	Retain for Further Evaluation
Institutional Controls	Site Access Controls	Y	Y	Y	Y
	WMA C Access Controls	Y	Y	Y	Y
	Site-Wide Integrated Safety Management System Program	Y	Y	Y	Y
	WMA C Work Control Process	Y	Y	Y	Y
Containment	Surface Barrier – Modified Asphalt	Y	Y	Y	Y
	Surface Barrier – Geomembrane	Y	Y	n	n
	Surface Barrier – Evapotranspiration Barrier	Y	n	n	n
	Surface Barrier – Treated Concrete	Y	Y	n	n
	Isolation Barrier – Concrete	Y	Y	Y	Y
	Isolation Barrier – Soil/Rock	Y	n	n	n
	Horizontal Subsurface Barrier	Y	n	n	n
	Vertical Slurry Wall Barrier	Y	n	n	n
	Vertical Grout Wall – Auger Mixed	Y	n	n	n
	Vertical Sheet Pile Wall	Y	n	n	n
	Surface Barrier – Hanford	Y	n	n	n
	Surface Barrier – Modified RCRA C	Y	n	n	n
	Subsurface Barrier – Freeze Barrier	Y	n	n	n
	Subsurface Barrier – Jet Grouting	Y	n	n	n
	Permeation Grouting – Wax	Y	Y	n	n
	Permeation Grouting – Grout	Y	Y	n	n

Table C-1. Remedial Technologies Screened for Further Consideration. (3 sheets)

General Response Category	Technology	Technical Maturity	Applicable to WMA C	Effectiveness at WMA C	Retain for Further Evaluation
Treatment (in situ)	In Situ Vitrification	Y	n	n	n
	In Situ Uranium Recovery – Leaching & Recovery	Y	n	n	n
	In Situ Chemical Treatment – Getters (silicate minerals)	Y	Y	n	n
	Carbonate Sequestration	Y	Y	n	n
	Chemical Oxidation	Y	Y	n	n
	Gaseous Reduction	n	Y	n	n
	Zero Valent Iron	Y	Y	n	n
	Phosphate/Apatite Sequestration	Y	Y	n	n
	Sodium Dithionate Injection	Y	n	n	n
	Sulfide Mineral Injection	Y	n	n	n
	Microbial Bioremediation	Y	n	n	n
	Exotic Nanoparticles	n	n	n	n
	Electrokinetic Mobilization and Recovery	n	Y	n	n
	Soil Moisture Extraction	Y	n	n	n
	In Situ Thermal Desorption	Y	n	n	n
	In Situ Soil Flushing	Y	n	n	n
	Deep Soil Mixing (reagent delivery)	Y	n	n	n
	Surface Infiltration (reagent delivery)	Y	n	n	n
	Gas-Phase Delivery of Reactant/Chemical (reagent delivery)	Y	n	n	n
	Foam Delivery of Reactant/Chemical (reagent delivery)	n	n	n	n
	Injection/Extraction Wells (reagent delivery)	Y	Y	n	n
	Hybrid Electrokinetic Delivery of Treatment Chemicals (reagent delivery)	Y	n	n	n
	Shear Thinning Fluid (reagent delivery)	n	n	n	n

Table C-1. Remedial Technologies Screened for Further Consideration. (3 sheets)

General Response Category	Technology	Technical Maturity	Applicable to WMA C	Effectiveness at WMA C	Retain for Further Evaluation
Treatment (in situ) (continued)	Enhanced Volatilization	Y	n	n	n
	Soil Vapor Extraction	Y	n	n	n
	In Situ – Carbon Nanotubes	n	Y	n	n
	In Situ – Zeolites	Y	n	n	n
RTD: Removal	Conventional Excavation	Y	Y	Y	Y
	Excavation Using Dragline Excavators	Y	Y	n	n
	Remotely Operated Excavation Equipment	Y	Y	Y	Y
	Vacuum Excavation	Y	Y	Y	Y
	Drilling and Soil Replacement (auger bucket)	Y	Y	n	n
	Standard Sloping and Benching for Excavation Support	Y	Y	Y	Y
	Soil Nail Walls for Excavation Support	Y	Y	Y	n
	Secant or Tangent Pile Walls for Excavation Support	Y	Y	Y	n
	Reinforced Concrete Walls for Excavation Support	Y	Y	Y	n
	Jet Grouting Walls for Excavation Support	Y	Y	Y	n
	Deep-Mixed Walls for Excavation Support	Y	Y	Y	n
	Sheet Piling for Excavation Support	Y	Y	Y	n
	Cofferdams for Excavation Support	Y	Y	Y	n
	Tunneling	Y	Y	n	n
	Diaphragm Walls for Excavation Support	Y	Y	Y	n
	Caissons for Deep Soil Excavation Support	Y	Y	n	n
	Sheet Pile Walls	Y	Y	Y	Y
	Soldier Piles and Lagging for Excavation Support	Y	Y	n	n
	Ex Situ Vitrification	Y	Y	n	n

Table C-1. Remedial Technologies Screened for Further Consideration. (3 sheets)

General Response Category	Technology	Technical Maturity	Applicable to WMA C	Effectiveness at WMA C	Retain for Further Evaluation
RTD: Ex Situ Treatment	Ex Situ Soil Washing	**Y**	n	n	n
	Ex Situ Soil Sorting and Screening	**Y**	n	n	n
	Molecular Sieves	n	**Y**	n	n
	Supported Growth Biological Reactors	**Y**	n	n	n
	Solidification (grout/pozzolanic materials)	**Y**	**Y**	**Y**	**Y**

Notes:

Y = the technology meets the requirements of the criterion.
n = the technology does not meet the requirements of the criterion.
RCRA = Resource Conservation and Recovery Act of 1976
RTD = remove, treat, and dispose. Disposal options must be determined for all waste removed.
WMA = waste management area

Table C-2. Identified and Screened Technologies Retained for Alternatives Development. (1 of 2 sheets)

Technology	Process Options	General Response Action	Effectiveness	Implementability	Relative Cost
Concrete Isolation Barrier	Isolation Barrier: Concrete isolation barriers use conventional construction practices to create a physical barrier to shallow contamination.	Containment	HIGH – Short-term effectiveness for breaking the direct-contact exposure pathway. LOW – Long-term effectiveness does not provide long-term reduction of contaminant mobility or impacts to groundwater. Technology can be executed under current documented safety analysis.	HIGH – Concrete pads have been successfully constructed in the tank farms for structural purposes.	LOW
Modified-Asphalt Surface Barrier	Infiltration Barrier Systems: Modified-asphalt barriers can be constructed using commercial paving equipment to install impervious asphalt over contaminated soil to reduce water infiltration and migration of mobile contaminants. Infiltration barriers are sloped for surface precipitation drainage control away from contaminated soil.	Containment	HIGH – Short-term effectiveness for breaking the direct-contact exposure pathway. LOW to HIGH – Long-term effectiveness: LOW if mobile contaminants are deep in vadose zone near the water table and HIGH if mobile contaminants are near the surface.	HIGH – A modified-asphalt barrier was successfully constructed in the 241-TY Tank Farm.	MEDIUM – depending on area covered.
Conventional Excavation	Conventional or Remotely Operated Excavation: Uses an operator on the machine (backhoe or trackhoe) for shallow to mid-range depths, and an extended-reach trackhoe and access ramp for deeper soil (>100 feet). Note: equipment would require substantial modification to add shielding for excavation of highly contaminated soils.	Removal	HIGH – Short-term effectiveness after completion of removal action. LOW – Short-term effectiveness during implementation due to worker exposure and potential for airborne contamination. HIGH – Long-term effectiveness for contaminated soil that can be removed and packaged for disposal using conventional equipment. Equipment shielding will need to be balanced against the personal protective equipment required. Technology has limited applicability to removal of soils at WMA C without substantial engineering controls. Technology is suited to excavating and handling large quantities of soil, rock, and debris, and for excavating localized areas of contaminated soil in low-level radiation fields. A process hazards analysis will be required before implementing this technology.	LOW – Implementability is contingent on contamination levels. Potential for airborne contamination. LOW – Implementability for removal of shallow soil contamination with substantial gamma contamination levels. Engineering controls will be required to address hazards. A Process Hazards Analysis will be required for the design. Technical Safety Requirements will depend on contamination levels and contingency for unanticipated conditions. Analysis for removal of contaminated soils with high gamma concentrations would likely include: confinement structures to control airborne contamination, heavily shielded equipment and waste containers to reduce worker dose, confinement structure ventilation, mitigation measures for dust control, and contingency plans for unanticipated conditions. Potential to generate waste that exceeds waste acceptance criteria for on-site disposal.	HIGH – VERY HIGH
Remotely Operated Excavation	Conventional or Remotely Operated Excavation: A remote-control system is attached to heavy-duty hydraulic equipment, such as excavators, loaders, etc., that allows the machinery to be operated remotely in hazardous environments to reduce worker exposures. Once fitted with the controls system, standard machines are transformed into remote-operated units capable of undertaking a range of demanding tasks with the operator removed from the danger zone to a safe location.	Removal	HIGH – Short-term effectiveness during and just after implementation. Short-term effectiveness during implementation is affected by worker exposures and potential for airborne contamination. HIGH – Long-term effectiveness for contaminated soil that can be removed and packaged for disposal using remote equipment. Remotely-controlled excavation equipment would allow for operation of the excavation equipment but is typically less productive than conventional excavation equipment. Worker exposures would be associated with handling waste containers, equipment repair, and waste transport. A Process Hazards Analysis will be required before implementing this technology.	LOW – Remote equipment is commercially available; however, the application to excavation of contaminated soils within a confinement structure would require extensive planning and evaluation during project design. Engineered controls will be required to address hazards. A Process Hazards Analysis will be required of the design. Technical Safety Requirements will depend on contamination levels and contingency for unanticipated conditions. Analysis for removal of contaminated soils with high gamma concentrations would likely include: confinement structures to control airborne contamination, waste boxes to reduce worker dose, confinement structure ventilation, mitigation measures for dust control, and contingency plans for unanticipated conditions (redundant excavation equipment to recover from equipment failures). Potential to generate waste with contaminant levels that exceed waste acceptance criteria for on-site disposal. Requires extensive worker training to operate equipment and handle waste. Remote excavation equipment is commercially available, but in combination with the other engineered controls, the technology would require substantial design, analysis, and testing before use at WMA C.	HIGH – VERY HIGH

1

Table C-2. Identified and Screened Technologies Retained for Alternatives Development. (2 of 2 sheets)

Technology	Process Options	General Response Action	Effectiveness	Implementability	Relative Cost
Standard Sloping and Benching Systems	Standard Excavation Sloping and Benching: Both benching and sloping systems are used to prevent cave-ins to an excavation and thereby protect workers. Benching is one or more steps cut into the side-walls of an excavation, usually with vertical or near-vertical surfaces between levels. Sloping requires cutting sidewalls into relatively smooth, angled planes dipping toward the excavation at a specific (or lesser) angle depending on various soil types, anticipated weather conditions, and surface or near-surface loads that may affect the soil in the area of the trench.	Removal	LOW – Short-term effectiveness to support implementation of excavations due to worker exposure and potential for airborne contamination from contaminated soil. Best suited for shallow excavations, with no interferences, and large open space. Not applicable – Long-term effectiveness.	MODERATE – Both the resources and the services required to provide sloping and benching are common and readily available. Limited by the depth of excavation, due to increased volume of excavation and backfill and the amount of open space required.	LOW – HIGH depending on size, depth, and location of the excavation.
Sheet Pile Walls	Sheet Pile Walls: Typically used to support excavation of deeper soils, sheet piles are driven at regular intervals along the planned excavation perimeter. Interlocking sheets provide a structural wall to support excavation.	Removal	MODERATE – Short-term effectiveness during implementation. Subsurface conditions at WMA C are anticipated to be suitable for use of sheet piles. Provides a near-vertical excavation wall to minimize excavation and backfill volumes and the amount of work area required. Installation difficulty increases with depth.	MODERATE – SVZ / IVZ; LOW – DVZ. Both the resources and the services required to install sheet pile walls are readily available. However, sheet pile wall installation is problematic when infrastructure or large rocks may be encountered.	HIGH – Complexities are related to the presence of buried utilities and equipment, soil disposal volumes, and contamination concentrations encountered.
RTD: Ex Situ Solidification & Stabilization	Ex Situ Solidification & Stabilization: Removed soils are combined with pozzolanic ingredients, water, and/or proprietary reagents to solidify and stabilize the soil waste in preparation for transport to a disposal facility. COCs are physically bound or enclosed in a stabilized mass.	RTD: Treatment	HIGH – Short-term effectiveness as a treatment technology for soil waste and debris where void fill or stabilization is required to meet waste acceptance criteria. HIGH – Long-term effectiveness as stabilized waste supports waste acceptance in an engineered landfill.	HIGH – void fill in disposal boxes; MODERATE – where waste form considerations are necessary. Soils with high contaminant concentrations may require mixing soils with a stabilizing agent to create a waste form suitable for on-site disposal.	LOW – HIGH. Varies based on treatment and contaminated soil quantity.

Notes:
COC = contaminant of concern
DVZ = deep vadose zone
IVZ = intermediate vadose zone
SVZ = shallow vadose zone
WMA C = Waste Management Area C

The process options in this table address both radiological and non-radiological contaminants of concern.

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APPENDIX D

POTENTIAL FEDERAL AND STATE APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

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Potential Federal and State Applicable or Relevant and Appropriate Requirements are listed in Table D-1.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Chemical Specific			
Hazardous Waste Clean Up/Model Toxics Control Act of 1989, Ch. 70.105D RCW			Alternatives 3 through 6 apply.
Model Toxics Control Act of 1989, WAC 173-340-720 through -7492	ARAR	This act identifies the methods used to develop cleanup standards and their use in selection of a cleanup action. Cleanup and remediation levels are based on protection of human health and the environment, the location of the site, and other regulations that apply to the site. The standard specifies cleanup goals that implement the strictest Federal or State cleanup criteria.	Certain requirements of Model Toxics Control Act (MTCA) pertaining to the setting of cleanup standards in WAC 173-340-720 through -7492 are applicable to WMA C remedial actions. As a containment alternative, MTCA acknowledges that numeric cleanup levels cannot be met but that reliance on controls (e.g., barriers, groundwater monitoring, and institutional controls) will be used to preclude contact above the numeric cleanup levels and minimize the migration of hazardous substances.
Dangerous Waste Regulations, Ch. 70.105 RCW			Alternatives 5 and 6 apply.
Dangerous Waste Regulations, WAC 173-303			
Designation of Waste, WAC 173-303-070 through 110	ARAR	Establishes the methods and procedures to determine if solid waste requires management as dangerous waste.	The requirements of this section are applicable because dangerous waste may be generated during characterization and remedial actions.
Releases from Regulated Units, WAC 173-303-645	ARAR	Establishes action levels for releases to groundwater from dangerous waste management units.	The standard is not applicable since treatment, storage, disposal units are not present at WMA C. However, action levels established in these requirements are ARAR to remedial actions.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Solid Waste Management, Recovery and Recycling Act of 1969, Ch. 70.95 RCW			Alternatives 3 through 6 apply.
Minimum Functional Standards for Solid Waste Handling, WAC 173-304-460	ARAR	Sets groundwater MCLs at the same levels as the drinking water standards under 40 CFR 141.	The standard is applicable since solid waste management will be associated with remedial actions.
Water Pollution Control/Water Resource Act of 1971, Ch. 90.48 RCW/Ch. 90.54 RCW			Alternatives 3 through 6 apply.
Surface Water Quality Standards, WAC 173-201A	ARAR	These standards set water quality standards at levels protective of aquatic life.	Groundwater below the 200 Areas discharges to the Columbia River; therefore, surface water quality criteria established under this chapter must be taken under consideration when developing cleanup standards for soil and groundwater associated with 200 Area remedial actions.
Department of Health Standards for Public Water Supplies, WAC 246-290	ARAR	The rule established under WAC 246-290 defines the regulatory requirements necessary to protect consumers using public drinking water supplies. The rules are intended to conform with the Federal SDWA, as amended. WAC 246-290-310 establishes MCLs that define the water quality requirements for public water supplies. WAC 246-290-310 establishes both primary and secondary MCLs and identifies that enforcement of the primary standards is the Department of Health's first priority.	Alternatives 3 through 6 apply. The requirements of WAC 246-290-310 are ARAR to WMA C remedial actions because groundwater is classified as a potential future source of drinking water.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
State Radiation Protection Requirements, 70.98 RCW			Alternatives 3 through 6 apply.
Radiation Protection Standards, WAC 246-221	ARAR	Washington State Radiation Protection Requirements are implemented under specific sections of WAC 246. Chapter 246-221-290 establishes annual average concentration limits for radioactive releases in gaseous and liquid effluent released to unrestricted areas. Occupational dose to adults and minors are set in these requirements. Dose limits that individual members of the public may receive in unrestricted areas from external sources are also set. The standard identifies the methods required to demonstrate compliance and provides derived air concentration and annual limit on uptake values that may be used to determine an individual's occupational dose. The standard specifies requirements for monitoring personnel exposure for both external and internal exposure.	This regulation is not applicable because it does not apply to Federal agencies under the Atomic Energy Act. However, it is considered ARAR because it establishes standards for acceptable levels of exposure to radiation.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Washington Clean Air Act of 1967, Ch. 70.94 RCW and Ch. 43.21A RCW			Alternatives 2 through 6 apply.
Radiation Protection - Air Emissions, WAC 246-247	ARAR	This regulation decrees limits for airborne radionuclide emissions per WAC 173-480 and Title 40, Code of Federal Regulations, Part 61, "National Emission Standards for Hazardous Air Pollutants", (40 CFR 61), Subparts H and I. Ambient air standards under WAC 173-480 require that the most stringent standard be enforced. Ambient air standards under 40 CFR 61 Subparts H and I are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public. The ambient standard in WAC 173-480 specifies that radionuclide emissions to air must not cause a dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. These standards specify emissions monitoring requirements and application of best available radionuclide technology requirements.	This regulation is considered applicable because it sets emission limits and use of BART for airborne radionuclides.
Radiation Protection at Uranium and Thorium Milling Operations, WAC 246-252	ARAR	Radium-226 concentrations are required to be less than 5 pCi/g averaged over the upper 15 cm and not more than 15 pCi/g averaged over any 15 cm interval deeper than 15 cm from the surface. Groundwater protection standards established for gross alpha excluding radon and uranium are set at 15 pCi/L, and for combined radium-226 and radium-228, not to exceed 5 pCi/L.	This is not applicable to WMA C remedial actions because the facility was not a uranium or thorium milling operations; however, the regulation is ARAR because it contains specific soil cleanup limits for radium-226 and radium-228 and groundwater protection limits.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Location Specific			
Department of Fish and Wildlife Procedures, WAC 232-012	ARAR	This standard defines requirements that the Department of Fish and Wildlife must meet to protect endangered or threatened wildlife.	Alternatives 2 through 6 apply. These requirements may be ARAR, if endangered or threatened wildlife are identified near WMA C during wildlife surveys. The requirements of this chapter will be re-evaluated should protected wildlife species be identified within the 200 Areas.
National Area Preserves, RCW 79.70			Alternatives 1 through 6 are TBC.
Washington Natural Heritage Program	TBC	The Washington State Natural Heritage Program is authorized under RCW 79.70, "Natural Area Preserves," and serves as an advisory council to the Washington State Department of Natural Resources, Washington State Department of Fish and Wildlife, the Parks and Recreation Commission, and other State agencies that manage State-owned lands or natural resources. The list of State endangered, threatened, and sensitive plants developed by the program, along with program-recommended levels of protection, are to be used to assist resource managers in determining which species of concern occur in their areas and recommend their protection. The designations provided to plants by the Washington State Natural Heritage program are advisory and do not specify a regulatory level of protection.	The requirements of the Natural Heritage Program are TBC guidance for remedial actions at WMA C. No threatened or endangered plant species have been currently identified in the 200 Areas.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
		Action Specific	
Hazardous Waste Cleanup Model Toxics Control Act of 1989, Ch. 70.105D RCW			Alternatives 2 through 6 apply.
Model Toxics Control Act Cleanup Regulations of 1989, WAC 173-340-720 through 7492	ARAR	Establishes a process for setting cleanup standards of contaminated sites in the State. Specifies that all cleanup actions be protective of human health and ecological receptors, comply with all applicable State and Federal regulations.	Certain requirements of MTCA pertaining to the setting of cleanup standards in WAC 173-340-720 through -7492 are applicable to WMA C remedial actions. As a containment alternative, MTCA acknowledges that numeric cleanup levels cannot be met but that reliance on controls (e.g., barriers, groundwater monitoring, and institutional controls) will be used to preclude contact above the numeric cleanup levels and minimize the migration of hazardous substances.
Hazardous Waste Management Act of 1985, 70.105 RCW			Alternatives 5 and 6 apply.
Dangerous Waste Regulations, WAC 173-303	ARAR	Establishes the design, operation, and monitoring requirements for management of dangerous waste.	Applicable to dangerous wastes generated during remedial activities. All sections of this chapter may be applicable to dangerous waste management activities during WMA C remediation. Key sections are highlighted below.
Land Disposal Restrictions, WAC 173-303-140	ARAR	Identifies dangerous wastes that are restricted from land disposal and describes requirements for State-only restricted wastes, and define the circumstances under which a prohibited waste may be disposed.	Applicable to the disposal of dangerous waste generated during WMA C characterization and remedial actions.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Spills and Discharges into the Environment, WAC 173-303-145	ARAR	Sets forth the requirements that apply when any dangerous waste or hazardous substances are intentionally or accidentally spilled or discharged into the environment such that human health and the environment are threatened, regardless of the quantity of dangerous waste or hazardous substance.	Alternatives 5 and 6 apply. Applicable should dangerous waste or hazardous substances be spilled or discharged into the environment.
Requirements for Generators of Dangerous Waste, WAC 173-303-170 through 230	ARAR	Requirements defined under this section include a 90-day waste accumulation period, specific levels of training, emergency preparedness, and record keeping.	Applicable to actions performed at the site if dangerous waste is generated.
Siting Criteria, WAC 173-303-282(6) and (7)	ARAR	Establishes siting criteria that serve as an initial screen for consideration of sites for dangerous waste management.	Applicable to WMA C alternatives that may involve disposal of dangerous waste.
General Requirements for Dangerous Waste Management Facilities, WAC 173-303-280 through 395	ARAR	General requirements include siting standards and procedures for permitting, training, emergency preparedness, security, inspections, contingency planning, waste analysis, and management of containers.	Applicable to remedial actions that include treatment, storage, or disposal of designated dangerous waste.
Landfills, WAC 173-303-665	ARAR	Specifies environmental performance standards, monitoring and testing, and post-closure care requirements for the storage, treatment, and disposal of waste in landfills.	No alternative would apply. Applicable to WMA C alternatives that include receipt of waste from other CERCLA actions, as these alternatives would create a disposal unit.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Solid Waste Management, Recovery, and Recycling Act of 1969, Ch. 70.95 RCW			Alternatives 2 through 6 apply.
Minimum Functional Standards for Solid Waste Handling, WAC 173-304	ARAR	These standards establish requirements to be met for managing solid waste. Solid waste controlled by this act includes garbage, industrial waste, construction waste, and ashes. Requirements for containerized storage, collection, transportation, treatment, and disposal of solid waste are included.	These regulations are applicable to on-site management and disposal of solid waste that may be generated during characterization or remedial activities.
NRC 10 CFR 20 Subpart E, Cancer Risk Range	ARAR	These requirements establish incremental cancer risk ranges for radionuclides to be considered protective of human health and the environment.	Alternatives 3 through 6 apply. After stopping waste management operations, remediation goals for radioactive wastes and radioactively contaminated soils for human receptors are considered to be based on EPA radionuclide soil cleanup guidance. For practical purposes, a 15 mrem/yr dose above background (generally representing a risk level of approximately 3.0×10^{-4}) is used during Hanford Site cleanup activities to achieve the CERCLA risk range. Standards for maximum contaminant levels for certain radionuclides, based on an annual dose limit, are listed in 40 CFR 141.
40 CFR 141, Maximum contaminant levels for certain radionuclides, based on annual dose limit.	ARAR		
Radioactive Waste Management, DOE Order 435.1, 1999, Radioactive Waste Management	ARAR		

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
DOE Order 5400.5, 1993 Radiation Protection of the Public and the Environment	ARAR	DOE dose limits of 500 mrem/yr for radiological workers as long as operations continue at WMA C. After WMA C closure, institutional controls would exist to prevent access to contaminated material.	Alternatives 2 through 6 apply. Institutional controls exist with effective barriers to prevent access to contaminated materials.
Water Pollution Control/Water Resources Act of 1971, Ch. 90.48 RCW/Ch. 90.54 RCW			No alternatives apply.
Protection of Upper Aquifer Zones, WAC 173-154	ARAR	This regulation directs Ecology to provide for protection of upper aquifers and upper aquifer zones to avoid depletions, excessive water level declines, or reductions in water quality.	This regulation does not apply to remedial actions, as it establishes the policy and program for Ecology. However, the regulation is considered ARAR, since protection of the aquifer from adverse impacts caused by waste management units is a primary goal.
State Waste Discharge Program, WAC 173-216	ARAR	The chapter identifies specific discharges prohibited under the program. The intent of the law is to maintain the highest possible standards, and the law requires the use of all known available and reasonable methods to prevent and control the discharge of wastes into the waters of the State.	Requirements of this program are ARAR to remedial actions that include discharges to the ground. Disposal alternatives may result in runoff that would need to meet the substantive requirements of these regulations.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Washington Clean Air Act of 1967, Ch. 70.94 RCW & Ch. 43.21A RCW			Alternatives 3 through 6 apply.
General Regulations for Air Pollution, WAC 173-400	ARAR	This regulation requires all site sources of air contaminants to meet emission standards for visible, particulate, fugitive, odors, and hazardous air emissions. This section requires that all emission units use reasonably available control technology, which may be determined for some source categories to be more stringent than the emission limitations listed in this chapter. The regulation requires that source testing and monitoring be performed. A new source would include any process or source that may increase emissions or ambient air concentration of any contaminant for which Federal or State ambient or emission standards have been established.	General standards for control of fugitive emissions are applicable to remedial actions at the site due to the generation of fugitive dust that occurs during demolition or other types of construction activities (e.g., barrier construction).
Ambient Air Quality Standards for Particulate Matter, WAC 173-470	ARAR	These requirements set maximum acceptable levels for particulate matter in the ambient air at 150 $\mu g/m^3$ over a 24-hour period, or 60 $\mu g/m^3$ annual geometric mean. It also sets the 24-hour ambient air concentration standard for particles less than 10 µm in diameter (PM10), which are set at 105 $\mu g/m^3$ and 50 $\mu g/m^3$ geometric mean. The section defines standards for particle fallout not to exceed 10 g/m^2 per month in an industrial area or 5 g/m^2 per month in residential or commercial areas. Alternate levels for areas where natural dust levels exceed 3.5 g/m^2 per month are set at 6.5 g/m^2 per month, plus background levels for industrial areas, and 1.5 g/m^2 per month plus background in residential and commercial areas.	Alternatives 5 and 6 apply. These requirements are applicable to remedial actions that may emit particulate matter to the air.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
Ambient Air Quality Standards and Emission Limits for Radionuclides, WAC 173-480	ARAR	These requirements establish that the most stringent Federal or State ambient air quality standard for radionuclides be enforced. WAC 173-480 defines the maximum allowable level for ambient air radionuclides, which shall not cause a maximum accumulated dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. However, ambient air standards under 40 CFR 61 Subparts H and I are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public. Emission standards for new and modified emission units shall utilize best available radionuclide control technology.	Alternatives 3 through 6 apply. Requirements of this State-authorized standard are ARAR to remedial actions performed at the site that may emit radionuclides to the air.
40 CFR 761 Toxic Substances Control Act of 1976	ARAR	Polychlorinated biphenyl (PCB) remediation waste does not depend on the current concentration of PCBs in the waste if a spill occurs.	Alternatives 5 and 6 apply. PCB-containing material should be managed as PCB remediation waste.
Emission Standards and Controls for Sources Emitting Volatile Organic Compounds (VOC), WAC 173-490	ARAR	This chapter establishes technically feasible and attainable standards for sources emitting volatile organic compounds.	Alternatives 5 and 6 may apply. This regulation is probably not applicable to remedial actions conducted at WMA C because the source of potential volatile organic compound emissions generated by remedial actions most likely does not meet the definition of emission sources specified under WAC 173-490-030. However, this regulation may be considered ARAR if remedial actions have the potential to emit volatile organic compounds into the air.

Table D-1. Identification of Potential Federal and State Applicable or Relevant and Appropriate Requirements and To Be Considereds for the Waste Management Area C Corrective Measures Alternatives.

ARAR Citation	ARAR or TBC	Requirement	Rationale for Use with Alternative
State Radiation Protection Requirements, Ch. 70.98 RCW			Alternatives 2 through 6 apply.
Radioactive Waste Licensing Land Disposal, WAC 246-250	ARAR	WAC 246-250 sets the procedures, criteria, and conditions for licensing low-level radioactive waste land disposal facilities. This section presents specific levels of radiation protection and technical requirements for land disposal of radioactive waste.	These requirements are considered ARAR if remedial alternatives allow radioactive waste to remain on-site. Some radioactive waste will remain in the soil and in tanks.

Notes:

ARAR	= applicable or relevant and appropriate requirement	MCL	= maximum contaminant level
CERCLA	= Comprehensive Environmental Response, Compensation, and Liability Act of 1980	MTCA	= Model Toxics Control Act
CFR	= Code of Federal Regulations	RCW	= Revised Code of Washington
Ecology	= Washington State Department of Ecology	SDWA	= Safe Drinking Water Act
EPA	= U.S. Environmental Protection Agency	TBC	= to be considered
		WAC	= Washington Administrative Code

REFERENCES

10 CFR 20, "Standards for Protection Against Radiation," Subpart E—Radiological Criteria for License Termination, Code of Federal Regulations, as amended.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Code of Federal Regulations, as amended.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart H—National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities, Code of Federal Regulations, as amended.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart I—National Emission Standards for Radionuclide Emissions from Federal Facilities Other Than Nuclear Regulatory Commission Licensees and Not Covered by Subpart H, Code of Federal Regulations, as amended.

40 CFR 141, "National Primary Drinking Water Regulations," Code of Federal Regulations, as amended.

40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," Code of Federal Regulations, as amended.

Atomic Energy Act of 1954, 42 USC 2011, et seq., as amended.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9622, et seq.

DOE O 435.1, 2001, Radioactive Waste Management, U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5, 1993, Radiation Protection of the Public and the Environment, Change 2, U.S. Department of Energy, Washington, D.C.

RCW 43.21A, "Department of Ecology," Revised Code of Washington, as amended.

RCW 70.94, "Washington Clean Air Act," Revised Code of Washington, as amended.

RCW 70.95, "Solid Waste Management—Reduction and Recycling," Revised Code of Washington, as amended.

RCW 70.98, "Nuclear Energy and Radiation," Revised Code of Washington, as amended.

RCW 79.70, "National Area Preserves," Revised Code of Washington, as amended.

RCW 70.105, "Hazardous Waste Management," Revised Code of Washington, as amended.

RCW 70.105D, "Hazardous Waste Cleanup — Model Toxics Control Act," Revised Code of Washington, as amended.

RCW 90.48, "Water Pollution Control," Revised Code of Washington, as amended.

RCW 90.54, "Water Resources Act of 1971," Revised Code of Washington, as amended.

Safe Drinking Water Act of 1974, 42 USC 300, et seq.

Toxic Substances Control Act of 1976, 15 USC 2601, et seq.

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

WAC 173-216, "State Waste Discharge Permit Program," Washington Administrative Code, as amended.

WAC 173-303, "Dangerous Waste Regulations," Washington Administrative Code, as amended.

WAC 173-303-070, "Designation of Dangerous Waste," Washington Administrative Code, as amended.

WAC 173-303-110, "Sampling, Testing Methods, and Analytes," Washington Administrative Code, as amended.

WAC 173-303-140, "Land Disposal Restrictions," Washington Administrative Code, as amended.

WAC 173-303-145, "Spills and Discharges into the ESnvironment," Washington Administrative Code, as amended.

WAC 173-154, "Protection of Upper Aquifer Zones," Washington Administrative Code, as amended.

WAC 173-303-170, "Requirements for Generators of Dangerous Waste," Washington Administrative Code, as amended.

WAC 173-303-230, "Special Conditions," Washington Administrative Code, as amended.

WAC 173-303-280, "General Requirements for Dangerous Waste Management Facilities," Washington Administrative Code, as amended.

WAC 173-303-282, "Siting Criteria," Washington Administrative Code, as amended.

WAC 173-303-395, "Other General Requirements," Washington Administrative Code, as amended.

WAC 173-303-645, "Releases from Regulated Units," Washington Administrative Code, as amended.

WAC 173-303-665, "Landfills," Washington Administrative Code, as amended.

WAC 173-304-460, "Landfilling Standards," Washington Administrative Code, as amended.

WAC 173-340, "Model Toxics Control Act—Cleanup," Washington Administrative Code, as amended.

WAC 173-340-720, "Groundwater Cleanup Standards," Washington Administrative Code, as amended.

WAC 173-340-7492, "Simplified Terrestrial Ecological Evaluation Procedures," Washington Administrative Code, as amended.

WAC 173-400, "General Regulations for Air Pollution Sources," Washington Administrative Code, as amended.

WAC 173-470, "Ambient Air Quality Standards for Particulate Matter," Washington Administrative Code, as amended.

WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides," Washington Administrative Code, as amended.

WAC 173-490, "Emission Standards and Controls for Sources Emitting Volatile Organic Compounds (VOC)," Washington Administrative Code, as amended.

WAC 173-490-030, "Registration and Reporting," Washington Administrative Code, as amended.

WAC 232-12, "Permanent Regulations," Washington Administrative Code, as amended.

WAC 246-221, "Radiation Protection Standards," Washington Administrative Code, as amended.

WAC 246-221-290, "Appendix A—Annual Limits on Intake (ALI) and Derived Air Concentrations (DAC) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sanitary Sewerage," Washington Administrative Code, as amended.

WAC 246-247, "Radiation Protection—Air Emissions," Washington Administrative Code, as amended.

WAC 246-250, "Radioactive Waste—Licensing Land Disposal," Washington Administrative Code, as amended.

WAC 246-252, "Radiation Protection—Uranium or Thorium Milling," Washington Administrative Code, as amended.

WAC 246-290, "Group A Public Water Supplies," Washington Administrative Code, as amended.

WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)," Washington Administrative Code, as amended.

Washington Natural Heritage Program, Department of Natural Resources, Olympia, Washington.

APPENDIX E

DETAILED COST ESTIMATE

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TERMS

Terms and acronyms used throughout this appendix, including tables, are listed as follows:

AACEI	Association for the Advancement of Cost Engineering International.
ADS	Advanced Drainage Systems.
approx.	approximately.
bgs	below ground surface.
cf	cubic feet/foot.
cfh	cubic feet per hour.
cfm	cubic feet per minute.
cm	cubic meters.
CMS	corrective measures study.
CTA	container transfer area.
cy	cubic yard.
decon.	decontamination.
ea	each.
eng.	engineer.
ERDF	Environmental Restoration Disposal Facility.
ESF	every square foot
ET	evapotranspiration.
ft	feet or foot.
FTE	full-time equivalent.
HEPA	high-efficiency particulate air.
hr	hour.
HVAC	heating, ventilation, and air conditioning.
in.	inch.
ISB	interim surface barrier.
K	thousand or 1,000.
lb	pound.
lf	linear foot.
ls	lump sum.
mo	month.
PVC	polyvinyl chloride.
rad	radioactive.
SOW	statement of work.
SST	single-shell tank.
TBD	to be determined.
TEC	total estimated cost.
qty	quantity.
UPR	unplanned release.
vol	volume.
WA	Washington.
WCS	Waste Control Specialist, LLC, Andrews, Texas.
wk.	week.
WMA	waste management area.
WRPS	Washington River Protection Solutions.

wt.	weight.
yd^2	square yard.
yd^3	cubic yard.
yr	year.

E1.1 Introduction

This appendix contains the detailed cost estimates prepared for the corrective measures alternatives developed in Section 3.0 of RPP-RPT-59379, "Waste Management Area C Phase 2 Corrective Measures Study Report" (CMS). The following information is provided in this appendix:

- Cost estimate development methods (Section E1.2),
- Alternatives descriptions (Section E1.3),
- Primary cost assumptions (Section E1.4),
- Labor costs (Section E1.5),
- Equipment costs (Section E1.6),
- Alternative-specific assumption (Section E1.7),
- Exclusions (Section E1.8),
- Markups (Section E1.8),
- Sensitivity Analysis (Section E1.9),
- Detailed estimated cost tables (Section E1.10).

E1.2 Cost Estimate Development Methods

The cost estimates were developed in accordance with WRPS cost-estimating procedures and the U.S. Environmental Protection Agency (EPA) guidance EPA 540-R-00-002, A Guide to Developing and Documenting Cost Estimates during the Feasibility Study. The cost estimate was generated using the 2016 version of Microsoft® Excel®[1] Software. No unverified algorithms or software were used to generate this cost estimate.

The cost estimating workbook in conjunction with historical cost data and estimated allowances were used to develop the cost estimate for each of the corrective measure alternatives. Assumed project scope items were itemized and unit costs were applied as shown in Section 0. Past cost estimates for similar WRPS projects were utilized in developing unit costs and labor rates as available. Costs from past estimates were escalated to 2016 at a rate of 3% per year. Cost buildups are generated through the combination of one or more unit costs and/or an additional factor, typically a duration or percentage, to generate a new unit cost. In the absence of historical data to support cost development, the project engineer or cost estimator have provided cost allowances, either as lump sums or percentages, from previous project experience at the Hanford Site.

The information in the cost estimate tables (Section 4.1.7) is based on the best available information regarding the anticipated scope of the alternatives; cost elements are derived from input parameters readily available at the time of preparation. These are order-of-magnitude engineering cost estimates that are anticipated to range within -30% to +50% of the actual project cost (per EPA/540/R-00/002) and are not to be used to establish or negotiate project budgets. The final costs of the selected corrective measure alternative would depend on actual

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labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule, and other factors at the time of implementation.

E1.3 Alternatives Descriptions

This section briefly describes each alternative. Refer to Section 3.0 in the main body of the CMS for a more complete description of each alternative.

E1.3.1 Alternative 1 – No Action

The "no action" alternative is defined as what would most likely happen, if no corrective actions occurred.

E1.3.2 Alternative 2 – Institutional Controls

This alternative consists of a continuation of existing institutional controls for both the Hanford Site and WMA C. No actions would be taken to reduce the toxicity, mobility, or volume of contaminated soil, or mitigate the risks from exposure to shallow (15 feet [ft] deep) soil contamination. During implementation of this alternative, on-site access would be limited to performing routine monitoring and surveillance activities pending final closure actions (e.g., placement of the closure cap), after completing tank closure activities and above-grade facilities and equipment removal at WMA C.

E1.3.3 Alternative 3 – Isolation Barriers

This alternative consists of constructing concrete isolation barriers, as an interim remedy, to mitigate risks to WMA C workers from exposure to contamination in shallow soil. Areas where ^{137}Cs or ^{126}Sn concentrations exceed action levels for direct-contact with shallow soil are selected for barrier construction. The isolation barriers would not provide a substantial reduction in infiltration and would not reduce anticipated, future groundwater impacts from continued migration of mobile contaminants.

The isolation barriers would be constructed over single-shell tanks (SSTs) after tank closure activities are completed and above-grade equipment is removed from WMA C. Activities included in isolation barriers construction include the following:

- Construct isolation barriers to isolate localized areas where ^{137}Cs or ^{126}Sn concentrations exceed action levels for direct-contact with shallow soil.

- Each isolation barrier would require placing forms and reinforcing steel followed by filling the forms with a commercial-grade concrete mixture to a thickness of approximately 0.5 ft.

- A thicker concrete isolation barrier or structure would be constructed over the irregular shotcrete cap surfaces over UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 to avoid disturbing the contamination.

E1.3.4 Alternative 4 – Isolation + Infiltration Barriers System

This alternative consists of constructing modified-asphalt infiltration barriers over the top of the Alternative three isolation barriers to reduce infiltration and mitigate anticipated, future groundwater quality impacts from mobile contaminants. An infiltration barrier would be constructed over the 100-series SSTs and around the three UPRs: UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86.

At both UPR-200-E-82 and UPR-200-E-86 actions previously taken in response to the transfer line leaks included placing gravel over the exposed leak area and later covering the gravel with shotcrete. At both of these locations, the mounded surface does not lend itself to covering with modified asphalt without disturbing the UPRs. These UPRs will be covered with a concrete isolation barrier to avoid removing existing cover material. The infiltration barrier system will then be placed over the isolation barriers to provide a larger barrier footprint and storm water collection and conveyance out of WMA C.

This alternative utilizes a low permeability modified-asphalt material over WMA C to minimize infiltration. To collect and control storm water runoff, a sloped subgrade would be established by placing and compacting fill material to establish a minimum slope. Modified-asphalt material would then be placed using commercial paving equipment for hot mix asphalt. After placement, the modified-asphalt landfill cap system would serve to minimize infiltration into the vadose zone beneath the infiltration barrier footprint. An evapotranspiration basin will be constructed as a part of the landfill cap system to limit storm water discharges near adjacent waste sites.

Given the uncertainties associated with the depth and lateral extent of the mobile contaminants at WMA C the footprint for the infiltration barrier is assumed to cover the SSTs and the UPRs on the upper portion of the C Tank Farm (UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86). The infiltration barrier footprint over the SSTs would reach approximately (450x500 ft) in area. The barriers over UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 would be a combination of an isolation barrier directly over the UPRs and a modified asphalt barrier.

Construction of the interim surface barrier involves:

- Establishing drainage subgrade within the footprint of the interim barrier through a combination of cut and fill. Any regrading of the existing WMA surface could disturb potentially contaminated material and would be minimized to the extent possible. Constructing a subgrade over the 100 series tanks to establish a one-percent slope would require approximately 20,000 ft^3 of fill material. Commercial earthwork equipment would be used to haul, place, and compact the fill material. Water would be used to aid in compaction and control dust but use would be controlled to avoid mobilizing contamination.

- Installing a storm water collection and conveyance system.

- Constructing the interim surface barrier. The modified asphalt would be placed using commercial paving practices. A specialty binder would be used along with conventional hot mix asphalt materials to produce the modified asphalt for surface barrier applications.

- Constructing an evapotranspiration basin northeast of WMA C. The evapotranspiration basin would be sized to accommodate the barrier runoff and placed to limit the need to excavate in contaminated areas and to allow gravity drainage to the basin if possible.

E1.3.5 Alternative 5 – Excavation/On-Site Disposal

This alternative consists of selective removal of shallow contaminated soils at three target areas within WMA C. The three target areas include UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 where the highest concentrations of COCs in the shallow soil have been observed and exceed action levels by 3 to 7 orders of magnitude. If required, contaminated soils would be treated per the Hanford Site Environmental Restoration Disposal Facility (ERDF) waste acceptance criteria and transported to ERDF for disposal. Excavation activities would be delimited by the assumed limit of technology for surface based excavation of 40 ft in depth. After soil removal, clean backfill would be placed in the excavation locations to restore the C Tank Farm surface.

Based on the available characterization data an excavation footprint of 65x80 ft would be sufficient to remove the majority of the shallow contaminated soils associated with each of the target excavation areas: UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86. Applying a standard layback of 1.5:1 would provide for an excavation footprint of 20x20 ft at a depth of 15 ft with an allowance for an equipment access ramp. After reaching the 15-ft excavation depth a sheet pile retention wall would be installed to support continued excavation to a depth of 40 ft. This would allow for confirmatory sampling to be conducted and continued excavation below the 15-ft depth if necessary based on contamination levels.

Field implementation would include the following actions:

- Construct a temporary enclosure over each excavation area with airlocks for personnel and equipment entry and exit. The enclosure will be sized to accommodate the anticipated footprint of the excavation with some contingency allowing for an increase of the footprint based on field conditions.

- Install a ventilation system with HEPA filtration to maintain the interior of the enclosure at a slight negative pressure and control potential air emissions.

- Install electrical power distribution for lighting ventilation, and monitoring systems from existing site utilities or from the use of a temporary generator. Electrical power could be obtained by tying into existing nearby electrical service or by utilizing temporary portable generators.

- Establish a container transfer area (CTA) for managing transfer of containers with contaminated materials out of the C Tank Farm. Once the containers inside of the confinement tent are filled, they would be transferred into the CTA for survey, decontamination of the exterior surfaces if/as required, sampling and analysis, and staging while shipping documentation is completed.

- Install a control trailer for remote equipment operations.

- Implement a safety program and environmental monitoring program to support excavation activities, before initiating operations.

- Remove soil using remotely operated excavation equipment, and place it into roll on/roll off containers. A variety of methods are anticipated to minimize contamination spread during excavation including water fogging and spray on fixatives for dust suppression (e.g., dust bond from D&D Emulsions, Inc.)

- Treat where required to meet ERDF waste acceptance criteria, contaminated soils and debris with macro-encapsulation prior to transfer to the CTA.

- Transfer waste containers from the confinement enclosure to the CTA for staging.

- Crimp and shear direct buried pipe encountered in the excavation and place into a dedicated disposal box using readily available demolition attachments for excavators. To meet void-fill requirements the disposal box will be filled with self-consolidating grout prior to shipment to ERDF.

- Establish the extent of the excavation with confirmatory surveys.

- Place and compact clean fill to reestablish the grade at the completion of excavation activities.

- Dismantle the enclosures, which will be contaminated after contaminated soil removal activities, and transport them to ERDF for disposal.

E1.3.6 Alternative 6 – Excavation + Infiltration Barriers System

This alternative consists of a combination of the actions taken for Alternatives 4 and 5. Shallow contaminated soils will be removed at three target areas within WMA C. The three target areas include UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 where the highest concentrations of COCs in the shallow soil have been observed and the maximum concentrations exceed action levels by 3 to 7 orders of magnitude. If required, contaminated soils would be treated to meet the ERDF waste acceptance criteria and transported to ERDF for disposal. Excavation activities would be limited to the assumed technology limit of 40 ft of depth for surface-based excavation. After soil removal, clean backfill would be placed in the excavation locations to restore the C Tank Farm surface.

After backfill and removal of the containment structures are completed, a modified-asphalt surface barrier would be constructed over the UPR locations and over the 100-series tanks. The footprint of the modified asphalt barrier would be the same as for Alternative 4. After the removal action at the UPRs, there would no longer be a need to install an isolation barrier so the infiltration barrier system would cover the entire UPR areas.

E1.4 Primary Cost Assumptions

The primary cost assumptions of the workbook are described in Table E-1.

Table E-1. Main Engineering Assumptions Pertaining to Cost Estimation.

Topic	Assumption
Work Period	
Seasonal closures	Assumes no seasonal closures: construction is 365 calendar days.
Work shifts	One work week equals four days per calendar week. One workday equals one 10-hour shift.
Work stoppages	Work stoppages or shutdowns caused by inclement or extreme weather (i.e., snow, high winds, lightning storms, etc.) are not factored into the estimates.
Work delays	Work delays or stoppages caused by waiting for receipt of laboratory analytical results or approval for backfilling waste-site excavations are not factored into the estimates.
Procurement	
Concrete costs	Per yd^3 includes rebar, forms, and form bracing. Rebar is 0.5-inch diameter at 0.5-ft spacing.
Construction	
Existing site trailer	Assumes existing Waste Management Area C trailer is available for use throughout the project performance period.
Mobilization costs	Subcontractor mobilization costs are assumed to be 8% of total construction costs for an alternative. Covers bonding and insurance requirements associated with personnel and equipment mobilization.
Enclosure demolition	Enclosures demolition costs enclosures are assumed to be 20% of the enclosure capital costs.
Miscellaneous consumables	Assumed to be $1K per day ($4K per work week) during construction activities.
Personal protective equipment consumables	Assumed to be 5% of the total field labor costs.
Operations	
Backfill material	Assumed to originate from on site. During design phase, the actual source location would be identified and comply with National Environmental Policy Act requirements.
Waste Disposal	
Disposal weight	Assumes disposal weight is 5% of barrier volume (concrete/asphalt) with 2 yd^3 of material per ton.

E1.5 Labor Costs

Labor costs found within the cost estimate utilize information from past WRPS cost estimates. A composite labor was developed rate for waste retrieval and closure activities that involve both design and field activities. Past estimates included 70,829 labor hours for a total fully burdened estimated cost of $7,844,462 in fiscal year (FY) 2015 dollars (this cost was not escalated to 2016 dollars). This yields an average fully burdened labor rate of $110.75/hr. With the addition of a 10.75% fee to capture workers' compensation, unemployment taxes, fringe benefits, and medical insurance, the rate equals a rounded value of $123/hr for the purpose of ROM estimating. This $123/hr rate was used to build up a single full- time equivalent (FTE) rate of $4,920 per week, assuming a 40-hour-per-week schedule. This FTE rate was used as a base to generate labor rates for both WRPS and subcontractor crews ranging from 0.25 FTE up to 19 FTE. Specific crew makeup and individual labor rates were not used in the creation of this cost estimate.

A labor rate of $123/hr was used as a generalized cost for surveying at Hanford. This labor rate was utilized for all labor activities within this cost estimate.

Additional labor items are captured in this cost estimate as part of the lump sum or buildup costs for select activities. Additionally, subcontractor defined labor rates from past WRPS estimates are used if available.

E1.6 Equipment Costs

Miscellaneous equipment costs were assumed to be 30% of the total field work costs. As field labor costs constitute the other 70% of the total field work costs, equipment costs were calculated as follows:

$$Equipment\ Costs = \left(\frac{Sum(Field\ Labor\ Costs)}{70\%}\right) \times 30\%$$

High priced equipment specific to an alternative (e.g., remote excavator with attachments) were included as separate cost elements during the procurement phase.

E1.7 Alternative-Specific Assumptions

The following alternative-specific assumptions were used in developing the project scope, durations, and costs for each corrective measures alternative.

E1.7.1 Alternative 1 – No Action

No alternative-specific assumptions are associated with Alternative 1.

E1.7.2 Alternative 2 – Institutional Controls

Costing assumptions specific to Alternative 2 include: No actions, other than maintaining existing institutional controls, would be implemented.

E1.7.3 Alternative 3 – Isolation Barriers

Costing assumptions specific to Alternative 3 include:

1. The project duration would be 12 months (one year).
2. WRPS project management support for the project duration would include:
   a. 0.25 FTE – project manager,
   b. One FTE (total) – buyer technical representative, administrative, quality assurance, and procurement, and
   c. 0.5 FTE – project engineer.
3. Subcontractor architect/engineer design services would be $75K.
4. WRPS design review and oversight would be $25K.
5. WRPS air permitting support would include two FTEs for five weeks.
6. WRPS regulatory support would require one FTE for two weeks.
7. WRPS general project support is assumed to be 12% of the procurement estimate. This allowance covers legal fees, statement of work creation, safety planning, and engineering support staff.
8. Gravel and concrete materials quantities are based on the values in Table D-3.
9. Allowance for personal protective equipment added that is 5% of total field labor costs.
10. Broad air monitoring is a monthly allowance to cover air monitoring operations across WMA C during site activities for duration of the project.
11. Assume one test of the concrete material at $3K per test.
12. Allowance for mobilization of crews and equipment added that is 8% of total construction costs.
13. Assumes an eight FTE subcontractor crew for one week to perform site preparations (e.g., staging and setup).
14. Assumes eight site workers and 15 subcontract workers (23 total) require project-specific training at $2.5K per worker. Assume that a minimum of two industrial hygienists, two radiological technicians, and one field work supervisor are included in the eight site workers.

15. WRPS field work support crew would include full-time support of one field supervisor, two industrial hygienists and two radiological technicians for one week.

16. Assumes an eight FTE subcontractor crew for one week each to build the concrete forms, place the steel rebar, and remove the forms.

17. Assumes a 12 FTE subcontractor crew for one week to place and finish the concrete.

18. Equipment allowance added that is 30% of the total field labor costs.

19. Assumes an eight FTE subcontractor crew for one week each to perform disposal activities and demobilize.

20. Disposal quantities for ERDF class “WG” waste are based on the values in Table D-3.

21. Assume one work package each for gravel placement, site prep, and concrete placement (3packages total at $15K each).

22. Assume $15K for a project completion report.

E1.7.4 Alternative 4 – Isolation + Infiltration Barrier System

Costing assumptions specific to Alternative 4 include:

1. Project duration of 24 consecutive months assuming one year of design and planning and one year of construction.

2. WRPS project management support for the project duration would include:

3. 1 FTE (each) – Project Manager and Project Engineer.

4. 2 FTE (total) – Buyer Technical Representative, Administrative, Quality Assurance, and Procurement.

5. Subcontractor architect/engineer design services would be $500K (based on SX Farm interim surface barrier design costs).

6. WRPS design review and oversight would be $50K (based on SX Farm ISB Design costs).

7. WRPS air permitting support of two FTEs for five weeks.

8. WRPS regulatory support of one FTE for five weeks.

9. WRPS general project support is assumed to be 10% of the procurement estimate. This allowance covers legal fees, statement of work creation, safety planning, and engineering support staff.

10. For the subgrade, costs are assumed to be \$500/cubic yard (yd3), based on T Farm interim surface barrier actuals for subgrade fill. This covers material placement and compaction. This includes gravel pads for isolation barriers at UPR-200-E-82 (60×60×0.75 ft) and UPR-200-E-86 (320×170×0.75 ft).

11. Gravel and concrete quantities are based on the values in Table E-4.

12. Assume geomembrane for evapotranspiration barrier cost would be \$1/ft^2 (based on a 2010 quote of \$0.80/ft^2 for a Layfield Enviroliner with underlayment and overlayment).

13. Riser extensions (bollards, corrugated metal pipe, and miscellaneous protective components) were scaled from the cost at SX Farm, which was \$40K for 3.3-acre pavement. The scaling factor is 1.73, making the approximate cost \$70K.

14. For PVC drain line from the storm water boxes to the evapotranspiration basin, assume 1,200 ft of 18-inch-diameter corrugated metal and 6,000 ft of 12-inch-diameter perforated PVC would be needed for the drain line in from the storm water boxes to the evapotranspiration basin.

15. Six precast storm water boxes (12×6×4 ft) with grating are needed at an estimated cost of \$2K each.

16. Allowance for miscellaneous construction consumables added that is estimated at \$1,000/day or \$4,000/workweek for the duration of construction activities.

17. Allowance for personal protective equipment added that is 5% of total field labor costs.

18. A double-wide trailer and bathroom trailer will be rented for the duration of construction activities.

19. For grade testing, assume one subcontractor surveyor on-site for three weeks during subgrade preparation.

20. Assume ground scans for evapotranspiration basin excavation and drain line trenching would be approximately \$50K.

21. Assume one test of the concrete material at \$3K per test.

22. Broad air monitoring is a monthly allowance to cover air monitoring operations across WMA C during site activities for duration of construction activities.

23. For asphalt mix testing, assume two subcontractor technical representatives on-site for three weeks during construction at a total rate of approximately $3,600 per day, which includes travel, and lay-down and compaction tests.

24. Allowance for mobilization of crews and equipment added that is 8% of total construction costs.

25. Assumes an eight FTE subcontractor crew for one week to perform site preparations (e.g., staging and setup).

26. Assumes eight site workers and 25 subcontract workers (33 total) require project-specific training at $2,500 per worker. Assume that a minimum of two industrial hygienists, two radiological technicians, and one field work supervisor are included in the eight site workers.

27. WRPS field work support crew would include full-time support of one field supervisor, two industrial hygienists and two radiological technicians for one year.

28. Basin earthwork includes clearing and grubbing evapotranspiration basin area (approximately eight acres), excavating and stockpiling materials, backfill evapotranspiration basin, and installing drain line header & perforated drain line. Assume duration of 12 weeks and costs are based on historical commercial estimate from Swaggart Brothers Construction of $647,500 for the TY Basin. TY basin was 80,000 ft^2 (per MatCon website); the WMA C evapotranspiration basin will be approximately 2.25 times this size. ($647,000×2.25 = Lump Sum estimate of $1.457M.)

29. Install geomembrane for the evapotranspiration basin would require a subcontracted crew of 10 FTE for two weeks, including a seam sealer and excavation equipment for the anchor trench.

30. For establishing plant cover over evapotranspiration basin, assume approximately $1K per acre.

31. For excavation of a 900 ft of trench (3 ft deep) and placement of storm water catch basins and drain lines around and between barriers and evapotranspiration basin, assume a 12 FTE subcontractor crew for four weeks.

32. Assume laying and paving of asphalt would be comparable to SX farm, with a 1.7 scaling factor. Assume $264K/acre for Matcon barrier, including production, haul, and laydown and a subcontractor 12 FTE crew.

33. Assume a four FTE subcontractor crew for one week each to build the concrete forms, place the steel rebar, place and finish the concrete, and remove the forms.
34. Equipment allowance added that is 30% of the total field labor costs.

35. Assumes an eight FTE subcontractor crew for one week each to perform disposal activities and demobilize.

36. Disposal quantities, ERDF class “WG”, are assumed to be 5% of the sum of the modified asphalt and concrete values in Table D-4. Assume one yd^3 of disposal material equals one ton. Earthwork excavated from basin would not be disposed in ERDF and instead stockpiled for future use.

37. Assume three work packages of moderate complexity ($15K each) taking place between design and field work.

38. Assume $20K for project completion report.

E1.7.5 Alternative 5 – Excavation

Costing assumptions specific to Alternative 5 include:

1. Project duration of 108 months (9 years). Assume two years for design development, one year for procurement and equipment qualification testing, one year for construction and acceptance testing, 4.5 years for excavation, and six months for deactivation.

2. WRPS project management support for the project duration (468 weeks) would include:

3. One FTE (each) – Project Manager, Project Engineer, and Project Controls.

4. Four FTE (total) –Quality Assurance and Procurement.

5. Subcontractor architect/engineer design services would require the equivalent of eight FTEs for 104 weeks (2 years).

6. Subcontractor procurement and equipment qualification testing services would require the equivalent of six FTEs for 78 weeks (1.5 years).

7. WRPS design review and oversight would be 10% of the subcontractor architect/engineer design services.

8. Additional WRPS project support would include:

9. Nuclear Safety and Licensing – four FTE for 35 weeks.

10. Hazard and Operability Analysis – four FTE for 17 weeks.

11. Regulatory Support – one FTE for 26 weeks.

12. Air Permitting – two FTE for 26 weeks.

13. WRPS general project support is assumed to be 8% of the procurement estimate. This allowance covers legal fees, statement of work creation, safety planning, and engineering support staff.

14. Assume three enclosures would be required, each a RUBB fabric covered enclosure 100×140 ft. Use \$165.17/ft^2 (see RPP-RPT-47167, "241-C Tank Farm – Tank Removal Study") and escalate from 2010 to 2016 costs (at 3%/year). Assume surface area of each structure approximately 30,000 ft^2 (3,300 yd^2). Using 30-ounce/yd^2 coated fabric (per RUBB technical specs) yields approximately 3.125 tons of fabric per structure.

15. Assume three smaller enclosures (airlocks) would provide control for equipment and personnel entry/exit (30×30 ft). Use \$165.17/ft^2 (see RPP-RPT-47167) and escalate from 2010 to 2016 costs (at 3%/year).

16. Gravel for a site access road (40×250×0.3 ft) is estimated to be \$50/yd^3.

17. Assume a ventilation system of 50,000 cubic feet per minute (cfm) required to provide a minimum of 10 air changes per hour. One ventilation train would be used to support all three UPR locations. Scaling from a 1,500 cfm system that cost \$1M in 2010 dollars (see RPP-RPT-47167) = \$1M × (50,000 cfm/1,500 cfm) = \$33.33M (in 2010 dollars).

18. Engineer estimate for the application specific design for the ventilation intake ducting is approximately \$100K.

19. Two remote excavators would be required. Quote is for two customized Brokk 400 remote excavators with heavy duty shear and attachments, including clamshell.

20. Equipment procurements includes two remote excavators (Brokk) with two heavy duty shear attachments and one clamshell attachment. Costs are based upon a vendor quote.

21. Estimate for a pile driver with a vibratory hammer attachment is \$200K. Equipment is needed for installing sheet piles for excavation between 15 and 40 ft below ground surface.

22. Engineer estimate for the customization of the remote excavators is approximately \$100K. This includes the addition of radiation and area monitors.

23. Assume control trailer for remote excavation (with two operator stations) is \$100K. Six radiation-hardened cameras to support remote excavation would be required at a cost of \$30K each.

24. Will require container handling equipment (2 tractors) to move containers from the excavation tent to the CTA for surveying. Cost would be \$100K each.

25. Will require 20 RO-RO containers (multi use boxes) at a cost of \$20K each, plus two transfer trucks at a cost of \$100K/truck.

26. Based on assumed distribution of contamination, 25% of the excavation would go in a bull run box with a capacity of 8 yd^3 at a cost per box of \$5K.
Number of boxes = 25% × 6027.8 yd^3 × 1.3 swell factor × (1 box/8 yd^3) = 273.

27. Based on assumed distribution of contamination, 15% of excavation would go in highly shielded box with a capacity of 4 yd^3. Cost per box is \$45,500 based on 4-inch plate, calculated weight of box, and \$1.75 /pound cost for fabricated steel boxes. Assume 90% of boxes filled with 90% contaminated soil and 10% void space. Assume 10% of boxes filled 50% with soil and 50% with grout. Total soil = 15% × 6,027.8 yd^3 × 1.3 swell factor = 1,176 yd^3. Total boxes = 353.

28. Anchors and enclosures would require 400 yd^3 concrete at \$200/yd^3 for grade beams plus \$25K for helical anchors.

29. One single-wide trailer (break trailer) and one sanitation facility trailer will each be rented for 60 months (5 years).

30. Two double-wide trailers for offices will each be rented for 108 months (nine years).
31. Allowance for miscellaneous construction consumables added that is estimated at \$1,000/day or \$4,000/workweek for the duration of construction activities.

32. Allowance for personal protective equipment added that is 5% of total field labor costs.

33. Test equipment procurement includes a Brokk remote excavator with vibratory hammer attachment to be used for equipment qualification, training, and verification testing.

34. The grout material pricing of \$165/yd^3 is from the WMA C closure ROM estimate (need reference). Quantity of grout needed is estimated to be 5% of the combined volumes of the bull run boxes and the heavily shielded boxes.

35. Broad air monitoring is a monthly allowance to cover air monitoring operations across WMA C during site activities for 54 months (4.5 years) during excavation activities.

36. Focused air monitoring is a monthly allowance to cover air monitoring within the UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 containment structures for 16 months at each site.

37. Soil sampling labor (subcontractor) assumes two FTE for six weeks. Assume eight soil grab samples collected using the remote excavator. Confirmation samples would be collected every 5 ft, beginning at 15 ft down to 40 ft of depth, for six sample intervals. Assume one week for sampling activity for each interval.

38. Soil sampling costs of $500/ sample is assumed to include materials, processing and analysis. Assume eight soil grab samples per interval collected using the remote excavator. Confirmation samples would be collected every 5 ft, beginning at 15 ft down to 40 ft of depth, for six sample intervals. Six sample intervals with eight samples per interval equals 48 samples collected per location. For three excavation sites this yields 144 total samples.

39. Assume one test of the grout material at $3K per test.

40. Allowance for mobilization of crews and equipment added that is 8% of total construction costs.

41. Assumes a 12 FTE subcontractor crew for a duration of one week to perform site preparations (e.g., staging and setup).

42. Assume ground scan for evapotranspiration basin excavation and drain line trenching would be approximately $20K.

43. Assumes eight site workers and 35 subcontract workers (43 total) require project-specific training at $2,500 per worker. Assume that a minimum of two industrial hygienists, two radiological technicians, and one field work supervisor are included in the eight site workers.

44. WRPS construction management support crew of 10 FTE for a duration of 52 weeks (one year). This crew consists of 10 construction management staff.

45. Subcontractor field work support crew of nine FTE for a duration of 52 weeks (one year), four industrial hygiene technicians, four radiological technicians, and one field work supervisor.

46. Enclosure construction would require a subcontractor crew of 15 FTEs for a duration of 10 weeks.

47. Initial installation and testing of the enclosure ventilation system would require a subcontractor crew of eight FTEs for a duration of four weeks.

48. Construction of the Container Transfer Area (CTA) at the enclosure would require a subcontractor crew of six FTEs for a duration of two weeks. The CTA would include a dedicated transfer area, decontamination station, and tarping station.

49. Assume electrical service to support trailers, control trailers, HVAC system, and enclosures would be installed requiring a subcontractor crew of eight FTEs for a duration of four weeks.

50. Installation and setup of control trailer would require a subcontractor crew of six FTEs for a duration of two weeks.

51. Developing and installing support trailers, roads, parking and infrastructure would require a subcontractor crew of eight FTEs for a duration of four weeks.

52. Construction acceptance testing would require a subcontractor crew of eight FTEs for a duration of four weeks.

53. Constructing shoring for excavation would require a subcontractor crew of six FTEs for a duration of six weeks.

54. For each UPR excavation, assume a subcontractor crew of six FTEs for a duration of 57 weeks. Assume three of the crew members would be dedicated to remote excavator operations. This assumes a production rate of 48 ft^3 per hour at 5 hours of operation per shift for 922 hours or 185 days.

55. For UPR-200-E-81 and UPR-200-E-82, assume a subcontractor crew of 12 FTEs for a duration of two weeks (each) to reroute ducting, startup, and test ventilation.

56. For backfilling the UPRs, assume an allocation of \$40/yd^3 for loadout at borrow pit, hauling, placement, and compaction. This is based on an FY 2010 estimate in RPP-RPT-47167 (841,000 yd^3 backfill for TEC of \$27.95M yielding \$33.24/ yd^3) and escalated to FY 2016. Volume of backfill is based on total excavation value calculated in Table D-5.

57. For waste container handling operations, assume a subcontractor crew of 12 FTEs for a duration of 171 weeks (57 weeks for each of the three UPRs). Assume this covers the survey of boxes for disposal.

58. For waste container transport, assume a subcontractor crew of three FTEs for a duration of 171 weeks.

59. Labor for grouting containers is on a per container basis assuming four hours to grout each container. Quantity is 10% of the number of heavily shielded disposal boxes.

60. Equipment allowance added that is 30% of the total field labor costs.

61. Demolition of the enclosures added that is 20% of the enclosure capital costs.

62. Assume disposal activities would require an eight FTE subcontractor crew for a duration of one week.

63. Assume two tons of miscellaneous waste (e.g., forms, personal protective equipment) generation per month throughout the project meeting ERDF waste class "WG" requirements. Duration includes construction and acceptance testing, excavation, and deactivation.

64. Assume total volume of bulk contaminated soil for disposal at ERDF (waste class "WG") equals 60% of the total excavation. Total volume = 6027.8 yd^3 × 60% × 1.3 swell factor = 4,702 yd^3. Assuming a soil density of 130 pounds per cubic feet (ft^3) and converting to pounds yields approximately 8,252 tons of bulk contaminated soil.

65. Assume the volume of piping and soils of moderate contamination for disposal at ERDF (waste class "WC") is 25% of the total excavation, approximately 273 bull run boxes. Quantity calculation of 273 boxes multiplied by box dimensions 5×5×9 ft.

66. Assume there would be 353 highly shielded disposal boxes for disposal at ERDF (waste class "WC") based on the assumption that 15% of the soil volume is highly contaminated. Quantity calculation of 353 boxes multiplied by box dimensions 4×4×8 ft.

67. Assume 25% of enclosure structure area (SF) to be disposed at ERDF (waste class "WG"). Three 100×140 ft structures yield an estimated weight of one ton per 20 square feet (ft^2.)

68. Assume demobilization activities would require an eight FTE subcontractor crew for a duration of four weeks.

69. Assume 10 work plans of moderate complexity to be developed between design and field work, at a cost of $15K each.

70. Assume $20K for project completion report.

E1.7.6 Alternative 6 – Excavation + Infiltration Barrier System

Assumptions specific to both Alternative 4 (Section 0) and Alternative 5 (Section 0) apply to Alternative 6a with the following exceptions:

1. There would be no concrete procured for UPR-200-E-82 and UPR-200-E86.

2. As no concrete is being poured, there would be no subcontractor labor required for building forms, placing steel rebar, pacing and finishing concrete, and removing forms.

3. Disposal quantities, ERDF class "WG," are assumed to be 5% of the sum of the modified asphalt values in Table D-6a. Assume one yd^3 of disposal material equals

one ton. Earthwork excavated from basin would not be disposed in ERDF and instead stockpiled for future use.

4. Activities associated with Alternative 4 and Alternative 5 are assumed separate and will not share resources.

5. Activities associated with Alternative 5 will be conducted prior to initiation of activities associated with Alternative 4. Alternative 4 activities are not assumed to begin after completing Alternative 5 activities.

E1.8 Exclusions

This section identifies scope items and costs excluded from the corrective measures alternatives cost estimates. The following items have been excluded from the estimate:

- Escalation beyond FY 2016 are not been included in these calculations. The estimated costs are based on FY 2016 costs. Historic costs have been escalated to 2016, as necessary.

- Substantial amounts of contaminants or contaminated materials not previously identified are not included.

- Reduction in the waste material, beyond the minimum needed to manage and transport waste to ERDF, is not included in the cost estimate.

- Costs associated with final remedial decision making are not included. The corrective measures activities would provide a measure of protection from direct contact with soil contamination, until a final closure activity may be completed at WMA C. As of July 2016, a final remedial decision has not been made for WMA C. Activities associated with final remedial activities may occur after completing corrective measures activities. However, costs for conducting those activities are not included in this cost estimate.

- Annual and periodic operation and maintenance activities are not included.

- Costs associated with performing the Hanford Site-Wide CERCLA 5-year reviews.

E1.9 Markups

The following markups are used in the cost estimates for each alternative and applied in the following order (Section 0) cost tables for delineation of subtotals and summation of markups):

- Washington Tax Factor: A Washington State sales tax of 8.6% is applied to capital unit costs that may include materials and equipment. Labor-only line items do not receive a sales tax markup. WRPS labor items do not incur sales tax markups.

- Markup Factor: A 35% markup was applied to subcontractor resources. This markup covers contractor profit, overhead, and WRPS oversight and G&A of contractor items. Markup factors were not applied to WRPS-specific resources.

- Contingency: Contingency is factored into a cost estimate to cover unknowns, unforeseen circumstances, or unanticipated conditions that are not possible to evaluate from the available data at the time the estimate is prepared. Contingency ranges from a low of 30% for Alternatives 3 and 4, up to 50% for Alternatives 5 and 6, because of the variety of work scope between the alternatives and the excavation activities.

E1.10 Sensitivity Analysis

A sensitivity analysis for this cost estimate was not performed. However, the following factors may cause the estimate to change significantly: 1) levels of contamination encountered; 2) newly discovered hazardous conditions; 3) availability of qualified workers; and 4) less favorable working conditions and/or increased monitoring requirements that would significantly increase the impact of working in health and safety protection and/or increase the health, safety, monitoring, and regulatory requirements.

Because of these factors: 1) the remedy selection process must consider differences in response action cost uncertainties/cost risks in addition to response action specific cost estimates and ranges; and 2) funding needs must be carefully reviewed before making specific financial decisions or establishing final budgets.

E1.11 Detailed Estimated Cost Tables

Table E-2 summarizes the subtotal capital cost for each alternative, and the total cost with markups applied and the -30% to +50% anticipated accuracy range for each alternative. Estimated costs are presented in 2016 dollars. Details of the cost estimates are presented in Tables E-3 through E-7.

Table E-2. Summary of Rough Order of Magnitude Estimated Costs.

Cost Estimating Categories ($Millions)	Alternatives					
	1	2	3	4	5	6
	No Action	Institutional Controls	Isolation Barriers	Isolation + Infiltration Barriers	Excavation	Excavation + Infiltration Barrier System
Subtotal, no markups	$0	$1.14	$3.09	$15.8	$153.00	$229.00
Total, with markups	$0	$1.37	$4.61	$26.70	$311.00	$478.00
-30% Totals	$0	$0.96	$3.23	$18.70	$218.00	$335.00
+50% Totals	$0	$2.06	$6.92	$40.10	$467.00	$717.00

The detailed capital cost estimate tables include the following information:

- Project Scope: The main action(s) within the alternative that alternative activities are designed to support, e.g., constructing isolation barriers.

- Activity Group: Similar or related activities are grouped into categories, such as design, construction, and operations.

- Activity: Activities are line-item-specific actions.

- Quantity: User-entered or linked quantity are specific to a line item activity.

- Rate: Total dollar amounts for each unit are calculated as rates. These rates are multiplied by the appropriate line-item quantity to achieve the subtotal cost for each line item.

- Unit: Units of measurement are associated with each line-item quantity and unit cost.

- Subtotal: The dollar amount resulting from multiplying the appropriate quantities and their respective rates are calculated as subtotals.

- Resource: Either WRPS or a subcontractor are entities proposed to complete an associated activity.

- WA Tax Factor: Washington State sales tax is applied as a calculation factor (Section 0).

- Factor (Markups): A 35% markup is applied to subcontractor items.

- Est w/ Markups: The cost of each line item includes subtotal costs multiplied by the "WA Tax Factor" and "Factor (Markups)" items.

- Contingency: A percentage factor is applied to cover project uncertainties. A contingency value increases with increased scope complexity, with a value range from -30 to +50% across the alternatives.

- Est w/ Contingency: The total cost of each line item includes the cost from "Est w/ Markups" multiplied by the contingency value.

No costs are associated with Alternative 1. Detailed estimated costs for the remaining Alternatives are presented in Tables E-2 through E-6.

E1.11.1 Table E-3. Alternative 2

Table E-3. Alternative 2 Capital Cost Estimate.

Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Tax &Markups	Contingency	Est w/ Contingency	Assumptions
Annual Institutional Controls	30.00	$38,000.00	yr	$1,140,000	WRPS	1.086	1	$1,238,040	10%	$1,361,844	Institutional controls are not direct WMA C costs. Institutional controls will be implemented between 2020 & 2050.

E1.11.2 Table E-5. Alternative 3

Table E-4. Alternative 3 Capital Cost Estimate. (3 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wk.)	Assumptions	Notes
Construct Concrete Isolation Barriers	Project Management (WRPS)	Overall Project Management - 1/4 FTE	52.00	$1,230.00	wk.	$63,960	WRPS	1	1	$63,960	30%	$83,148	0.25			52	Assume 1 wk. equals 40 hours, and 1 day equals 10 hours.	
		Buyer Technical Representative, Admin, Quality Assurance, Procurement Support - 1 FTE	52.00	$4,920.00	wk.	$255,840	WRPS	1	1	$255,840	30%	$332,592	1.00			52	Assume 1 wk. equals 40 hours, and 1 day equals 10 hours.	
		Project Engineer - 1/2 FTE	52.00	$2,460.00	wk.	$127,920	WRPS	1	1	$127,920	30%	$166,296	0.50			52	Assume 1 wk. equals 40 hours, and 1 day equals 10 hours.	
	Design	Architect/Engineer Design Services - $75K	1.00	$75,000.00	ls	$75,000	Subcontractor	1	1.35	$101,250	30%	$131,625					Assume $75,000.	
		WRPS Design Review & Oversight - $25K	1.00	$25,000.00	ls	$25,000	WRPS	1	1	$25,000	30%	$32,500					Assume $25,000.	
	Project Support	Air Permitting - 2 FTE	5.00	$9,840.00	wk.	$49,200	WRPS	1	1	$49,200	30%	$63,960	2.00				Assume 2 FTE for 5 wks.	
		Regulatory Support - 1 FTE	2.00	$4,920.00	wk.	$9,840	WRPS	1	1	$9,840	30%	$12,792	1.00			2	Assume 1 FTE for 2 wks.	
		General Project Support (12% of procurement estimate)	1.00	12%	%	$52,007.45	WRPS	1	1	$52,007	30%	$67,610						Allowance for covering of legal fees, SOW creation, safety planning, and engineering support staff
	Procurement	Gravel	1555.56	$50.00	cy	$77,778	Subcontractor	1.086	1.35	$114,030	30%	$148,239		42000	1555.56		Engineer estimates $50/cy.	For a gravel road for site access (40x250x0.3 ft), and gravel pads for

Table E-4. Alternative 3 Capital Cost Estimate. (3 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wk.)	Assumptions	Notes
																		isolation barriers at UPR-200-E-81 (60x60x0.75 ft) and SST areas (320x170x0.75 ft).
		Concrete	1633.33	$200.00	cy	$326,667	Subcontractor	1.086	1.35	$478,926	30%	$622,604		44100	1633.33		Concrete $200/yd. includes rebar, forms, form bracing.	
		Survey Crew - 2 FTE	1.00	$9,840.00	wk.	$9,840	Subcontractor	1.086	1.35	$14,426	30%	$18,754					Survey Crew for 1 wk. during procurement.	Generalized cost for surveying at Hanford
		Personal Protective Equipment Consumables	1.00	5%	%	$19,111	Subcontractor	1.086	1.35	$28,019	30%	$36,424	2			3	5% of field labor cost	
	Sampling and Characterization	Air Monitoring - Broad	12.00	$20,000.00	mo.	$240,000	Subcontractor	1.086	1.35	$351,864	30%	$457,423				52		
		Concrete material testing	1.00	$3,000.00	ls	$3,000	Subcontractor	1.086	1.35	$4,398	30%	$5,718					$3K engineer allowance.	
	Mobilization	Mobilization (incl. bonding and insurance)	1.00	8%	%	$21,131.20	Subcontractor	1.086	1.35	$30,980	30%	$40,275					Estimator allowance for mobilizing crews and equipment	
		Site prep (e.g., staging & setup) - 8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		
	Construction	Training for construction staff	23.00	$2,500.00	ea	$57,500	Subcontractor	1	1.35	$77,625	30%	$100,913	23				Assume $2,500/worker for construction and specialty subs. Assume 8 site workers, and 15 subcontracted workers.	
		WRPS Field work support crew - 6 FTE	1.00	$29,520.00	wk.	$29,520	WRPS	1	1	$29,520	30%	$38,376	5			1	1. Assume 1 wk. equals 40 hours, and 1 day equals 10 hours. 2. Assume trailer currently on-site will be available for use during project.	1. Crew includes a general support crew (includes minimum 2 industrial hygienists, 2 radiological technicians, 1 field supervisor, 1 construction manager) + eight carpenters or laborers. 2. A labor rate of $123/hour for generalized surveying at Hanford was applied to all labor activities for the purposes of ROM estimating.
		Build forms - 8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		
		Place steel rebar -8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		
		Place & finish concrete - 12 FTE	1.00	$59,040.00	wk.	$59,040	Subcontractor	1	1.35	$79,704	30%	$103,615	12			1		
		Remove forms - 8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		

Table E-4. Alternative 3 Capital Cost Estimate. (3 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wk.)	Assumptions	Notes
	Operations	Equipment - 30% of Total Field Labor	1.00	30%	%	$163,809	Subcontractor	1.086	1.35	$240,160	30%	$312,208					Equipment rental and operation costs equal to 30% of total field labor costs.	
	Closeout and disposal	Disposal Labor - 8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1	Percent or lump sum for truck, driver, and wt./vol.	1. Crew includes a general support crew (includes minimum 2 industrial hygienists, 2 radiological technicians, 1 field supervisor, 1 construction manager) + eight carpenters or laborers. 2. A labor rate of $123/hour for generalized surveying at Hanford was applied to all labor activities for the purposes of ROM estimating.
		Disposal: ERDF Class "WG"	40.83	$69.70	ton	$2,846	Subcontractor	1.086	1.35	$4,173	30%	$5,424					Disposal quantity is 5% of concrete material and 2 yd3 of disposal material equals 1 ton. Clean material does not require treatment.	
		Demobilization - 8 FTE	1.00	$39,360.00	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		
	Document prep	Work Package - $15K	3.00	$15,000.00	ea	$45,000	WRPS	1	1	$45,000	30%	$58,500					1 work plan for gravel and site prep, 1 for concrete. Assume $15K each.	
		Project Completion Report - $15K	1.00	$15,000.00	ea	$15,000	WRPS	1	1	$15,000	30%	$19,500					$15K allocation.	
	0	Annual Institutional Controls	30	$38,000.00	yr	$1,140,000	WRPS	1.086	1	$1,238,040	10%	$1,361,844					Institutional controls will be implemented between 2020 & 2050.	

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E1.11.3 Table E-5. Alternative 4

Table E-5. Alternative 4 Capital Cost Estimate. (3 sheets)

Table	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area		Time (wks.)	Assumptions	Notes
Construct Concrete Isolation Barriers and Interim Surface Barrier	Project Management (WRPS)	Overall Project Management - 1 FTE	104	$4,920	wk.	$511,680	WRPS	1	1	$511,680	30%	$665,184	1				104	1 wk. equals 40 hrs., and 1 day equals 10 hrs.	1 FTE for 2 yr.
		Buyer Technical Representative, Admin, Quality Assurance, Procurement Support - 2 FTE	104	$9,840	wk.	$1,023,360	WRPS	1	1	$1,023,360	30%	$1,330,368	2				104	1 wk. equals 40 hrs., and 1 day equals 10 hrs.	Equivalent of 2 FTE for 2 yr.
		Project Engineer - 1 FTE	104	$4,920	wk.	$511,680	WRPS	1	1	$511,680	30%	$665,184	1				104	Assume 1 wk. equals 40 hrs., and 1 day equals 10 hrs.	1 FTE for 2 yr.
	Design	Architect/Engineer Design Services - $500K	1	$500,000	ls	$500,000	Subcontractor	1	1.35	$675,000	30%	$877,500					52	Assume $500K based on SX Farm ISB Design Costs.	Assumed duration of 1 year
		WRPS Design Review & Oversight - $50k	1	$50,000	ls	$50,000	WRPS	1	1	$50,000	30%	$65,000					52	Assume $50K based on SX Farm ISB Design Costs.	Assumed duration of 1 year
	Project Support	Air Permitting - 2 FTE	5	$9,840	wk.	$49,200	WRPS	1	1	$49,200	30%	$63,960	2				5	Assume 2 FTE for 5 wks.	
		Regulatory Support - 1 FTE	5	$4,920	wk.	$24,600	WRPS	1	1	$24,600	30%	$31,980	1				5	Assume 1 FTE for 5 wks.	
		General Project Support (10% of procurement estimate)	1	10%	%	$378,095.11	WRPS	1	1	$378,095	30%	$491,524							Allowance for covering of legal fees, SOW creation, safety planning, and engineering support staff
	Procurement	Subgrade (materials, placement, compaction)	5396	$500	cy	$2,698,148	Subcontractor	1.086	1.35	$3,955,755	30%	$5,142,482		5396.296296				Based on T Farm ISB actuals for subgrade fill @$500/cy. This covers material placement and compaction.	
		Gravel	123	$50	cy	$6,173	Subcontractor	1.086	1.35	$9,050	30%	$11,765							For a gravel road for site access (40x250x0.3 ft)
		Concrete	770	$200	cy	$154,074	Subcontractor	1.086	1.35	$225,888	30%	$293,654		770.3703704				Same as in Alternative 3	Engineer allowance of $200/yd3
		Geomembrane	225,625	$1	ft^2	$225,625	Subcontractor	1.086	1.35	$330,789	30%	$430,025			225625	ft^2		Geomembrane liner for evapotranspiration basin.	$1/$ft^2$ (Based on a 2010 quote for a Layfield Enviroliner with underlayment & overlayment @ $0.80/$ft^2$t)
		Riser extensions (bollards, corrugated metal pipe, miscellaneous protective components)	1	$70,000	ls	$70,000	Subcontractor	1.086	1.35	$102,627	30%	$133,415						Scaled cost from SX Farm estimate ($40K for 3.3-acre pavement). Scaling factor is 1.73 for C Farm. Equates to approximately $70K.	
		12-in. drain line, PVC perforated	6000	$13	lf	$76,200	Subcontractor	1.086	1.35	$111,717	30%	$145,232						1,200 ft of 16-in. + 6,000 ft of 12-in. Advanced Drainage Systems perforated pipe	Drain line in Farm from storm water boxes to basin.
		18-in. drain line, corrugated metal	1200	$20	lf	$24,000	Subcontractor	1.086	1.35	$35,186	30%	$45,742							
		Storm water Boxes	6	$2,000	ea	$12,000	Subcontractor	1.086	1.35	$17,593	30%	$22,871						6 precast storm water boxes 12x6x4 ft w/ grating at $2K each.	

Table E-5. Alternative 4 Capital Cost Estimate. (3 sheets)

Table	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
		Misc. consumables construction (e.g., water, fuel, storage)	52	$4,000	wk.	$208,000	Subcontractor	1.086	1.35	$304,949	30%	$396,433					Assume a dollar amount per day, or allocate a percent.	allocation for office trailer, fuel, water, etc. Assume ~$1K/day during construction
		Personal Protective Equipment Consumables	1	5%	%	$256,331	Subcontractor	1.086	1.35	$375,807	30%	$488,549					5% of labor	
		Double-Wide Trailer	12	$1,700	mo.	$20,400	Subcontractor	1.086	1.35	$29,908	30%	$38,881					Estimator Allowance. Rental for 1 year.	
		Toilet Facilities Trailer	12	$2,500	mo.	$30,000	Subcontractor	1.086	1.35	$43,983	30%	$57,178					Estimator Allowance. Rental for 1 year.	
		Survey Crew - 2 FTE	3	$9,840	wk.	$29,520	Subcontractor	1.086	1.35	$43,279	30%	$56,263	2			3	Survey Crew for 3 wks. during procurement.	Generalized cost for surveying at Hanford
	Sampling and Characterization	Grade testing - 1 FTE	3	$4,920	wk.	$14,760	Subcontractor	1.086	1.35	$21,640	30%	$28,132	1			3		Surveyor 1 FTE on-site during subgrade prep ~3 wks.
		Ground scans - $50K	1	$50,000	ls	$50,000	Subcontractor	1.086	1.35	$73,305	30%	$95,297					Assume $50k.	Ground scan for ET basin excavation and drain line trenching
		Concrete material testing	1	$3,000	ls	$3,000	Subcontractor	1.086	1.35	$4,398	30%	$5,718					Same as in Alternative #3	
		Air Monitoring - Broad	12	$20,000	mo.	$240,000	Subcontractor	1.086	1.35	$351,864	30%	$457,423						
		Asphalt mix testing - 2 FTE	3	$14,400	wk.	$43,200	Subcontractor	1.086	1.35	$63,336	30%	$82,336	2			3		Assume 2 tech reps on-site for 3 wks. during construction @ $3,600/day includes travel. Includes lay-down and compaction tests. (Matcon used previously.)
	Mobilization	Mobilization (incl. bonding and insurance)	1	8%	%	$400,683	Subcontractor	1.086	1.35	$587,442	30%	$763,674						
		Site prep (e.g., staging & setup) - 8 FTE	1	$39,360	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8			1		
	Construction	Training for construction staff	33	$2,500	ea	$82,500	Subcontractor	1	1.35	$111,375	30%	$144,788					Assume $2,500/worker for construction and specialty subs. Assume 8 site workers, and 25 subcontracted workers.	
		WRPS Field work support crew - 6 FTE	52	$29,520	wk.	$1,535,040	WRPS	1	1.00	$1,535,040	30%	$1,995,552	5			52	Assume minimum of two industrial hygienists, two radiological technicians, one field work supervisor, and one construction manager.	
		Basin earthwork	1	$1,457,000	ls	$1,457,000	Subcontractor	1.086	1.35	$2,136,108	30%	$2,776,940				10	Based on commercial estimate from Swaggart Brothers Construction of $647,500 for TY Basin. CMS estimate is $1,457,000.	Clearing and grubbing ET basin area, which is ~8 acres in size. Includes excavation and stockpiling materials, and backfilling ET basin. Includes placement of ~6,000 ft of perforated Advanced Drainage Systems pipe - duration 2 wks.
		Install Geomembrane liner- 10 FTE	2	$49,200	wk.	$98,400	Subcontractor	1	1.35	$132,840	30%	$172,692	10			2		Subcontract crew of 10 w/seam sealer & excavation equip for anchor trench for 2wks.

Table E-5. Alternative 4 Capital Cost Estimate. (3 sheets)

Table	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area		Time (wks.)	Assumptions	Notes
		Install plant cover over evapotranspiration basin	8	$1,000	acre	$8,000	Subcontractor	1.086	1.35	$11,729	30%	$15,247			8	acres	0.2	Assume ~$1K/acre for establishing cover. Assume total area of 8 acres.	
		Excavation & placement of storm water catch basins & drain lines around barriers and between barriers and evapotranspiration basin - 12 FTE	4	$59,040	wk.	$236,160	Subcontractor	1	1.35	$318,816	30%	$414,461	12				4	Assume 6 precast storm water boxes 12x6x4 ft w/grating. ~900 ft of trench 3' deep. Subcontract crew.	
		Laying and paving of asphalt - 12 FTE	5.73	$264,000	acre	$1,512,720	Subcontractor	1.086	1.35	$2,217,799	30%	$2,883,138	12				4	Assume comparable to SX Farm; scaling factor is 1.7. Assume $264K/acre for Matcon barrier, including production/haul/laydown.	Subcontract 12-person crew.
		Build forms - 4 FTE	1	$19,680	wk.	$19,680	Subcontractor	1	1.35	$26,568	30%	$34,538	4				1		General construction crew.
		Place steel rebar - 4 FTE	1	$19,680	wk.	$19,680		1	1.35	$26,568	30%	$34,538	4				1		General construction crew.
		Place & finish concrete - 4 FTE	1	$19,680	wk.	$19,680	Subcontractor	1	1.35	$26,568	30%	$34,538	4				1		General construction crew.
		Remove forms - 4 FTE	1	$19,680	wk.	$19,680	Subcontractor	1	1.35	$26,568	30%	$34,538	4				1		General construction crew.
	Operations	Equipment - 30% of Total Field Labor	1	30%	%	$2,197,123	Subcontractor	1.086	1.35	$3,221,202	30%	$4,187,562						Assume equipment rental and operation costs equal to 30% of total field labor costs.	Allowance to cover rental and operational costs of equipment. Does not cover subcontractor-owned vehicles or equipment.
	Closeout and disposal	Disposal Labor - 8 FTE	1	$39,360	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8				1	Percent or lump sum for truck, driver, and wt./vol.	Crew is as above.
		Disposal: ERDF Class "WG"	269.81	$69.70	ton	$18,806	Subcontractor	1.086	1.35	$27,572	30%	$35,843						Assume volume of disposed materials is 5% of concrete and asphalt material. Assume 1 yd3 of disposal material equals 1 ton. Earthwork excavated from basin would not be disposed in ERDF and instead stockpiled for future use.	
		Demobilization - 8 FTE	1	$39,360	wk.	$39,360	Subcontractor	1	1.35	$53,136	30%	$69,077	8				1	Percent or lump sum for demobilization.	
	Document prep	Work Package - $15K	3	$15,000	ea	$45,000	WRPS	1	1	$45,000	30%	$58,500						Assume three work plans of moderate complexity. Takes place between design and field work. Approx. $15K each.	
		Project Completion Report - $20K	1	$20,000	ea	$20,000	WRPS	1	1	$20,000	30%	$26,000						Assume allocation of $20K.	
	Institutional Controls	Annual Institutional Controls	30	$38,000.00	yr	$1,140,000	WRPS	1.086	1	$1,238,040	10%	$1,361,844					1560	Assume institutional controls will be implemented between 2020 & 2050.	

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E1.11.4 Table E-6. Alternative 5

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
Excavation (40 ft bgs)	Project Management (WRPS)	Overall Project Management - 1 FTE	468.00	$4,920	wk.	$2,302,560	WRPS	1	1	$2,302,560	50%	$3,453,840	1.00			468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
		Buyer Technical Representative, Administration, Quality Assurance, Procurement Support - 4 FTE	468.00	$19,680	wk.	$9,210,240	WRPS	1	1	$9,210,240	50%	$13,815,360	4.00			468	1 wk. = 40 hours; 1 day = 10 hours.	Equivalent of 4 FTE for project duration.
		Project Controls - 1 FTE	468.00	$4,920	wk.	$2,302,560	WRPS	1	1	$2,302,560	50%	$3,453,840	1.00			468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
		Project Engineer - 1 FTE	468.00	$4,920	wk.	$2,302,560	WRPS	1	1	$2,302,560	50%	$3,453,840	1.00			468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
	Design	Architect/Engineer Design Services - 8 FTE	104.00	$39,360	wk.	$4,093,440	Subcontractor	1	1.35	$5,526,144	50%	$8,289,216	8.00			104	Equivalent of 8 FTEs for 2 years for design	
		Procurement and Equip Qualification Testing -6 FTE	78.00	$29,520	wk.	$2,302,560	Subcontractor	1	1.35	$3,108,456	50%	$4,662,684	6.00			78	Equivalent of 6 FTEs for 1.5 year	
		WRPS Design Review & Oversight - 10%	1.00	10%	%	$639,600	WRPS	1	1	$639,600	50%	$959,400					Assume 10% of design costs	
	Project Support	Nuclear Safety & Licensing - 4 FTE	35.00	$19,680	wk.	$688,800	WRPS	1	1	$688,800	50%	$1,033,200	4.00			35	Allocation - 4 FTEs for 8 months	
		Hazard and Operability Analysis - 4 FTE	17.00	$19,680	wk.	$334,560	WRPS	1	1	$334,560	50%	$501,840	4.00			17	Allocation - 4 FTEs for 4 months	
		Regulatory Support - 1 FTE	26.00	$4,920	wk.	$127,920	WRPS	1	1	$127,920	50%	$191,880	1.00			26	Estimator Allowance - 1 FTE for 6 months	
		Air Permitting - 2 FTE	26.00	$9,840	wk.	$255,840	WRPS	1	1	$255,840	50%	$383,760	2.00			26	Allocation - 2 FTEs for 6 months	
		General Project Support (8% of procurement estimate)	1.00	8%	%	$5,783,958.04	WRPS	1	1	$5,783,958	50%	$8,675,937					Allowance for covering of legal fees, SOW creation, safety planning, and engineering support staff	
	Procurement	Gravel	123.46	$50	cy	$6,173	Subcontractor	1.086	1.35	$8,333	50%	$12,500					For a gravel road for site access (40x250x0.3 ft)	
		Enclosures	3.00	$2,761,103	ea	$8,283,309	Subcontractor	1.086	1.35	$12,144,159	50%	$18,216,239					3 enclosures required - RUBB fabric covered enclosure 100x140 ft. Use $165.17/ft^2 (see RPP-RPT-47167) and escalate from 2010 to 2016 (3%/yr). Assume surface area of each structure approximately 30,000 ft2^{t2} (3333.33 SY). 30 oz. per SY fabric (coated. per RUBB technical specs). 3.125 tons of fabric per structure.	
		Airlock	3.00	$177,499	ea	$532,497	Subcontractor	1.086	1.35	$780,694	50%	$1,171,041					3 small enclosures provide control for equipment and personnel entry/exit (30x30 ft)	
		Ventilation System	1.00	$39,801,743	ls	$39,801,743	Subcontractor	1.086	1.35	$58,353,336	50%	$87,530,004					Ventilation system of 50,000 cfm required to provide min 10 air changes/hr. 1 ventilation train will be used to support all 3 locations.	

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
																	Scaling 1,500 cfm=$1M (RPP-RPT-47167). Scale at Cost = $1M* (50,000 cfm/1,000 cfm)^0.6 = $8.2M (in 2010 dollars)	
		Ventilation Ductwork	1.00	$100,000	ls	$100,000	Subcontractor	1.086	1.35	$146,610	50%	$219,915					Engineer estimate - application specific design for intake ducting - $100K	
		Remote excavator (Customized Brokk 400 w/ Heavy Duty Shear)	2.00	$577,680	ea	$1,155,360	Subcontractor	1.086	1.35	$1,693,873	50%	$2,540,810					Quantity 2 require, BROKK quote for machine and attachments	
		Remote excavator Clamshell attachment	1.00	$74,880	ea	$74,880	Subcontractor	1.086	1.35	$109,782	50%	$164,672						
		Pile Driver/Vibratory Hammer	1.00	$200,000	ea	$200,000	Subcontractor	1.086	1.35	$293,220	50%	$439,830					Equipment for installing sheet piles for excavation between 15 and 40 ft bgs	
		Customization of remote equip (monitors)	1.00	$100,000	ls	$100,000	Subcontractor	1.086	1.35	$146,610	50%	$219,915					Engineer estimate - application specific design for rad monitors on excavator and area monitoring $100K	
		Control trailer & cameras	1.00	$280,000	ls	$280,000	Subcontractor	1.086	1.35	$410,508	50%	$615,762					Control trailer (with 2 operator stations) $100K, rad hardened cameras to support remote excavation, qty. 6 @ $30K ea.	
		Container handling equipment	1.00	$200,000	ls	$200,000	Subcontractor	1.086	1.35	$293,220	50%	$439,830					Tractor to move containers from excavation tent to CTA for survey. Includes two vehicles.	Qty. 2 required for operation, $100K ea.
		Roll-on/Roll-off Containers	20.00	$20,000	ea	$400,000	Subcontractor	1.086	1.35	$586,440	50%	$879,660					Multi use boxes - assume a qty. of 20 boxes	Cost per box is $20K
		Bull Run Boxes (5x5x9') single use disposal boxes	273.00	$5,000	ea	$1,365,000	Subcontractor	1.086	1.35	$2,001,227	50%	$3,001,840					Based on assumed distribution of contamination 25% of excavation will go in bull run box, capacity 8 cy. Assume boxes filled 90%, with 10% void space. Volume = 25% of 6027.8 yd3 = 1507 yd3 x 1.3 swell factor ~1,959 yd3 * 1box/ 90% of 8cy= 273 boxes	Cost per box is $5K
		Heavily shielded disposal boxes (4x4x8')	353.00	$45,500	ea	$16,061,500	Subcontractor	1.086	1.35	$23,547,765	50%	$35,321,648					Based on assumed distribution of contamination, 15% of excavation will go in highly shielded box, capacity 4 yd3. Assume 90% of boxes filled 90% contaminated soil, 10% with void space. Assume 10% of boxes filled 50% with soil, 50% with grout. Volume calculation = 15% of 6027.8 yd3 = 904 yd3 x 1.3 swell factor ~1176 yd3 total soil. Total number of boxes = 353.	Cost per box is $45,.5K based on 4-in. plate, calculated weight of box, and $1.75 /lb cost for fabricated steel boxes.
		Concrete & Anchors for Enclosures	1.00	$105,000	ls	$105,000	Subcontractor	1.086	1.35	$153,941	50%	$230,911					400 yd3 concrete ($200/cy) for grade beams + $25K for helical anchors	
		Single-Wide Trailer	60.00	$1,000	mo	$60,000	Subcontractor	1.086	1.35	$87,966mo.0 %	$131,949						Rental – Break Trailer	

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
		Double-Wide Trailer	60.00	$1,700	mo.	$102,000	Subcontractor	1.086	1.35	$149,542	50%	$224,313					Rental - Office Trailer	
		Double-Wide Trailer	60.00	$1,700	mo.	$102,000	Subcontractor	1.086	1.35	$149,542	50%	$224,313					Rental - Office Trailer	
		Toilet Facilities Trailer	60.00	$2,500	mo.	$150,000	Subcontractor	1.086	1.35	$219,915	50%	$329,873					Rental - Bathroom/Shower Trailer	
		Misc. consumables construction (e.g., water, fuel, storage)	260.00	$4,000	wk.	$1,040,000	Subcontractor	1.086	1.35	$1,524,744	50%	$2,287,116					Assume $1K/day during construction, 4 days per wk.	Allocation for office trailer, fuel, water, etc.
		Personal Protective Equipment Consumables	1.00	5%	%	$1,239,459	Subcontractor	1.086	1.35	$1,817,170	50%	$2,725,755					5% of labor items	
		Test Equipment	1.00	$777,680	ea	$777,680	Subcontractor	1.086	1.35	$1,140,157	50%	$1,710,235					Includes 1 Brokk Excavator with Vibratory Hammer attachment to be used for equipment qualification, training, and verification testing.	
		Grout Material	987.12	$165	cy	$162,875	Subcontractor	1.086	1.35	$238,791	50%	$358,186						
		Survey Crew - 2 FTE	1.00	$9,840	wk.	$9,840	Subcontractor	1.086	1.35	$14,426	50%	$21,640	2.00			1	Survey Crew for 1 wk. during procurement.	Generalized cost for surveying at Hanford
	Sampling and Characterization	Air Monitoring - Broad	72.00	$20,000	mo.	$1,440,000	Subcontractor	1.086	1.35	$2,111,184	50%	$3,166,776					Estimator Allowance of $20,000 per month. Duration matched to sum of durations for construction and testing, excavation and deactivation activities.	WMA C Site air monitoring during occupied intervals throughout project life
		Air Monitoring - Focused	16.00	$20,000	mo.	$320,000	Subcontractor	1.086	1.35	$469,152	50%	$703,728					Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-82 during excavation activities and ventilation reconfiguration
		Air Monitoring - Focused	16.00	$20,000	mo.	$320,000	Subcontractor	1.086	1.35	$469,152	50%	$703,728					Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-81 during excavation activities and ventilation reconfiguration
		Air Monitoring - Focused	16.00	$20,000	mo.	$320,000	Subcontractor	1.086	1.35	$469,152	50%	$703,728					Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-86 during excavation activities and during backfilling of each UPR excavation
		Soil Sampling Labor - 2 FTE	6.00	$9,840	wk.	$59,040	Subcontractor	1	1.35	$79,704	50%	$119,556	2.00			6	Collect 144 soil grab samples: 8 confirmation samples at every 5-ft interval from 15 to 40 ft of depth.	

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
																	8 samples per interval x 6 intervals = 48 samples per location. 48 samples per location, multiplied by 3 excavation sites. 1 week for sampling activity for each interval.	
		Soil Sampling - Cost/Sample	144.00	$500	ea	$72,000	Subcontractor	1.086	1.35	$105,559	50%	$158,339					Collect 144 soil grab samples: 8 confirmation samples at every 5-ft interval from 15 to 40 ft of depth. 8 samples per interval x 6 intervals = 48 samples per location. 48 samples per location, multiplied by 3 excavation sites. 1 week for sampling activity for each interval.	
		Grout Material Testing	1.00	$3,000	ls	$3,000	Subcontractor	1.086	1.35	$4,398	50%	$6,597						
	Mobilization	Mobilization (incl. bonding and insurance)	1.00	8%	%	$532,114	Subcontractor	1.086	1.35	$780,132	50%	$1,170,198						
		Site prep (e.g., staging & setup) - 12 FTE	3.00	$59,040	wk.	$177,120	Subcontractor	1	1.35	$239,112	50%	$358,668	12.00			3	1. 1 wk. = 40 hours; 1 day = 10 hours. 2. construction and support trailers will be set up to support project. 3. that the inclusion of two industrial hygienists and two radiological technicians covers site sampling and characterization requirements.	This alternative does not require the setup component of building the gravel access road in Alt B. However, includes staging for both concrete and paving.
	Construction	Ground scans	1.00	$20,000	ls	$20,000	Subcontractor	1.086	1.35	$29,322	50%	$43,983					Ground scan for foundations (assume ~$20K)	
		Training for construction staff	43.00	$2,500	ea	$107,500	Subcontractor	1	1.35	$145,125	50%	$217,688				2	$2,500/worker for construction and specialty subs. Assume 8 site workers, and 35 subcontracted workers.	
		WRPS Construction Management support crew - 10 FTE	52.00	$49,200	wk.	$2,558,400	WRPS	1	1	$2,558,400	50%	$3,837,600				52	10 construction management staff for one year	
		Field work support crew - 9 FTE	52.00	$44,280	wk.	$2,302,560	WRPS	1	1	$2,302,560	50%	$3,453,840				52	4 industrial hygiene techs, 4 radiological technicians, and one field work supervisor for one year	
		Construct Enclosures (construction contractor) - 15 FTE	10.00	$73,800	wk.	$738,000	Subcontractor	1	1.35	$996,300	50%	$1,494,450	15.00			10		
		Install Ventilation System (construction contractor) - 8 FTE	4.00	$39,360	wk.	$157,440	Subcontractor	1	1.35	$212,544	50%	$318,816	8.00			4		
		Construct Container Transfer Area - 6 FTE	2.00	$29,520	wk.	$59,040	Subcontractor	1	1.35	$79,704	50%	$119,556	6.00			2	Dedicated transfer area, decontamination station, tarping station	
		Electrical Service - 8 FTE	4.00	$39,360	wk.	$157,440	Subcontractor	1	1.35	$212,544	50%	$318,816	8.00			4	Install electrical service to support trailers, control trailers, HVAC system, and enclosures	
		Install & Set up Control Trailer - 6 FTE	2.00	$29,520	wk.	$59,040	Subcontractor	1	1.35	$79,704	50%	$119,556	6.00			2		

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
		Support trailers, roads, parking, infrastructure -8 FTE	4.00	$39,360	wk.	$157,440	Subcontractor	1	1.35	$212,544	50%	$318,816	8.00			4		
		Construction Acceptance Testing - 8 FTE	4.00	$39,360	wk.	$157,440	Subcontractor	1	1.35	$212,544	50%	$318,816	8.00			4		General construction crew.
		Construct Shoring for Excavation - 6 FTE	6.00	$29,520	wk.	$177,120	Subcontractor	1.086	1.35	$259,676	50%	$389,513						General construction crew.
	Operations	Excavate UPR-200-E-82 - 6 FTE	57.00	$29,520	wk.	$1,682,640	Subcontractor	1	1.35	$2,271,564	50%	$3,407,346	6.00	2009.26		57.00	Production rate of 48 cfh & 5 hours' operation per shift = 922 hours or 185 days. 3 FTEs dedicated to remote excavator operations	
		Reconfigure ventilation for use at UPR-200-E-81 - 12 FTE	2.00	$59,040	wk.	$118,080	Subcontractor	1	1.35	$159,408	50%	$239,112	12.00			2	Crew of 12 for 2 wks. to reroute ducting, startup and test ventilation	
		Excavate UPR-200-E-81 - 6 FTE	57.00	$29,520	wk.	$1,682,640	Subcontractor	1	1.35	$2,271,564	50%	$3,407,346	6.00	2009.26		57.00	Production rate of 48 cfh & 5 hours of operation per shift = 922 hours or 185 days. 3 FTEs dedicated to remote excavator operations	
		Reconfigure ventilation for use at UPR-200-E-86 - 12 FTE	2.00	$59,040	wk.	$118,080	Subcontractor	1	1.35	$159,408	50%	$239,112	12.00			2	Crew of 12 for 2 wks. to reroute ducting, startup and test ventilation	
		Excavate UPR-200-E-86 - 6 FTE	57.00	$29,520	wk.	$1,682,640	Subcontractor	1	1.35	$2,271,564	50%	$3,407,346	6.00	2009.26		57.00	Production rate of 48 cfh & 5 hours' operation per shift = 922 hours or 185 days. 3 FTEs dedicated to remote excavator operations	
		Backfill UPRs	6027.78	$40	cy	$239,244	Subcontractor	1.086	1.35	$350,756	50%	$526,134		6027.78			Allocation of $33.24/cy (in FY2010 $) loadout at borrow pit, haul, place, and compact. Based on estimate in RPP-RPT-47167 (841,000 yd3 backfill for TEC of $27.95M in FY2010). Escalate to 2016	
		Waste container handling operations - 12 FTE	171.00	$59,040	wk.	$10,095,840	Subcontractor	1	1.35	$13,629,384	50%	$20,444,076	12.00			171.00	Crew of 12 FTE for duration of excavation activities to support transport of filled containers from enclosure to Container Transfer Area. Assume covers survey of boxes for disposal	
		Waste container transport - 3 FTE	171.00	$14,760	wk.	$2,523,960	Subcontractor	1	1.35	$3,407,346	50%	$5,111,019	3.00			171.00	Allocate 3 teamsters full time for container transfer from Container Transfer Area to Environmental Restoration Disposal Facility.	
		Grout Labor	36.00	$492	ea	$17,712	Subcontractor	1	1.35	$23,911	50%	$35,867					Assume 10% of Heavily shielded waste boxes require grouting. Assume each box takes 4 hours to grout.	
		Equipment - 30% of Total Field Labor	1.00	30%	%	$11,495,502.04	Subcontractor	1.086	1.35	$16,853,556	50%	$25,280,333					Assume equipment rental and operation costs equal to 30% of total field labor costs.	

Table E-6. Alternative 5 Capital Cost Estimate. (6 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (yd3)	Area	Time (wks.)	Assumptions	Notes
	Demolition of Enclosures	Demolition of Enclosures	1.00	20%	%	$1,656,662	Subcontractor	1.086	1.35	$2,428,832	50%	$3,643,248					Assume 20% of the enclosure capital costs	
	Closeout and disposal	Disposal Labor - 8 FTE	1.00	$39,360	wk.	$39,360	Subcontractor	1	1.35	$53,136	50%	$79,704	8.00			1	Disposal labor cost includes labor and transportation costs	
		Disposal: ERDF Class "WG"	144.00	$70	ton	$10,037	Subcontractor	1.086	1.35	$14,715	50%	$22,072					Assume 2 tons per month waste generation from construction and operations activities	
		Disposal: ERDF Class "WG"	8252.01	$70	ton	$575,165	Subcontractor	1.086	1.35	$843,250	50%	$1,264,874		4702.00			Volume = 60% of total excavation = 0.6*6027.77*1.3= ~4702 Cubic Yard @ ERDF. Assume soil density of 130 lb/cf, 2000 lb/ton	
		Disposal: ERDF Class "WC"	1739.36	$2,296	cm	$3,993,710	Subcontractor	1.086	1.35	$5,855,178	50%	$8,782,767					Volume= 25% of excavation = 273 bull run boxes. Assume each box weighs 6 tons (empty) plus 25% of excavated soil (130 lb/cf, 2000 lb/ton) - estimator allowance.	
		Disposal: ERDF Class "WC"	1279.47	$2,296	cm	$2,937,758	Subcontractor	1.086	1.35	$4,307,047	50%	$6,460,570					353 boxes based on assumption that 15% soil volume is highly contaminated. Assume each box weighs 13 tons (empty) plus weight of 15% of total excavated soil (130 lb/cf, 2000 lb/ton)	
		Disposal: ERDF Class "WG"	525.00	$70	ton	$36,593	Subcontractor	1.086	1.35	$53,648	50%	$80,472					Assume 25% of structure area (SF) to be disposed. Three structures. 1 ton per 20 ft2 - estimator judgment	
		Demobilization - 8 FTE	4.00	$39,360	wk.	$157,440	Subcontractor	1	1.35	$212,544	50%	$318,816	8.00			4	Assume 8 FTE for 4 wks. to remove trailers and disconnect utilities	
	Document prep	Work Package - $15K	10.00	$15,000	ea	$150,000	WRPS	1	1	$150,000	50%	$225,000					Assume 10 work plans of moderate complexity. Takes place between design and field work. Approx. $15K each.	
		Project Completion Report - $20K	1.00	$20,000	ea	$20,000	WRPS	1	1	$20,000	50%	$30,000					Assume allocation of $20K.	
	Institutional Controls	Annual Institutional Controls	30.00	$38,000	yr	$1,140,000	WRPS	1.086	1	$1,238,040	10%	$1,361,844					Assume institutional controls will be implemented between 2020 & 2050.	

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1 **E1.11.5 Table E-7. Alternative 6**

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Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
Excavation (40 ft bgs)	Project Management (WRPS)	Overall Project Management - 1 FTE	468.00	$4,920.00	wk.	$2,302,560.00	WRPS	1	1	$2,302,560.00	50%	$3,453,840.00	1	0	0	468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
		Buyer Technical Representative, Administration, Quality Assurance, Procurement Support - 4 FTE	468.00	$19,680.00	wk.	$9,210,240.00	WRPS	1	1	$9,210,240.00	50%	$13,815,360.00	4	0	0	468	1 wk. = 40 hours; 1 day = 10 hours.	Equivalent of 4 FTEs for project duration.
		Project Controls - 1 FTE	468.00	$4,920.00	wk.	$2,302,560.00	WRPS	1	1	$2,302,560.00	50%	$3,453,840.00	1	0	0	468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
		Project Engineer - 1 FTE	468.00	$4,920.00	wk.	$2,302,560.00	WRPS	1	1	$2,302,560.00	50%	$3,453,840.00	1	0	0	468	1 wk. = 40 hours; 1 day = 10 hours.	1 FTE for project duration
	Design	Architect/Engineer Design Services - 8 FTE	104.00	$39,360.00	wk.	$4,093,440.00	Subcontractor	1	1.35	$5,526,144.00	50%	$8,289,216.00	8	0	0	104	Equivalent of 8 FTEs for 2 years for design	0
		Procurement and Equip Qualification Testing -6 FTE	78.00	$29,520.00	wk.	$2,302,560.00	Subcontractor	1	1.35	$3,108,456.00	50%	$4,662,684.00	6	0	0	78	Equivalent of 6 FTEs for 1.5 year	0
		WRPS Design Review & Oversight - 10%	1.00	10%	%	$639,600.00	WRPS	1	1	$639,600.00	50%	$959,400.00	0	0	0	0	Assume 10% of design costs	0
	Project Support	Nuclear Safety & Licensing - 4 FTE	35.00	$19,680.00	wk.	$688,800.00	WRPS	1	1	$688,800.00	50%	$1,033,200.00	4	0	0	35	Allocation - 4 FTEs for 8 months	0
		Hazard and Operability Analysis - 4 FTE	17.00	$19,680.00	wk.	$334,560.00	WRPS	1	1	$334,560.00	50%	$501,840.00	4	0	0	17	Allocation - 4 FTEs for 4 months	0
		Regulatory Support - 1 FTE	26.00	$4,920.00	wk.	$127,920.00	WRPS	1	1	$127,920.00	50%	$191,880.00	1	0	0	26	Estimator Allowance - 1 FTE for 6 months	0
		Air Permitting - 2 FTE	26.00	$9,840.00	wk.	$255,840.00	WRPS	1	1	$255,840.00	50%	$383,760.00	2	0	0	26	Allocation - 2 FTEs for 6 months	0
		General Project Support (8% of procurement estimate)	1.00	8%	%	$5,783,958.04	WRPS	1	1	$5,783,958.04	50%	$8,675,937.06	0	0	0	0	Allowance for covering of legal fees, SOW creation, safety planning, and engineering support staff	0
	Procurement	Gravel	123.46	$50.00	cy	$6,172.84	Subcontractor	1.086	1.35	$8,333.33	50%	$12,500.00	0	0	0	0	For a gravel road for site access (40'x250'x4")	0
		Enclosures	3.00	$2,761,103.00	ea	$8,283,309.00	Subcontractor	1.086	1.35	$12,144,159.32	50%	$18,216,238.99	0	0	0	0	3 enclosures required - RUBB fabric covered enclosure 100x140 ft. Use $165.17/ft2 and escalate from 2010 to 2016 (3%/yr.). Each structure surface area = 30,000 ft2 (3333.33 yd2). 30 oz. per yd2 fabric (coated. per RUBB technical specs). 3.125 tons of fabric per structure.	see RPP-RPT-47167
		Airlock	3.00	$177,499.00	ea	$532,497.00	Subcontractor	1.086	1.35	$780,693.85	50%	$1,171,040.78	0	0	0	0	3 small enclosures provide control for equipment and personnel entry/exit (30x30 ft).	0

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
		Ventilation System	1.00	$39,801,743.22	ls	$39,801,743.22	Subcontractor	1.086	1.35	$58,353,335.73	50%	$87,530,003.60	0	0	0	0	Ventilation system of 50,000 cfm required to provide min 10 air changes/hr. 1 ventilation train will be used to support all 3 locations. Scaling 1,500 cfm=$1M (RPP-RPT-47167). Scale at Cost =$1M* (50,000 cfm/1,000 cfm)^0.6 = $8.2M (in 2010 dollars)	0
		Ventilation Ductwork	1.00	$100,000.00	ls	$100,000.00	Subcontractor	1.086	1.35	$146,610.00	50%	$219,915.00	0	0	0	0	Engineer estimate - application specific design for intake ducting - $100K	0
		Remote excavator (Customized Brokk 400 w/ Heavy Duty Shear)	2.00	$577,680.00	ea	$1,155,360.00	Subcontractor	1.086	1.35	$1,693,873.30	50%	$2,540,809.94	0	0	0	0	Quantity of 2 required, BROKK quote for machine and attachments	0
		Remote excavator Clamshell attachment	1.00	$74,880.00	ea	$74,880.00	Subcontractor	1.086	1.35	$109,781.57	50%	$164,672.35	0	0	0	0	0	0
		Pile Driver/Vibratory Hammer	1.00	$200,000.00	ea	$200,000.00	Subcontractor	1.086	1.35	$293,220.00	50%	$439,830.00	0	0	0	0	Equipment for installation of sheet piles for excavation between 15 feet and 40 feet below ground surface	0
		Customization of remote equip (monitors)	1.00	$100,000.00	ls	$100,000.00	Subcontractor	1.086	1.35	$146,610.00	50%	$219,915.00	0	0	0	0	Engineer Estimate - application specific design for radiation monitors on excavator and area monitoring $100K	0
		Control trailer & cameras	1.00	$280,000.00	ls	$280,000.00	Subcontractor	1.086	1.35	$410,508.00	50%	$615,762.00	0	0	0	0	Control trailer (with 2 operator stations) $100K, radiation hardened cameras to support remote excavation quantity 6 @ $30K each	0
		Container handling equipment	1.00	$200,000.00	ls	$200,000.00	Subcontractor	1.086	1.35	$293,220.00	50%	$439,830.00	0	0	0	0	Tractor to move containers from excavation tent to CTA for survey. Includes two vehicles.	Assume 2 required for operation, $100K ea.
		Roll-on/Roll-off Containers	20.00	$20,000.00	ea	$400,000.00	Subcontractor	1.086	1.35	$586,440.00	50%	$879,660.00	0	0	0	0	Multi use boxes - assume a quantity of 20 boxes	Cost per box is $20K
		Bull Run Boxes (5x5x9 ft) single use disposal boxes	273.00	$5,000.00	ea	$1,365,000.00	Subcontractor	1.086	1.35	$2,001,226.50	50%	$3,001,839.75	0	0	0	0	Based on assumed distribution of contamination 25% of excavation will go in bull run box, capacity 8 cy. Assume boxes filled 90%, with 10% void space. Volume = 25% of 6027.8 cy = 1507 cy x 1.3 swell factor ~1,959 cy * 1box/ 90% of 8cy= 273 boxes	Cost per box is $5K

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
		Heavily shielded disposal boxes (4x4x8 ft)	353.00	$45,500.00	ea	$16,061,500.00	Subcontractor	1.086	1.35	$23,547,765.15	50%	$35,321,647.73	0	0	0	0	Based on assumed distribution of contamination, 15% of excavation will be placed into highly shielded boxes, capacity 4 cy. Assume 90% of boxes filled 90% contaminated soil, 10% with void space. Assume 10% of boxes filled 50% with soil, 50% with grout. Volume calculation = 15% of 6027.8 cy = 904 cy x 1.3 swell factor ~1176 cy total soil. Total boxes = 353.	Cost per box is $45,500 based on 4" plate, calculated weight of box, and $1.75 /lb. cost for fabricated steel boxes.
		Concrete & Anchors for Enclosures	1.00	$105,000.00	ls	$105,000.00	Subcontractor	1.086	1.35	$153,940.50	50%	$230,910.75	0	0	0	0	400 cy concrete ($200/cy) for grade beams + $25K for helical anchors	0
		Single-Wide Trailer	60.00	$1,000.00	mo.	$60,000.00	Subcontractor	1.086	1.35	$87,966.00	50%	$131,949.00	0	0	0	0	Rental - Break Trailer	0
		Double-Wide Trailer	60.00	$1,700.00	mo.	$102,000.00	Subcontractor	1.086	1.35	$149,542.20	50%	$224,313.30	0	0	0	0	Rental - Office Trailer	0
		Double-Wide Trailer	60.00	$1,700.00	mo.	$102,000.00	Subcontractor	1.086	1.35	$149,542.20	50%	$224,313.30	0	0	0	0	Rental - Office Trailer	0
		Toilet Facilities Trailer	60.00	$2,500.00	mo.	$150,000.00	Subcontractor	1.086	1.35	$219,915.00	50%	$329,872.50	0	0	0	0	Rental - Bathroom/Shower Trailer	0
		Misc. consumables construction (e.g., water, fuel, storage)	260.00	$4,000.00	wk.	$1,040,000.00	Subcontractor	1.086	1.35	$1,524,744.00	50%	$2,287,116.00	0	0	0	0	Assume $1K/day during construction, 4 days per week	allocation for office trailer, fuel, water, etc.
		Personal Protective Equipment Consumables	1.00	5%	%	$1,239,458.60	Subcontractor	1.086	1.35	$1,817,170.25	50%	$2,725,755.38	0	0	0	0	5% of labor items	0
		Test Equipment	1.00	$777,680.00	ea	$777,680.00	Subcontractor	1.086	1.35	$1,140,156.65	50%	$1,710,234.97	0	0	0	0	Includes 1 Brokk Excavator with Vibratory Hammer attachment to be used for equipment qualification, training, and verification testing.	0
		Grout Material	987.12	$165.00	cy	$162,874.86	Subcontractor	1.086	1.35	$238,790.83	50%	$358,186.25	0	0	0	0	0	0
		Survey Crew - 2 FTE	1.00	$9,840.00	wk.	$9,840.00	Subcontractor	1.086	1.35	$14,426.42	50%	$21,639.64	2	0	0	1	Survey Crew for 1 week during procurement.	Generalized cost for surveying at Hanford
	Sampling and Characterization	Air Monitoring - Broad	72.00	$20,000.00	mo.	$1,440,000.00	Subcontractor	1.086	1.35	$2,111,184.00	50%	$3,166,776.00	0	0	0	0	Estimator Allowance of $20,000 per month. Duration matched to sum of durations for construction and testing, excavation and deactivation activities.	WMA C Site air monitoring during occupied intervals throughout project life
		Air Monitoring - Focused	16.00	$20,000.00	mo.	$320,000.00	Subcontractor	1.086	1.35	$469,152.00	50%	$703,728.00	0	0	0	0	Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-82 during excavation

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
																		activities and ventilation reconfiguration
		Air Monitoring - Focused	16.00	$20,000.00	mo.	$320,000.00	Subcontractor	1.086	1.35	$469,152.00	50%	$703,728.00	0	0	0	0	Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-81 during excavation activities and ventilation reconfiguration
		Air Monitoring - Focused	16.00	$20,000.00	mo.	$320,000.00	Subcontractor	1.086	1.35	$469,152.00	50%	$703,728.00	0	0	0	0	Estimator Allowance of $20,000 per month. Duration matched to UPR excavation duration.	Focused Air Monitoring within containment structure at UPR-200-E-86 during excavation activities and during backfilling of each UPR excavation
		Soil Sampling Labor - 2 FTE	6.00	$9,840.00	wk.	$59,040.00	Subcontractor	1	1.35	$79,704.00	50%	$119,556.00	2	0	0	6	Collect 144 soil grab samples: 8 confirmation samples at every 5-ft interval from 15 to 40 ft of depth. 8 samples per interval x 6 intervals = 48 samples per location. 48 samples per location, multiplied by 3 excavation sites. 1 week for sampling activity for each interval.	0
		Soil Sampling - Cost/Sample	144.00	$500.00	ea	$72,000.00	Subcontractor	1.086	1.35	$105,559.20	50%	$158,338.80	0	0	0	0	Collect 144 soil grab samples: 8 confirmation samples at every 5-ft interval from 15 to 40 ft of depth. 8 samples per interval x 6 intervals = 48 samples per location. 48 samples per location, multiplied by 3 excavation sites. 1 week for sampling activity for each interval.	0
		Grout Material Testing	1.00	$3,000.00	ls	$3,000.00	Subcontractor	1.086	1.35	$4,398.30	50%	$6,597.45	0	0	0	0	0	0
	Mobilization	Mobilization (incl. bonding and insurance)	1.00	8%	%	$532,113.60	Subcontractor	1.086	1.35	$780,131.75	50%	$1,170,197.62	0	0	0	0	0	0

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
		Site prep (e.g., staging & setup) - 12 FTE	3.00	$59,040.00	wk.	$177,120.00	Subcontractor	1	1.35	$239,112.00	50%	$358,668.00	12	0	0	3	1. 1 week = 40 hours; 1 day = 10 hours. 2. Construction and support trailers will be set up to support project. 3. Includes 2 industrial hygienists and 2 radiological technicians covers site sampling and characterization requirements.	This alternative does not require the setup component of building the gravel access road in Alt B. However, includes staging for both concrete and paving.
	Construction	Ground scans	1.00	$20,000.00	ls	$20,000.00	Subcontractor	1.086	1.35	$29,322.00	50%	$43,983.00	0	0	0	0	Ground scan for foundations (assume ~$20K)	0
		Training for construction staff	43.00	$2,500.00	ea	$107,500.00	Subcontractor	1	1.35	$145,125.00	50%	$217,687.50	0	0	0	2	Assume $2,500/worker for construction and specialty subs. Assume 8 site workers, and 35 subcontracted workers.	0
		WRPS Construction Management support crew - 10 FTE	52.00	$49,200.00	wk.	$2,558,400.00	WRPS	1	1	$2,558,400.00	50%	$3,837,600.00	0	0	0	52	Assume 10 Construction Management staff for one year	0
		Field work support crew - 9 FTE	52.00	$44,280.00	wk.	$2,302,560.00	WRPS	1	1	$2,302,560.00	50%	$3,453,840.00	0	0	0	52	Assume 4 industrial hygiene techs, 4 radiological technicians, and one field work supervisor for one year	0
		Construct Enclosures (construction contractor) - 15 FTE	10.00	$73,800.00	wk.	$738,000.00	Subcontractor	1	1.35	$996,300.00	50%	$1,494,450.00	15	0	0	10	0	0
		Install Ventilation System (construction contractor) - 8 FTE	4.00	$39,360.00	wk.	$157,440.00	Subcontractor	1	1.35	$212,544.00	50%	$318,816.00	8	0	0	4	0	0
		Construct Container Transfer Area - 6 FTE	2.00	$29,520.00	wk.	$59,040.00	Subcontractor	1	1.35	$79,704.00	50%	$119,556.00	6	0	0	2	dedicated transfer area, decontamination station, tarping station	0
		Electrical Service - 8 FTE	4.00	$39,360.00	wk.	$157,440.00	Subcontractor	1	1.35	$212,544.00	50%	$318,816.00	8	0	0	4	Install electrical service to support trailers, control trailers, HVAC system, and enclosures	0
		Install & Set up Control Trailer - 6 FTE	2.00	$29,520.00	wk.	$59,040.00	Subcontractor	1	1.35	$79,704.00	50%	$119,556.00	6	0	0	2	0	0
		Support trailers, roads, parking, infrastructure -8 FTE	4.00	$39,360.00	wk.	$157,440.00	Subcontractor	1	1.35	$212,544.00	50%	$318,816.00	8	0	0	4	0	0
		Construction Acceptance Testing - 8 FTE	4.00	$39,360.00	wk.	$157,440.00	Subcontractor	1	1.35	$212,544.00	50%	$318,816.00	8	0	0	4	0	General construction crew.

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
		Construct Shoring for Excavation - 6 FTE	6.00	$29,520.00	wk.	$177,120.00	Subcontractor	1.086	1.35	$259,675.63	50%	$389,513.45	0	0	0	0	0	General construction crew.
	Operations	Excavate UPR-200-E-82 - 6 FTE	57.00	$29,520.00	wk.	$1,682,640.00	Subcontractor	1	1.35	$2,271,564.00	50%	$3,407,346.00	6	2009.259259	0	57	Assume production rate of 48 ft3/hr. & 5 hrs. operation per shift = 922 hrs. or 185 days. 3 FTEs dedicated to remote excavator operations	0
		Reconfigure ventilation for use at UPR-200-E-81 - 12 FTE	2.00	$59,040.00	wk.	$118,080.00	Subcontractor	1	1.35	$159,408.00	50%	$239,112.00	12	0	0	2	Crew of 12 for 2 weeks to reroute ducting, startup and test ventilation	0
		Excavate UPR-200-E-81 - 6 FTE	57.00	$29,520.00	wk.	$1,682,640.00	Subcontractor	1	1.35	$2,271,564.00	50%	$3,407,346.00	6	2009.259259	0	57	Assume production rate of 48 ft3/hr. & 5 hrs. operation per shift = 922 hrs. or 185 days. 3 FTEs dedicated to remote excavator operations	0
		Reconfigure ventilation for use at UPR-200-E-86 - 12 FTE	2.00	$59,040.00	wk.	$118,080.00	Subcontractor	1	1.35	$159,408.00	50%	$239,112.00	12	0	0	2	Crew of 12 for 2 weeks to reroute ducting, startup and test ventilation	0
		Excavate UPR-200-E-86 - 6 FTE	57.00	$29,520.00	wk.	$1,682,640.00	Subcontractor	1	1.35	$2,271,564.00	50%	$3,407,346.00	6	2009.259259	0	57	Assume production rate of 48 ft3/hr. & 5 hrs. operation per shift = 922 hrs. or 185 days. 3 FTEs dedicated to remote excavator operations	0
		Backfill UPRs	6027.78	$39.69	cy	$239,244.30	Subcontractor	1.086	1.35	$350,756.07	50%	$526,134.10	0	6027.777778	0	0	Allocation of $33.24/cy (in FY2010 $) loadout at borrow pit, haul, place, and compact. Based on estimate in RPP-RPT-47167 (841,000 cy backfill for TEC of $27.95M in FY2010). Escalate to 2016	0
		Waste container handling operations - 12 FTE	171.00	$59,040.00	wk.	$10,095,840.00	Subcontractor	1	1.35	$13,629,384.00	50%	$20,444,076.00	12	0	0	171	Crew of 12 FTE for duration of excavation activities to support transport of filled containers from enclosure to Container Transfer Area. Assume covers survey of boxes for disposal	0
		Waste container transport - 3 FTE	171.00	$14,760.00	wk.	$2,523,960.00	Subcontractor	1	1.35	$3,407,346.00	50%	$5,111,019.00	3	0	0	171	Allocate 3 teamsters full time for container transfer from Container Transfer Area to Environmental Restoration Disposal Facility.	0
		Grout Labor	36.00	$492.00	ea	$17,712.00	Subcontractor	1	1.35	$23,911.20	50%	$35,866.80	0	0	0	0	Assume 10% of Heavily shielded waste boxes require grouting. Assume each box takes 4 hours to grout.	0
		Equipment - 30% of Total Field Labor	1.00	30%	%	$11,495,502.04	Subcontractor	1.086	1.35	$16,853,555.54	50%	$25,280,333.32	0	0	0	0	Assume equipment rental and operation costs equal to 30% of total field labor costs.	0

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
	Demolition of Enclosures	Demolition of Enclosures	1.00	20%	%	$1,656,661.80	Subcontractor	1.086	1.35	$2,428,831.86	50%	$3,643,247.80	0	0	0	0	Assume 20% of the enclosure capital costs	0
	Closeout and disposal	Disposal Labor - 8 FTE	1.00	$39,360.00	wk.	$39,360.00	Subcontractor	1	1.35	$53,136.00	50%	$79,704.00	8	0	0	1	Disposal labor cost includes labor and transportation costs	0
		Disposal: ERDF Class "WG"	144.00	$69.70	ton	$10,036.80	Subcontractor	1.086	1.35	$14,714.95	50%	$22,072.43	0	0	0	0	Assume 2 tons per month waste generation from construction and operations activities	0
		Disposal: ERDF Class "WG"	8252.01	$69.70	ton	$575,165.10	Subcontractor	1.086	1.35	$843,249.55	50%	$1,264,874.32	0	4702	0	0	Volume = 60% of total excavation = 0.6*6027.77*1.3= ~4702 Cubic Yard @ ERDF. Assume soil density of 130 lb./ft3, 2000 lb./ton	0
		Disposal: ERDF Class "WC"	1739.36	$2,296.08	cm	$3,993,709.69	Subcontractor	1.086	1.35	$5,855,177.78	50%	$8,782,766.66	0	0	0	0	Volume= 25% of excavation = 273 bull run boxes. Assume each box weighs 6 tons (empty) plus 25% of excavated soil (130 lb./ft3, 2000 lb./ton) - estimator allowance.	0
		Disposal: ERDF Class "WC"	1279.47	$2,296.08	cm	$2,937,757.89	Subcontractor	1.086	1.35	$4,307,046.85	50%	$6,460,570.27	0	0	0	0	353 boxes based on assumption that 15% soil volume is highly contaminated. Assume each box weighs 13 tons (empty) plus weight of 15% of total excavated soil (130 lb./ft3, 2000 lb./ton)	0
		Disposal: ERDF Class "WG"	525.00	$69.70	ton	$36,592.50	Subcontractor	1.086	1.35	$53,648.26	50%	$80,472.40	0	0	0	0	Assume 25% of structure area (ft2) to be disposed. Three structures. 1 ton per 20 ft2 - estimator judgment	0
		Demobilization - 8 FTE	4.00	$39,360.00	wk.	$157,440.00	Subcontractor	1	1.35	$212,544.00	50%	$318,816.00	8	0	0	4	Assume 8 FTE for 4 weeks to remove trailers and disconnect utilities	0
	Document prep	Work Package - $15K	10.00	$15,000.00	ea	$150,000.00	WRPS	1	1	$150,000.00	50%	$225,000.00	0	0	0	0	Assume 10 work plans of moderate complexity. Takes place between design and field work. Approximately $15K each.	0
		Project Completion Report - $20K	1.00	$20,000.00	ea	$20,000.00	WRPS	1	1	$20,000.00	50%	$30,000.00	0	0	0	0	Assume allocation of $20K.	0

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
Alternative 4																		
Construct Asphalt Interim Surface Barrier with Evapotranspiration Basin	Project Management (WRPS)	Overall Project Management - 1 FTE	104.00	$4,920.00	wk.	$511,680.00	WRPS	1	1	$511,680.00	30%	$665,184.00	1	0	0	104	Assume 1 week is equal to 40 hrs., and 1 day is equal to 10 hrs.	
		Buyer Technical Representative, Admin, Quality Assurance, Procurement Support - 2 FTE	104.00	$9,840.00	wk.	$1,023,360.00	WRPS	1	1	$1,023,360.00	30%	$1,330,368.00	2	0	0	104	Assume 1 week is equal to 40 hrs., and 1 day is equal to 10 hrs.	
		Project Engineer - 1 FTE	104.00	$4,920.00	wk.	$511,680.00	WRPS	1	1	$511,680.00	30%	$665,184.00	1	0	0	104	Assume 1 week is equal to 40 hrs., and 1 day is equal to 10 hrs.	
	Design	Architect/Engineer Design Services - $500K	1.00	$500,000.00	ls	$500,000.00	Subcontractor	1	1	$675,000.00	30%	$877,500.00	0	0	0	52	Assume $500K based on SX Farm ISB Design Costs.	
		WRPS Design Review & Oversight - $50k	1.00	$50,000.00	ls	$50,000.00	WRPS	1	1	$50,000.00	30%	$65,000.00	0	0	0	52	Assume $50K based on SX Farm ISB Design Costs.	
	Project Support	Air Permitting - 2 FTE	5.00	$9,840.00	wk.	$49,200.00	WRPS	1	1	$49,200.00	30%	$63,960.00	2	0	0	5	Assume 2 FTE for 5 weeks	
		Regulatory Support - 1 FTE	5.00	$4,920.00	wk.	$24,600.00	WRPS	1	1	$24,600.00	30%	$31,980.00	1	0	0	5	Assume 1 FTE for 5 weeks	
		General Project Support (10% of procurement estimate)	1.00	$0.10	%	$378,095.11	WRPS	1	1	$378,095.11	30%	$491,523.64	0	0	0	0	0	
	Procurement	Subgrade (materials, placement, compaction)	5396.30	$500.00	cy	$2,698,148.15	Subcontractor	1	1	$3,955,755.00	30%	$5,142,481.50	0	5396.296296	0	0	Assume, based on T Farm ISB actuals for subgrade fill @$500/cy. This covers material placement and compaction.	
		Gravel	123.46	$50.00	cy	$6,172.84	Subcontractor	1	1	$9,050.00	30%	$11,765.00	0	0	0	0	0	
		Geomembrane	225625.00	$1.00	lf	$225,625.00	Subcontractor	1	1	$330,788.81	30%	$430,025.46	0	0	225625	0	Geomembrane liner for evapotranspiration basin.	
		Riser extensions (bollards, corrugated metal pipe, miscellaneous protective components)	1.00	$70,000.00	ls	$70,000.00	Subcontractor	1	1	$102,627.00	30%	$133,415.10	0	0	0	0	Scaled cost from SX Farm estimate ($40K for 3.3-acre pavement). Scaling factor is 1.73 for C Farm. Equates to approximately $70K.	
		12-inch drain line, PVC perforated	6000.00	$12.70	lf	$76,200.00	Subcontractor	1	1	$111,716.82	30%	$145,231.87	0	0	0	0	1,200' of 16 inch and 6,000' of 12 inch ADS perf	
		18-inch drain line, corrugated metal	1200.00	$20.00	lf	$24,000.00	Subcontractor	1	1	$35,186.40	30%	$45,742.32	0	0	0	0	0	
		Storm water Boxes	6.00	$2,000.00	ea	$12,000.00	Subcontractor	1	1	$17,593.20	30%	$22,871.16	0	0	0	0	6 precast storm water boxes 12x6 ft x 4 ft deep with grating at $2K each.	
		Misc. consumables construction (e.g., water, fuel, storage)	52.00	$4,000.00	wk.	$208,000.00	Subcontractor	1	1	$304,948.80	30%	$396,433.44	0	0	0	0	Assume a dollar amount per day, or allocate a percent.	
		Personal Protective Equipment Consumables	1.00	$0.05	%	$256,331.00	Subcontractor	1	1	$375,806.88	30%	$488,548.94	0	0	0	0	5% of labor	

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
		Double-Wide Trailer	12.00	$1,700.00	mo.	$20,400.00	Subcontractor	1	1	$29,908.44	30%	$38,880.97	0	0	0	0	Estimator Allowance. Rental for 1 year.	
		Toilet Facilities Trailer	12.00	$2,500.00	mo.	$30,000.00	Subcontractor	1	1	$43,983.00	30%	$57,177.90	0	0	0	0	Estimator Allowance. Rental for 1 year.	
		Survey Crew - 2 FTE	3.00	$9,840.00	wk.	$29,520.00	Subcontractor	1	1	$43,279.27	30%	$56,263.05	2	0	0	3	Survey Crew for 3 wks. during procurement.	Generalized cost for surveying at Hanford
	Sampling and Characterization	Grade testing - 1 FTE	3.00	$4,920.00	wk.	$14,760.00	Subcontractor	1	1	$21,639.64	30%	$28,131.53	1	0	0	3	0	
		Ground scans - $50K	1.00	$50,000.00	ls	$50,000.00	Subcontractor	1	1	$73,305.00	30%	$95,296.50	0	0	0	0	Assume $50k.	
		Air Monitoring - Broad	12	$20,000.00	mo.	$240,000.00	Subcontractor	1	1	$351,864.00	30%	$457,423.20	0	0	0	0	0	
		Asphalt mix testing - 2 FTE	3.00	$14,400.00	wk.	$43,200.00	Subcontractor	1	1	$63,335.52	30%	$82,336.18	2	0	0	3	0	
	Mobilization	Mobilization (incl. bonding and insurance)	1.00	$0.08	%	$400,683.20	Subcontractor	1	1	$587,441.64	30%	$763,674.13	0	0	0	0	0	
		Site prep (e.g., staging & setup) - 8 FTE	1.00	$39,360.00	wk.	$39,360.00	Subcontractor	1	1	$53,136.00	30%	$69,076.80	8	0	0	1	0	
	Construction	Training for construction staff	33.00	$2,500.00	ea	$82,500.00	Subcontractor	1	1	$111,375.00	30%	$144,787.50	0	0	0	0	Assume $2,500/worker for construction and specialty subs. Assume 8 site workers, and 25 subcontracted workers.	
		WRPS Field work support crew - 6 FTE	52.00	$29,520.00	wk.	$1,535,040.00	WRPS	1	1	$1,535,040.00	30%	$1,995,552.00	5	0	0	52	Assume minimum of two industrial hygienists, two radiological technicians, one field work supervisor, and one construction manager.	
		Basin earthwork	1.00	$1,457,000.00	ls	$1,457,000.00	Subcontractor	1	1	$2,136,107.70	30%	$2,776,940.01	0	0	0	10	Based on commercial estimate from Swaggart Brothers Construction of $647,500 for the TY Basin. CMS estimate is $1,457,000.	
		Install Geomembrane liner- 10 FTE	2.00	$49,200.00	wk.	$98,400.00	Subcontractor	1	1	$132,840.00	30%	$172,692.00	10	0	0	2	0	
		Install plant cover over evapotranspiration basin	8.00	$1,000.00	acre	$8,000.00	Subcontractor	1	1	$11,728.80	30%	$15,247.44	0	0	8	0.2	Assume ~$1K/acre for establishing cover. Assume total area of 8 acres.	
		Excavation & placement of storm water catch basins & drain lines around barriers and between barriers and evapotranspiration basin - 12 FTE	4.00	$59,040.00	wk.	$236,160.00	Subcontractor	1	1	$318,816.00	30%	$414,460.80	12	0	0	4	Assume 6 precast storm water boxes 12' long x 6' wide x 4' deep w/grating. ~900 ft. of trench 3' deep. Subcontract crew.	
		Laying and paving of asphalt - 12 FTE	5.73	$264,000.00	acre	$1,512,720.00	Subcontractor	1	1	$2,217,798.79	30%	$2,883,138.43	12	0	0	4	Assume comparable to SX Farm; scaling factor is 1.7.	

Table E-7. Alternative 6 Capital Cost Estimate. (10 sheets)

Scope	Activity Group	Item	Quantity	Rate	Units	Subtotal	Resource	WA Tax Factor	Markup Factor	Est w/ Markups	Contingency	Est w/ Contingency	Rate (FTE)	Volume (cy)	Area	Time (weeks)	Assumptions	Notes
																	Assume $264K/acre for Matcon barrier, including production/haul/laydown.	
	Operations	Equipment - 30% of Total Field Labor	1.00	$0.30	%	$2,197,122.86	Subcontractor	1	1	$3,221,201.82	30%	$4,187,562.37	0	0	0	0	Assume equipment rental and operation costs equal 30% of total field labor costs.	
	Closeout and disposal	Disposal Labor - 8 FTE	1.00	$39,360.00	wk.	$39,360.00	Subcontractor	1	1	$53,136.00	30%	$69,076.80	8	0	0	1	Percent or lump sum for truck, driver, and wt./vol.	
		Disposal: ERDF Class "WG"	269.81	$69.70	ton	$18,806.09	Subcontractor	1	1	$27,571.61	30%	$35,843.10	0	0	0	0	Assume volume of disposed materials is 5% of concrete and asphalt material. Assume 1 cy of disposal material is equal to 1 ton. Earthwork excavated from basin would not be disposed in ERDF and instead stockpiled for future use.	
		Demobilization - 8 FTE	1.00	$39,360.00	wk.	$39,360.00	Subcontractor	1	1	$53,136.00	30%	$69,076.80	8	0	0	1	Assume 8 FTE for 1 week for demobilization	
	Document prep	Work Package - $15K	3.00	$15,000.00	ea	$45,000.00	WRPS	1	1	$45,000.00	30%	$58,500.00	0	0	0	0	Assume three work plans of moderate complexity. Takes place between design and field work. Approx. $15K each.	
		Project Completion Report - $20K	1.00	$20,000.00	ea	$20,000.00	WRPS	1	1	$20,000.00	30%	$26,000.00	0	0	0	0	Assume allocation of $20K.	
	Institutional Controls	Annual Institutional Controls	30.00	$38,000.00	yr	$1,140,000.00	WRPS	1	1	$1,238,040.00	10%	$1,361,844.00	0	0	0	1560	Assume institutional controls will be implemented between 2020 and 2050.	

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E1.12 References

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