RPT-188
Revision 0

Short-Term Risk Assessment for the Operable Unit 7-13/14 Feasibility Study

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April 2006

Idaho Cleanup Project

The Idaho Cleanup Project is operated for the
U.S. Department of Energy by CH2M◆WG Idaho, LLC

RPT-188
Revision 0
Project No. 23378

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Prepared under Subcontract No. 502199
for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14516

ABSTRACT

This document provides a short-term risk assessment comparison for activities associated with the implementation of remedial alternatives being evaluated in the feasibility study for the Subsurface Disposal Area at the Radioactive Waste Management Complex. Short-term risks are those risks that may occur during implementation of a specified remedial alternative. Calculations of risk throughout the report have been conservative, that is, giving an upper-bound estimate of the risks associated with the implementation of each remedial alternative. The upper-bound estimate gives the decision-maker assurance that the risk associated with the implementation of each alternative will not exceed the risk presented in this document. The analysis performed in the short-term risk assessment is both qualitative and quantitative.

This report outlines the procedures, evaluations, and calculations performed in arriving at the short-term risk. The risk assessment considered exposure to the Subsurface Disposal Area remediation workers, collocated workers, and the general public. Potentially complete risk pathways include the exposure to concentrations of radionuclides and chemical hazards that are prevalent throughout the Subsurface Disposal Area, injury to workers due to the nature of the work and heavy equipment, and transporting materials to the site and waste for disposition. The greatest overall risk comes from the implementation of the full retrieval, transport, and disposal alternative while the least risk stems from the no action alternative.

CONTENTS

ABSTRACT iii

ACRONYMS xi

1. INTRODUCTION 1-1

1.1 Purpose 1-1

1.2 Scope 1-4

1.3 Summary of Assembled Alternatives 1-4

1.3.1 No Action – Alternative 1 1-4
1.3.2 Surface Barrier – Alternative 2 1-4
1.3.3 In Situ Grouting – Alternative 3 1-8
1.3.4 Partial Retrieval, Treatment, and Disposal – Alternative 4 1-9
1.3.5 Full Retrieval, Treatment, and Disposal – Alternative 5 1-11

1.4 Summary of Selected Modules 1-14

1.5 Background 1-19

1.6 Report Organization 1-19

2. RISK ASSESSMENT METHODOLOGY 2-1

2.1 Exposure Scenarios 2-1

2.1.1 Radiological Inventory and Selection of Chemical Contaminants of Concern 2-1
2.1.2 Radiological and Chemical Release Mechanisms 2-11
2.1.3 Exposure Pathways and Receptors 2-12

2.2 Modeling Methodology 2-13

2.2.1 Radiological Release Modeling 2-13
2.2.2 Chemical Release Modeling 2-13

2.3 Toxicity Assessment 2-14

2.3.1 Chronic Reference Doses 2-15
2.3.2 Cancer Slope Factors 2-15
2.3.3 Acute Chemical Exposure 2-15

2.4 Risk Characterization 2-17

2.4.1 Radiological Risk 2-17
2.4.2 Chemical Risks 2-19

2.5 Uncertainty Analysis 2-20

2.5.1 Uncertainty Associated with Emission Inventory 2-20
2.5.2 Uncertainty Associated with Chemical Risk Assessment 2-20
2.5.3 Uncertainty Associated with Accident and Fatality Rates 2-22

3. RADIOLOGICAL ANALYSIS RESULTS 3-1

3.1 Dose and Risk Estimates for Remediation Workers 3-1

3.2 Dose and Risk Estimates for a Collocated Worker 3-1

3.3 Dose and Risk Estimates for a Member of the Public 3-1

3.4 Transportation Dose to Members of the Public 3-4

4. CHEMICAL ANALYSIS RESULTS 4-1

4.1 Risk Estimates for a Remediation Worker 4-1

4.2 Risk Estimates for a Collocated Worker 4-1

4.3 Risk Estimates for a Member of the Public 4-2

5. ACCIDENT AND TRANSPORTATION ANALYSIS 5-1

5.1 Industrial Injuries and Fatalities 5-1

5.2 Transportation Injuries and Fatalities 5-4

6. SUMMARY OF RESULTS 6-1

6.1 Risk Levels for the Radiological Risk Evaluation 6-1

6.2 Risk Levels and Hazard Indexes for the Chemical Risk Evaluation 6-1

6.3 Industrial and Transportation Injuries and Fatalities 6-3

6.4 Summary of Risks by Alternative 6-4

6.4.1 No Action – Alternative 1 6-4
6.4.2 Surface Barrier (RCRA Type C Cap) – Alternative 2a 6-4
6.4.3 Surface Barrier (Evapotranspiration Cap) – Alternative 2b 6-8
6.4.4 In Situ Grouting – Alternative 3 6-12
6.4.5 Two-Acre Retrieval, Treatment, and Disposal – Alternative 4a 6-17
6.4.6 Four-Acre Retrieval, Treatment, and Disposal – Alternative 4b 6-22
6.4.7 Full Removal, Treatment, and Disposal – Alternative 5 6-27

6.5 Comparison of Risk by Remedial Alternatives 6-31

6.5.1 No Action – Alternative 1 6-31
6.5.2 Surface Barrier Evapotranspiration Cap – Alternative 2b 6-33

6.5.3 In Situ Grouting – Alternative 3 6-33
6.5.4 Two-Acre Removal, Treatment, and Disposal – Alternative 4a 6-33
6.5.5 Four-Acre Removal, Treatment, and Disposal – Alternative 4b 6-34
6.5.6 Full Removal, Treatment, and Disposal – Alternative 5 6-34

6.6 Off-Normal Events 6-34

7. REFERENCES 7-1

Appendix A—Summary of Information Used for the Technical Approach to the Short-Term Risk Assessment A-1

Appendix B—Summary of Nonradioactive Releases and Chronic and Acute Risks from Modules 12, 13, and 14 ..... B-1

Appendix C—Details of the Industrial and Transportation Risk Calculations C-1

Appendix D—Radionuclide Data and Calculations D-1

FIGURES

1-1. Idaho National Laboratory showing the location of the Radioactive Waste Management Complex and other major facilities. 1-2

1-2. Radioactive Waste Management Complex showing the location of the Subsurface Disposal Area. 1-3

1-3. Preconceptual design for Alternative 2a – Resource Conservation and Recovery Act Subtitle C Cover. 1-5

1-4. Schematic of foundation grouting for Alternative 2a – Resource Conservation and Recovery Act Subtitle C Cover. 1-5

1-5. Preconceptual design for Alternative 2b – Evapotranspiration Cover 1-6

1-6. Pad A waste retrieval process. 1-7

1-7. Dynamic compaction operation. 1-7

1-8. Preconceptual design for Alternative 3 – In Situ Grouting. 1-8

1-9. Partial retrieval process. 1-10

1-10. Preconceptual design for Alternative 4a – Two-Acre Partial Retrieval, Treatment, and Disposal. 1-11

1-11. Preconceptual design for Alternative 4b – Four-acre partial retrieval, treatment, and disposal. 1-12

1-12. Full retrieval process. 1-13

1-13. Preconceptual design for Alternative 5 – Full retrieval, treatment, and disposal. 1-14

1-14. Summary of alternatives and the modules that compose each alternative. 1-15

2-1. Radiological conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex. 2-2

2-2. Chemical conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex. 2-3

2-3. Conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex. 2-4

TABLES

2-1. Two-acre retrieval waste types and volumes. 2-6

2-3. Four-acre retrieval waste types and volumes. 2-7

2-5. Full RTD waste types and volumes. 2-8

2-8. Volatile organic compounds of interest used for the risk assessment. 2-9

2-9. Volatile organic compounds not included in risk assessment. 2-9

2-12. Reference doses and slope factors for compounds of interest. 2-15

2-12. Summary of acute toxicity factors. 2-16

3-1. MEI remediation worker cancer risks by alternative. 3-2

3-2. Summary of MEI remediation worker cancer risks by alternative. 3-3

3-3. Module radionuclide dose to a collocated worker. 3-3

3-4. Module radionuclide cancer risk[a] to a collocated worker. 3-4

3-5. Radionuclide dose to a public member at site boundary. 3-4

3-6. Radionuclide risk[a] to a public member at site boundary. 3-4

3-7. Total dose to public for alternatives. 3-6

4-1. Chemical risks and hazard indexes to the collocated worker. 4-1

4-2. Chemical risks and hazard indices to members of the public. 4-2

5-1. Projected industrial injuries and fatalities calculated from module projections. 5-2

5-2. Summary of projected injuries and fatalities from industrial accidents, by alternative. 5-3

5-3. Projected transportation injuries and fatalities to the member of the public. 5-4

5-4. Summary of projected injuries and fatalities from transportation accidents to the public, by alternative. 5-5

5-5. Total projected injuries and fatalities from industrial and transportation accidents. 5-5

6-1. Radiological cancer incidence risk for each alternative. 6-1

6-2. Chemical cancer risk for each alternative. 6-2

6-3. Chemical noncancer chronic hazard for each alternative. 6-2

6-4. Chemical noncancer acute hazard for each alternative. 6-2

6-5. Total projected injuries and fatalities from industrial accidents for remediation workers. 6-3

6-6. Total projected injuries and fatalities from transportation accidents for collocated workers. 6-3

6-7. Total projected injuries and fatalities from transportation accidents for members of the public. 6-3

6-8. Summary of radiological risk for the RCRA Type C cap alternative. 6-5
6-9. Summary of chemical risks and hazards for the RCRA Type C cap alternative. 6-6
6-10. Summary of industrial and transportation injuries and fatalities for the RCRA Type C cap alternative.....6-7
6-11. Summary of radiological risk for the evapotranspiration cap alternative. 6-8
6-12. Summary of chemical risks and hazards for the evapotranspiration cap alternative. 6-10
6-13. Summary of industrial and transportation injuries and fatalities for the evapotranspiration cap alternative.....6-11
6-14. Summary of radiological risk for the in situ grouting alternative. 6-12
6-15. Summary of chemical risks and hazards for the in situ grouting alternative. 6-14
6-16. Summary of industrial and transportation injuries and fatalities for the in situ grouting alternative.....6-16
6-17. Summary of radiological risk for the two-acre RTD alternative. 6-17
6-18. Summary of chemical risks and hazards for the two-acre RTD alternative.....6-20
6-19. Summary of industrial and transportation injuries and fatalities for the two-acre RTD alternative.....6-21
6-20. Summary of radiological risk for the four-acre RTD alternative.....6-22
6-21. Summary of chemical risks and hazards for the four-acre RTD alternative. 6-25
6-22. Summary of industrial and transportation injuries and fatalities for the four-acre retrieval, treatment, and disposal alternative.....6-26
6-23. Summary of radiological risk for the full RTD alternative.....6-27
6-24. Summary of chemical risks and hazards for the full RTD alternative. 6-29
6-25. Summary of industrial and transportation injuries and fatalities for the full RTD alternative.....6-31
6-26. Summary of risks for each alternative. 6-32

ACRONYMS

ARP	Accelerated Retrieval Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWI	CH2M-WG Idaho, LLC
DOE	U.S. Department of Energy
EBR	Experimental Breeder Reactor
ERPG	Emergency Planning Guidelines
HEPA	high-efficiency particulate air
INL	Idaho National Laboratory
MEI	maximally exposed individual
OCVZ	organic contamination in the vadose zone
RCRA	Resource Conservation and Recovery Act
RIBRA	Remedial Investigation Baseline Risk Assessment
REL	Reference exposure limit
RH	remote-handled
RTD	retrieval, treatment, and disposal
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
STRA	Short-term Risk Assessment
TEDE	total effective dose equivalent
TEEL	Temporary Emergency Exposure Limits
TLD	thermoluminescent dosimetry/dosimeter
TRU	transuranic

Short-Term Risk Assessment for the Operable Unit 7-13/14 Feasibility Study

1. INTRODUCTION

The Idaho Cleanup Project requires an assessment of short-term risks associated with remedial modules being evaluated in the feasibility study for the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC). Short-term risks are those risks that may occur during implementation of a specified remedial alternative. The short-term risk analysis will support detailed and comparative analyses of assembled alternatives in the Operable Unit 7-13/14 feasibility study, as required in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1989). Figures 1-1 and 1-2 show the location of the RWMC and the Idaho National Laboratory (INL) Site, as well as the SDA within the RWMC.

This report outlines the procedures, evaluations, and calculations performed in arriving at the short-term risk. A summary of each key component associated with the risk assessment is presented in Section 2. The risk assessment considered exposure to the SDA operators, collocated workers, and the general public. Potentially complete risk pathways include the exposure to concentrations of radionuclides and chemical hazards that are prevalent throughout the SDA, the risk of injury to workers due to the nature of the work and heavy equipment, and the risk associated with transporting materials to the site and waste for disposition. The period bounding the risk assessment is the time of operation for each of the remedial alternatives in the SDA. At present, the period for each is based on the cost and schedule basis as outlined in the October 2005 CH2M-WG Idaho, LLC, Feasibility Study Cost Estimates.[a] Any deviations to that schedule may result in an incremental risk of accidents and fatalities or exposure to radiological or chemical constituents. This risk assessment is designed to report the risk from currently anticipated activities specific to the short-term risk associated with remedial actions.

1.1 Purpose

The purpose of this short-term risk assessment is to provide a reasonable basis for the comparison of short-term risks for implementation of each of the proposed remedial actions. Calculations of risk throughout the report have been conservative, that is, giving an upper-bound estimate of the risks associated with the implementation of each remedial alternative. The upper-bound estimate gives the decision-maker assurance that the risk associated with the implementation of each alternative will not exceed the risk presented in this document. For further discussion on why this risk assessment presents the upper-bound estimate the reader is referred to the Uncertainty Analysis discussion presented in Section 2.5.

The analysis performed in the short-term risk assessment is both qualitative, as discussed in Section 2.2.2 of Appendix C of the *Human Health Evaluation Manual* (EPA 1989b), and quantitative. Quantitative analysis is used when sufficient data are available to estimate the emissions and when releases or potential releases (1) are anticipated over a long period, (2) have a high potential for release, and (3) will include multiple contaminants. The methodology used to determine the risk for each of the modules must be consistent so decision-makers can compare them side-by-side when considering alternatives. The decision to perform a qualitative or quantitative analysis and the approach used for determining the risk in each module to remediation workers, collocated workers, and the public are explained Section 2.

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[a] These cost estimates will be included in document number DOE/ID-11268 which will be published in December 2006.

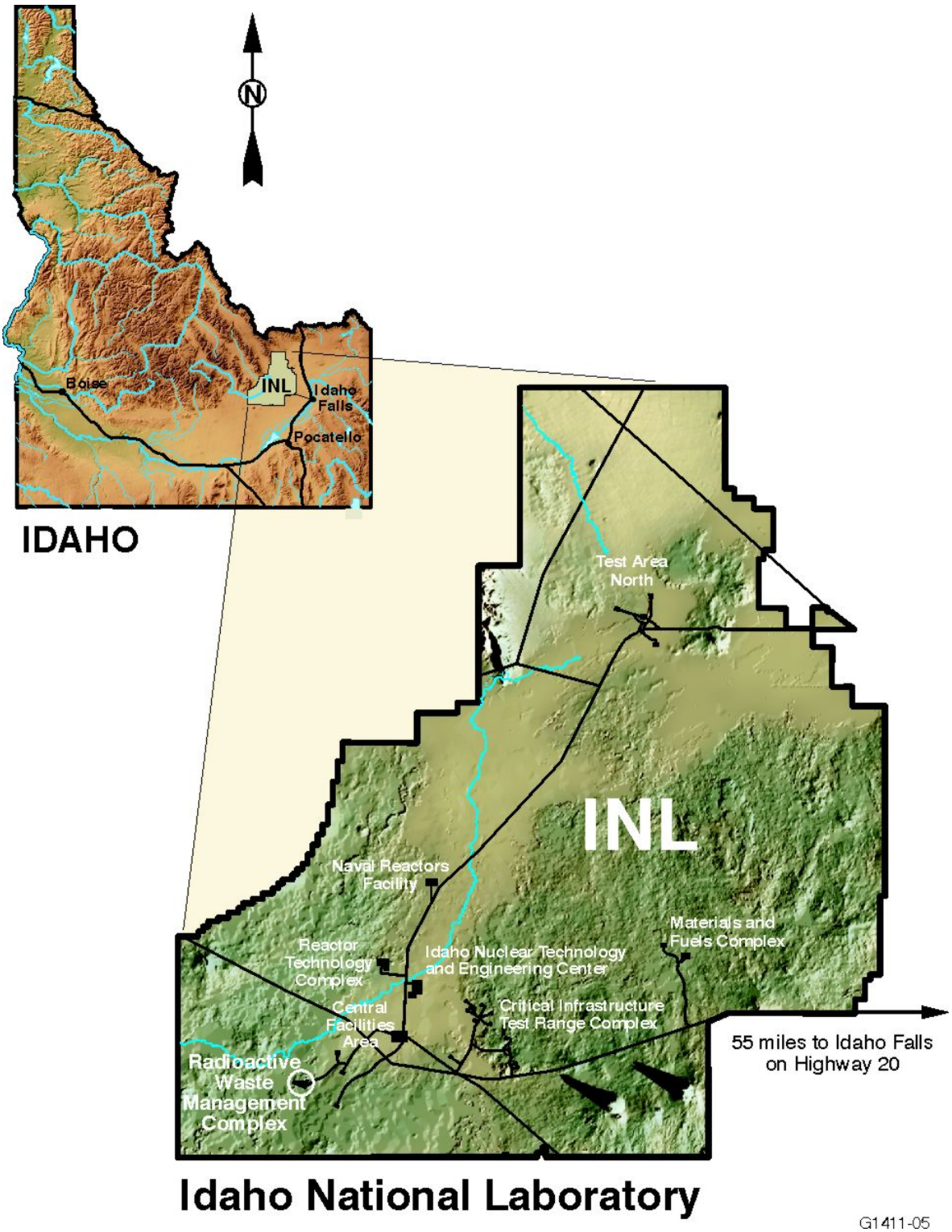

Figure 1-1 Idaho National Laboratory showing the location of the Radioactive Waste Management Complex and other major facilities.

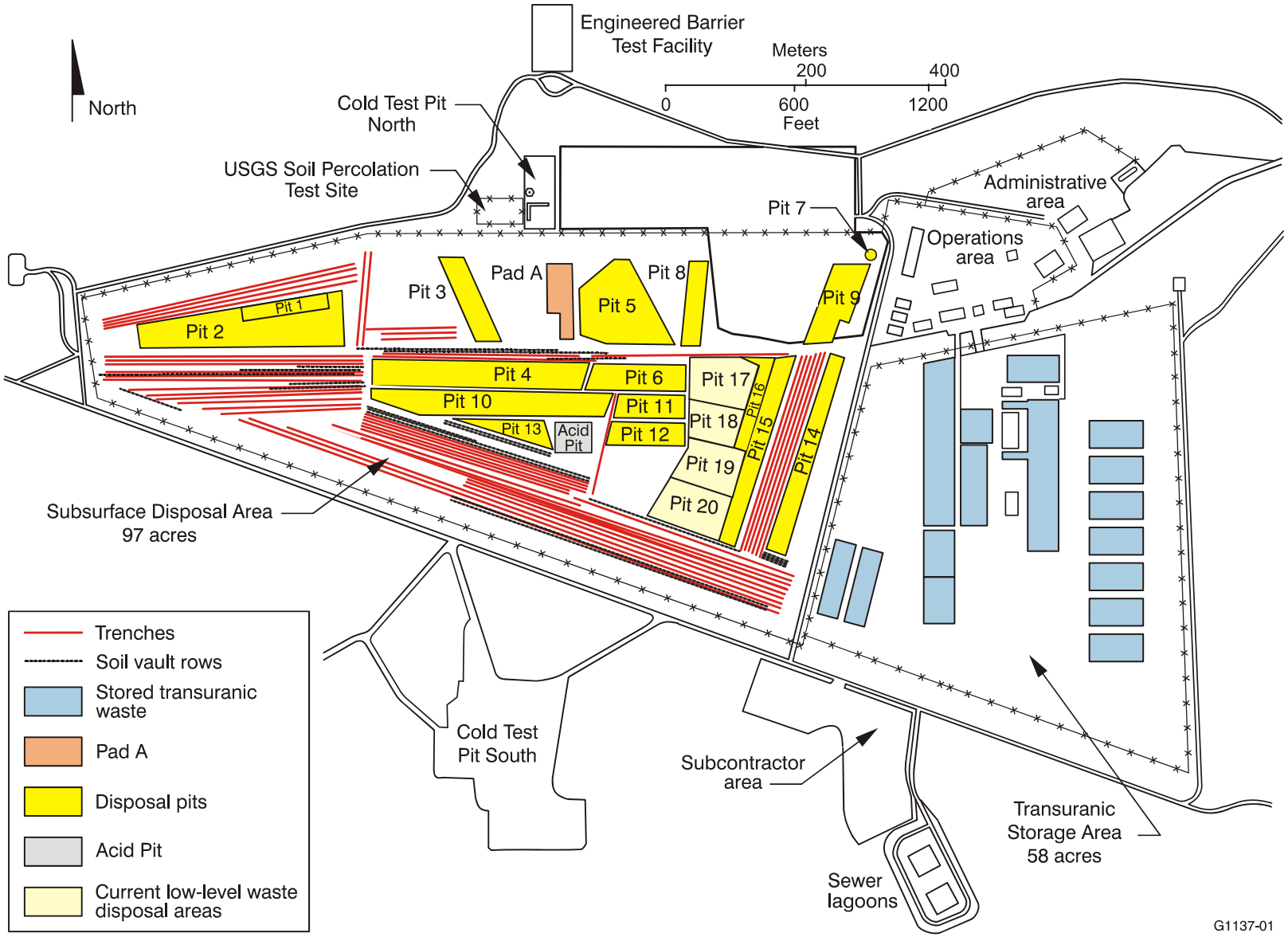

Figure 1-2. Radioactive Waste Management Complex showing the location of the Subsurface Disposal Area.

1.2 Scope

This report describes the results of the short-term risk assessment performed for the Operable Unit 7-13/14 feasibility study. Five alternatives (two alternatives contain subsets as discussed in Section 1.3) are evaluated for potential risk. With one exception, all the alternatives evaluated in the feasibility study are described in the *Second Addendum to the Work Plan for the Operable Unit 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study* (Holdren and Broomfield 2004). These five alternatives comprise 20 unique remedial modules. Combinations of the modules are used to form each alternative. The risks associated with each alternative are determined by summing the risks associated with each of the unique modules. By using a systematic and consistent approach for evaluating the risk, decision-makers can compare relative risks among the various alternatives. The alternatives can be compared even though the true magnitude of the risks is uncertain as long as the methodology and the assumptions used remain consistent throughout each module.

1.3 Summary of Assembled Alternatives

In accordance with the *Second Addendum* (Holdren and Broomfield 2004), five assembled alternatives are evaluated in detail in the Operable Unit 7-13/14 feasibility study and are compared against each other. From the general descriptions of the assembled alternatives, 20 modularized elements were defined to expedite analysis of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) balancing criteria, including evaluation of short-term effectiveness. The five assembled alternatives and the 20 modules that arose from those alternatives are described in the subsections that follow.

1.3.1 No Action – Alternative 1

The no action alternative evaluates the absence of remedial action to provide a baseline to compare other alternatives. Environmental monitoring (Module 19) is the only activity evaluated for the no action alternative.

1.3.2 Surface Barrier – Alternative 2

Two types of surface barriers are evaluated in the Operable Unit 7-13/14 feasibility study. In addition to post-construction maintenance, long-term institutional controls, and environmental monitoring, assembled alternatives for the two surface barriers incorporate two unique approaches to control subsidence, address Pad A, and inhibit build-up of organic vapors in the cap.

1.3.2.1 Modified Resource Conservation and Recovery Act Subtitle C Cover – Alternative 2a. This surface barrier alternative involves Module 10–Foundation grouting, Module 5–Resource Conservation and Recovery Act (RCRA) Type C cap, Module 7–Shallow extraction pipe, and Module 20–Organic contamination in the vadose zone (OCVZ) maintenance and operations (M&O). The modified RCRA Subtitle C cover is an engineered barrier constructed of multiple layers of asphalt and natural materials. A biotic barrier is incorporated into the cover to preclude biotic intrusion and transport of contaminants to the surface. Other enhancements for the RCRA cover include incorporating Pad A into the cover, installing grout columns in waste pits to provide a stable foundation, and expanding the existing organic contamination in the vadose zone system with shallow extraction wells. The implementation timeframe for the RCRA cover is approximately two years. A preconceptual design of the assembled alternative is shown in Figure 1-3.

Pad A would be incorporated into the surface barrier by adding additional layers over the existing Pad A cover. Steps to address subsidence of Pad A waste are not included in this alternative.

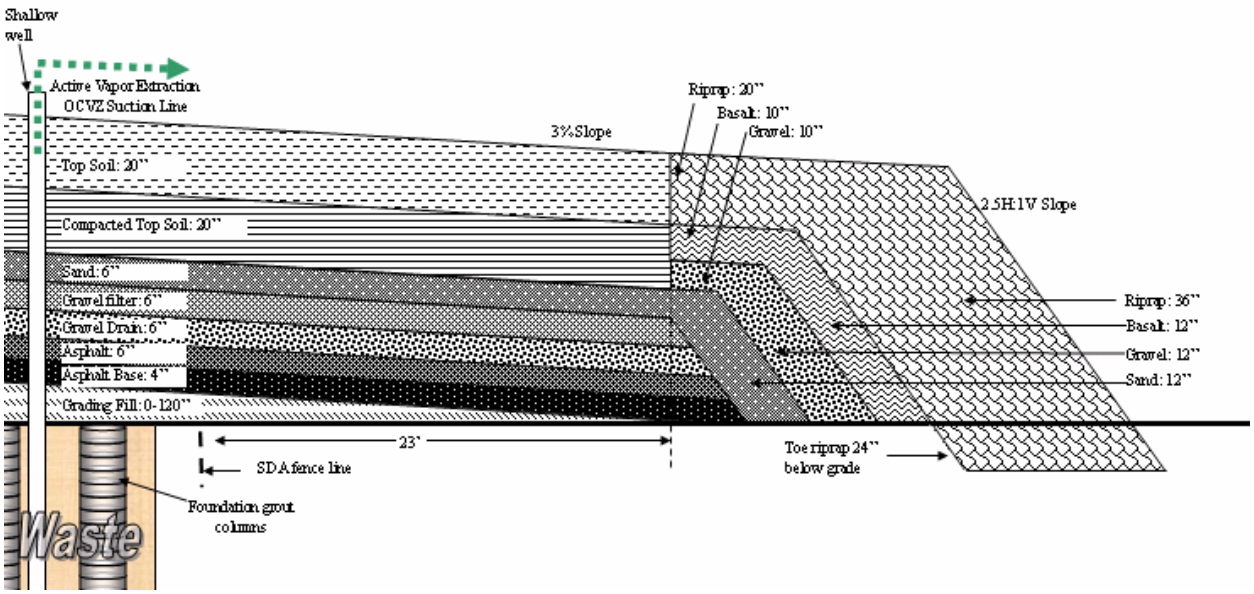

Figure 1-3. Preconceptual design for Alternative 2a – Resource Conservation and Recovery Act Subtitle C Cover.

A stable foundation for the SDA cover will be provided by installing grout columns. Figure 1-4 shows a schematic of the foundation grouting conceptual approach. Approximately 19 acres of the SDA would be grouted. Approximately 5,700 columns would be deployed over about 8.5 months, using two drill rigs and about 1 million gallons of grout.

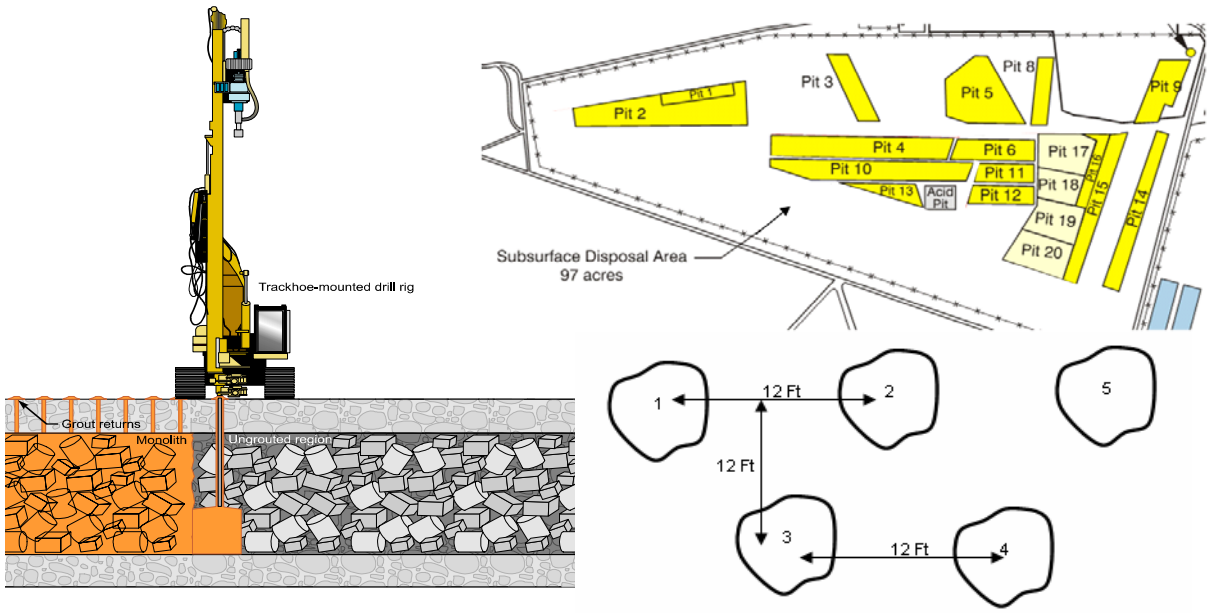

Figure 1-4. Schematic of foundation grouting for Alternative 2a – Resource Conservation and Recovery Act Subtitle C Cover.

The existing organic contamination in the vadose zone system would be enhanced with shallow extraction wells to preclude trapping organic vapors beneath asphalt layers of the cover. Gas extraction wells would be installed in eight locations in the completed cap. Wells would be completed at approximately 10 ft into the basalt layer immediately beneath the landfill and between pits to avoid intrusion into the buried waste. Risers would extend above the surface barrier and connect to the organic contamination in the vadose zone treatment system. Operation and maintenance of the treatment system would continue for approximately 65 years until organic contamination in the vadose zone remediation goals are satisfied.

1.3.2.2 Evapotranspiration Cover – Alternative 2b. This surface barrier alternative involves Module 15–Pad A removed without treatment and ship to Low-Level Waste Pit, Module 8–Dynamic compaction of pits, Module 3–Evapotranspiration cap, Module 6–Gas vent layer extraction pipe, and Module 20–Organic contamination in the vadose zone M&O. The evapotranspiration cover is a barrier that is specifically engineered for the climate conditions at the SDA site and is constructed of several layers of natural materials. A biotic barrier is incorporated into the cover to preclude biotic intrusion and transport of contaminants to the surface. Other evapotranspiration cover enhancements include transferring waste from Pad A into the Low-Level Waste Pit, dynamically compacting waste pits to provide a stable foundation, and incorporating a gas collection layer that is coupled to the existing organic contamination in the vadose zone system. The implementation timeframe for the evapotranspiration cover is approximately five years. A preconceptual design of the assembled alternative is shown in Figure 1-5.

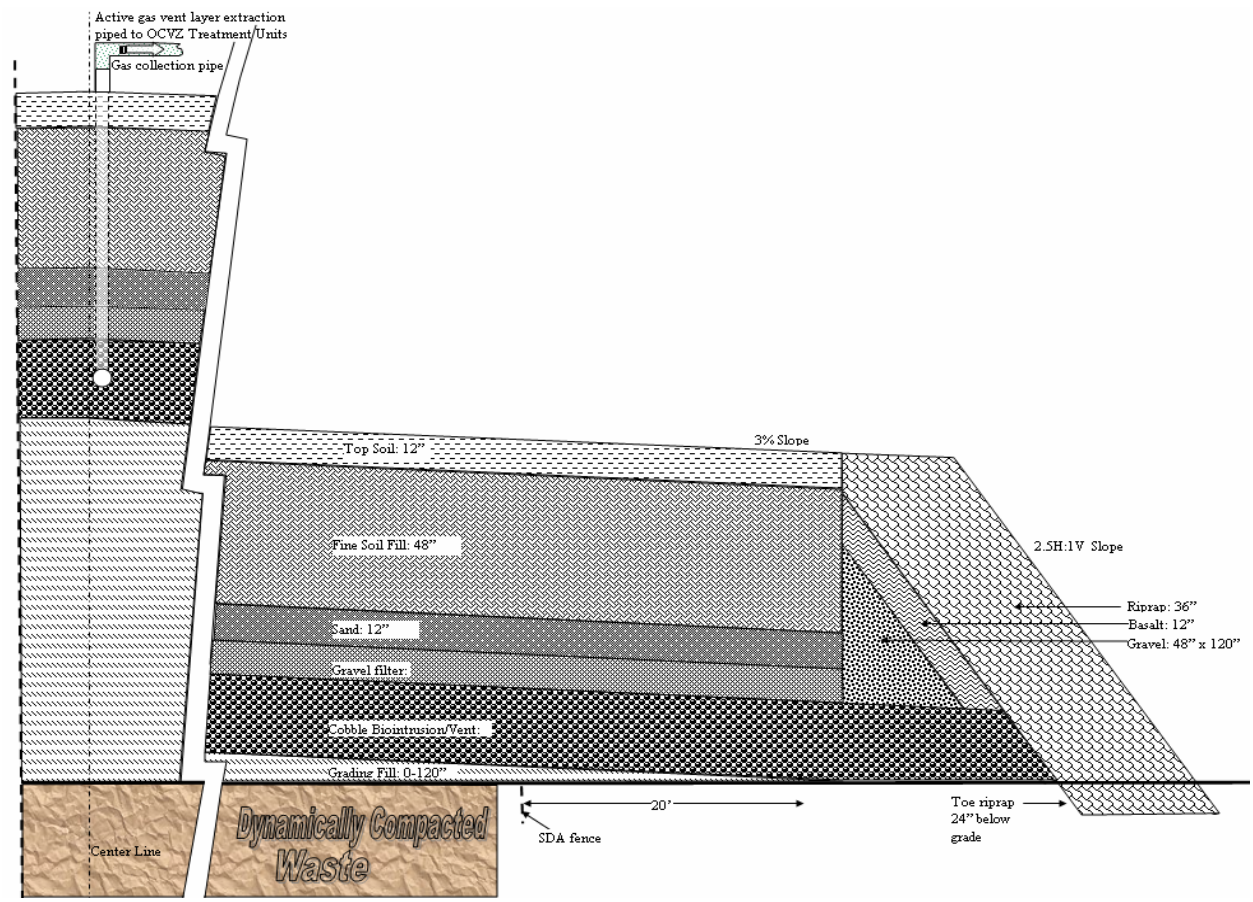

Figure 1-5. Preconceptual design for Alternative 2b – Evapotranspiration Cover.

Figure 1-6 illustrates the process for removing waste from Pad A and transferring it to the Low-Level Waste Pit within the SDA. Waste would be removed under a weather enclosure and would require approximately five years to complete. Almost 600 boxes containing intact drums and more than 3,000 lift liners containing loose waste would be transferred to storage and then shipped to the active Low-Level Waste Pit. Waste would not be treated prior to disposal.

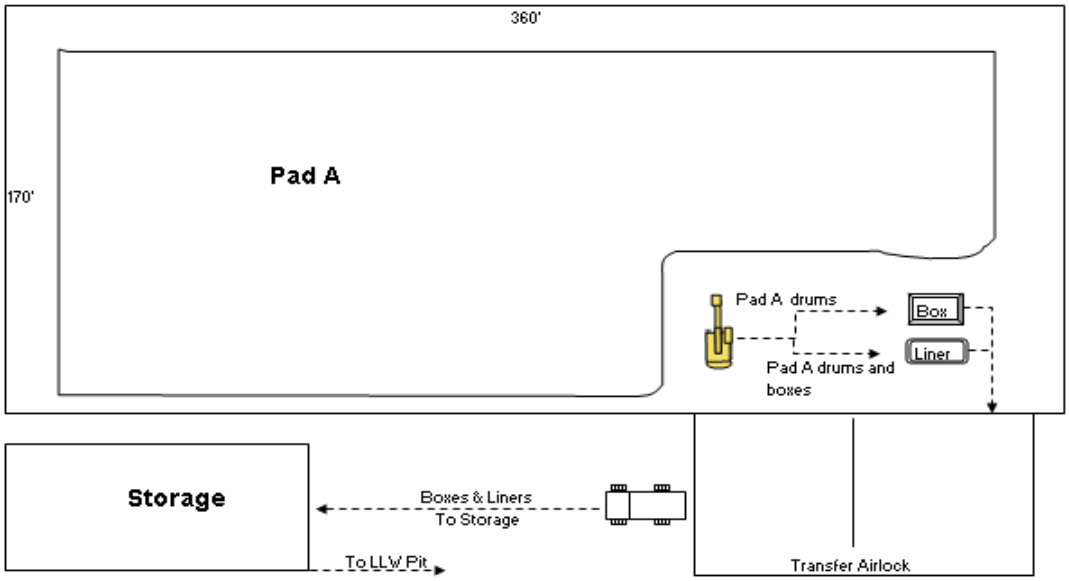

Figure 1-6. Pad A waste retrieval process.

Dynamic compaction would be applied to waste pits before constructing the cap to reduce subsidence. Figure 1-7 is a photo of a dynamic compaction operation. A 15-ton weight would be dropped from a height of up to 60 ft from a crane to compact the existing waste pits. A 1-ft-thick layer of soil would be placed over areas to be compacted prior to treatment to reduce the possibility of waste exposure.

Figure 1-7. Dynamic compaction operation.

To preclude buildup of vapors in the cap that could be detrimental to vegetation on the surface of the cover, the gas collection pipe, shown in Figure 1-5, would be installed during cover construction. Approximately 3,600 linear feet of 12-in. pile would be installed in the combined gas venting and biotic

intrusion layer, and connected to 37 risers. The risers would be connected to the organic contamination in the vadose zone treatment system following completion of cap construction. Operation and maintenance of the treatment system would continue for approximately 45 years until organic contamination in the vadose zone remediation goals are satisfied.

1.3.3 In Situ Grouting – Alternative 3

The in situ grouting alternative involves Module 18–Pad A removed with treatment and ship to Low-Level Waste Pit, Module 11–Contaminant grouting, Module 8–Dynamic compaction of pits, Module 3–Evapotranspiration cap, Module 6–Gas vent layer extraction pipe, and Module 20–Organic contamination in the vadose zone maintenance and operations. The in situ grouting alternative evaluates use of in situ stabilization of waste to retard migration of contaminants generated by INL reactor and fuel development operations. It includes removal and ex situ grouting of Pad A waste with subsequent relocation within the Operable Unit 7-13/14 area of contamination, dynamic compaction of pit areas to mitigate future waste subsidence, construction of an evapotranspiration surface barrier with a combined biotic intrusion and gas vent layer, and passive extraction of soil vapors from the surface barrier. In addition, post-construction maintenance, long-term institutional controls, and environmental monitoring are included. Operation and maintenance of the system would continue for approximately 45 years until organic contamination in the vadose zone remediation goals are satisfied. The implementation timeframe for in situ grouting is approximately 10 years. A preconceptual design of the assembled alternative is shown in Figure 1-8.

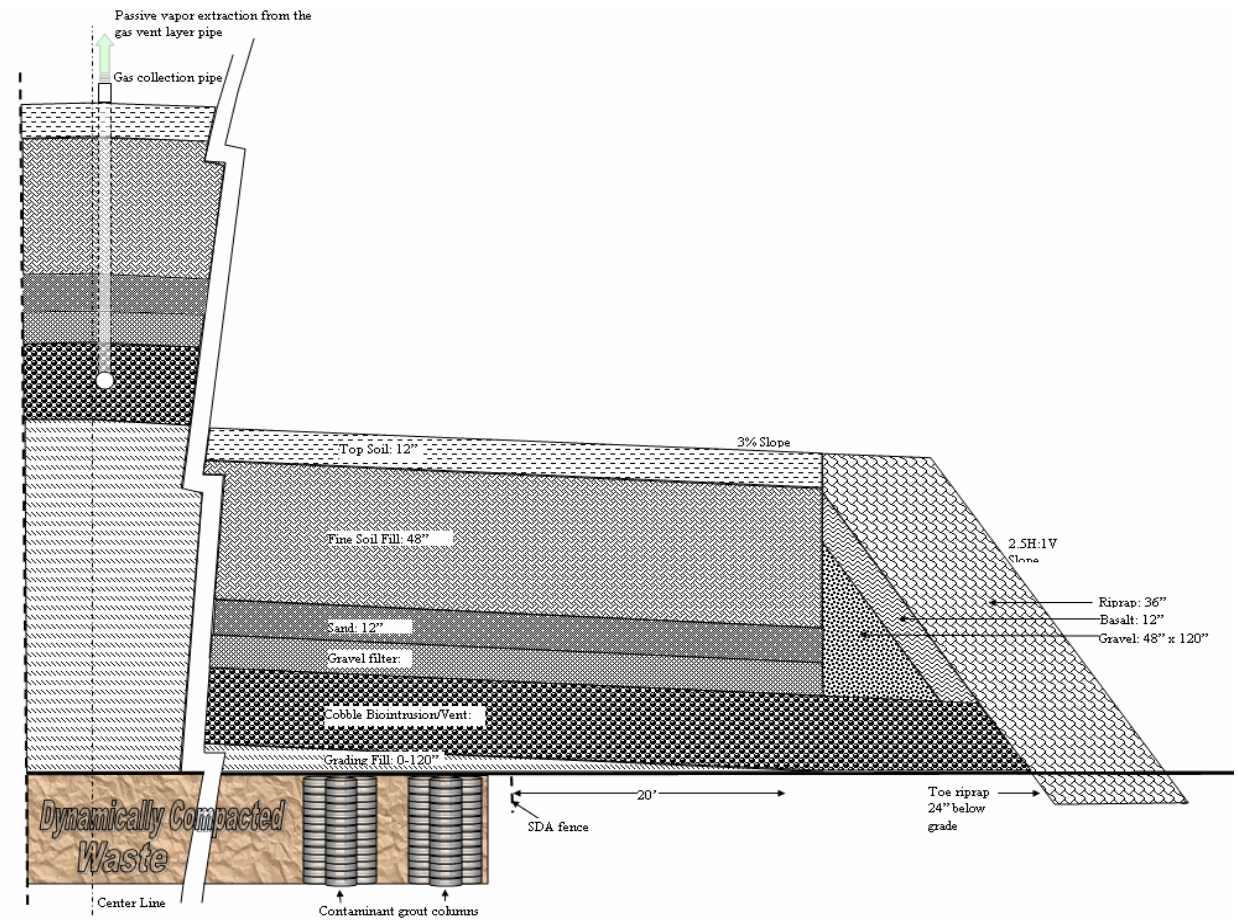

Figure 1-8. Preconceptual design for Alternative 3 – In Situ Grouting.

Specified waste will be encapsulated by in situ injection of a Portland cement grout using commercially available equipment. Liquid grout will be injected into the buried waste using a probe driven by a roto-percussion drill. High pressure jet grouting will mix grout with waste and soil to form homogeneous columns. Grout columns will be closely spaced on 20-in. centers to form a consolidated monolith. The stabilized waste monolith will be highly impermeable and will reduce contaminant diffusion to water that may infiltrate the waste zone.

Waste will be retrieved from Pad A in a retrieval enclosure. Because waste containers are expected to be highly degraded, waste types will not be segregated. Bulk waste will be separated into fines (<6-in. diameter) and debris (>6-in. diameter). Fines will be treated by mixing with a Portland cement grout. Debris will be placed into waste boxes and stabilized with flowable cement grout. Stabilized waste boxes will be transported to the Low-Level Waste Pit or another location within the Operable Unit 7-13/14 area of contamination. Upon completion of Pad A waste removal, the retrieval enclosure will be demobilized and the site prepared for surface barrier construction. Dynamic compaction will be applied to provide a stable foundation for the engineered barrier.

The in situ grouting alternative includes an evapotranspiration surface barrier with a passive gas-venting layer that dissipates organic vapors and inhibits biotic intrusion. The cover will reduce infiltration and contaminant transport into the subsurface and inhibit biotic transport to the surface.

1.3.4 Partial Retrieval, Treatment, and Disposal – Alternative 4

To facilitate scaling up or down to various retrieval sizes, two partial retrieval areas are evaluated as Alternatives 4a and 4b, representing 2 acres and 4 acres, respectively. These alternatives evaluate identical methods of retrieval, treatment, and disposal (RTD), but vary in their approaches to subsidence control and Pad A.

Operations are conducted within a large metal-framed, fabric retrieval enclosure equipped with air locks. Air locks house glove boxes for inspecting waste and loading drums, and also control contamination during ingress and egress for retrieval operations. Retrievals also occur within smaller mobile tent structures. Manned excavators modified for breathing air, dust suppression, and camera optics are used for retrieval. Determinations on whether a waste is targeted or nontargeted are made at or near the dig face. Nontargeted waste is returned to the excavation, while targeted waste is placed in cargo containers for transfer to sorting tables within the central retrieval enclosure. Drum carcasses are removed and separated along with various nontargeted items (e.g., miscellaneous packing material and items prohibited at the Waste Isolation Pilot Plant) on sorting tables. The retrieval process is illustrated in Figure 1-9.

Targeted waste is handled in one of two ways:

- Transuranic waste. Targeted transuranic waste exiting the sorting tables is moved to drum packaging stations for Waste Isolation Pilot Plant-certified visual examination loading into drums certified by the Waste Isolation Pilot Plant.
- Roaster oxides. Targeted roaster oxides are drummed and prepared for transfer to the Idaho CERCLA Disposal Facility (or similar on-Site or off-Site facility) for treatment and disposal. At the Idaho CERCLA Disposal Facility, the waste is stabilized by grouting.

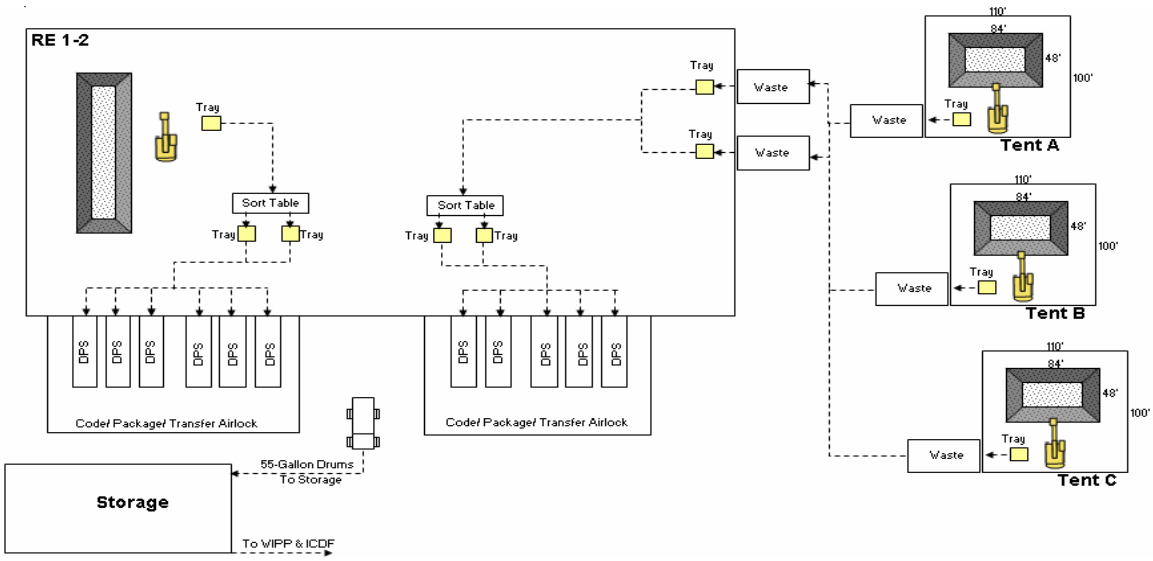

Figure 1-9. Partial retrieval process.

Both partial retrieval alternatives include an evapotranspiration surface barrier with a passive gas-venting layer that dissipates organic vapors and inhibits biotic intrusion. The cover will reduce infiltration and contaminant transport into the subsurface and inhibit biotic transport to the surface. The two-acre retrieval, treatment, and disposal alternative anchors the surface barrier to a subsurface slurry wall around the perimeter. Both assembled alternatives incorporate long-term maintenance, institutional controls, and environmental monitoring. Operation and maintenance of the system for both the two-acre and four-acre options would continue for approximately 30 years until organic contamination in the vadose zone remediation goals are satisfied. A description of the unique features of the two partial retrieval alternatives follows.

1.3.4.1 Two-Acre Partial Retrieval, Treatment, and Disposal – Alternative 4a. The two-acre RTD alternative involves Module 12–Two-acre excavation, Module 9–Dynamic compaction Pad A, Module 2–Proof rolling, Module 3–Evapotranspiration cap, Module 1–Slurry cut-off wall, Module 6–Gas vent layer extraction pipe, and Module 20–Organic contamination in the vadose zone maintenance and operations. The two-acre partial retrieval alternative involves retrieval, treatment, and disposal of waste from a two-acre footprint using methods described previously. The implementation timeframe for Alternative 4a is approximately 15 years.

To provide a stable foundation for the surface barrier and reduce subsidence, Pad A is dynamically compacted and waste pits are proof-rolled. A slurry cut-off wall is installed in surficial sediments around the perimeter of the SDA. A multi-layered evapotranspiration cover (see Alternative 2b) incorporating Pad A is placed over the entire SDA. A preconceptual design of the assembled alternative is shown in Figure 1-10.

1.3.4.2 Four-Acre Partial Retrieval, Treatment, and Disposal – Alternative 4b. The Module 13–Four-acre RTD alternative involves four-acre excavation, Module 16–Pad A removal and ship to Idaho CERCLA Disposal Facility for treatment and disposal, Module 8–Dynamic compaction of pits, Module 3–Evapotranspiration cap, Module 6–Gas vent layer extraction pipe, and Module 20–Organic contamination in the vadose zone maintenance and operations. The four-acre partial retrieval alternative involves retrieval, treatment, and disposal of waste from a four-acre footprint using methods described previously. The implementation timeframe for the this RTD is approximately 18 years.

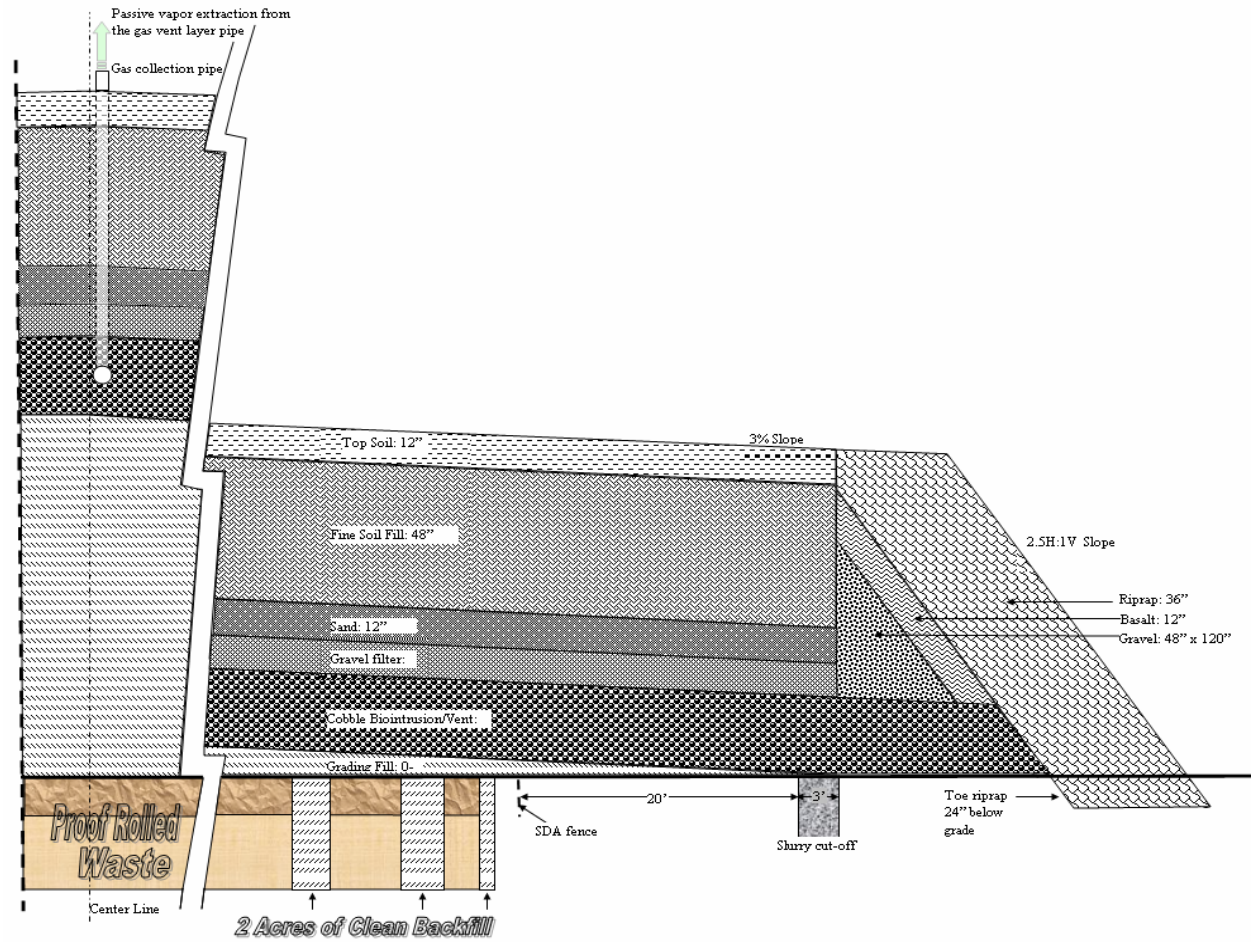

Figure 1-10. Preconceptual design for Alternative 4a – Two-Acre Partial Retrieval, Treatment, and Disposal.

To provide a stable foundation for the surface barrier and reduce subsidence, all waste pits are dynamically compacted. Waste is retrieved from Pad A and shipped to the Idaho CERCLA Disposal Facility for treatment (i.e., grouting) and disposal. A multi-layered evapotranspiration cover (Module 3) is placed over the entire SDA. A preconceptual design of the assembled alternative is shown in Figure 1-11.

1.3.5 Full Retrieval, Treatment, and Disposal – Alternative 5

The Module 14–Full RTD alternative involves full excavation, Module 17–Pad A removal and ship off-Site for treatment and disposal, Module 4–Evapotranspiration cap without gas vent layer, and Module 20–Organic contamination in the vadose zone maintenance and operations. The full retrieval, treatment, and disposal alternative involves retrieval of all waste from the SDA (including remote-handled objects and oversized objects) and disposal outside of the SDA. Operations are conducted within a large metal-framed, fabric retrieval enclosure equipped with air locks.

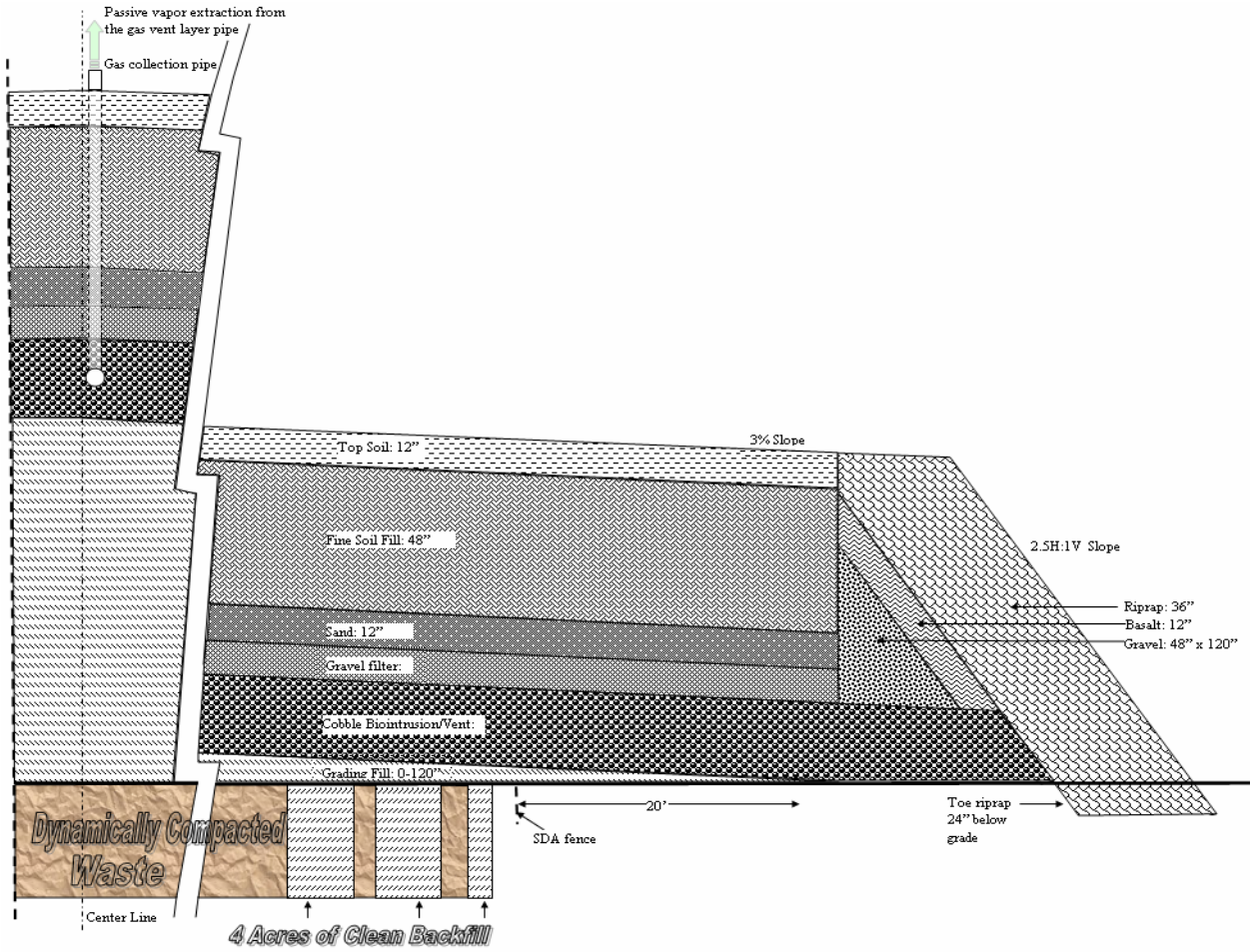

Figure 1-11. Preconceptual design for Alternative 4b – Four-acre partial retrieval, treatment, and disposal.

Air locks house glove boxes for inspecting waste and loading drums and also control contamination during ingress and egress to retrieval operations. Retrievals also occur within smaller mobile tent structures located outside the retrieval enclosure. Manned excavators modified for breathing air, dust suppression, and camera optics are used for retrieval. The process is illustrated in Figure 1-12.

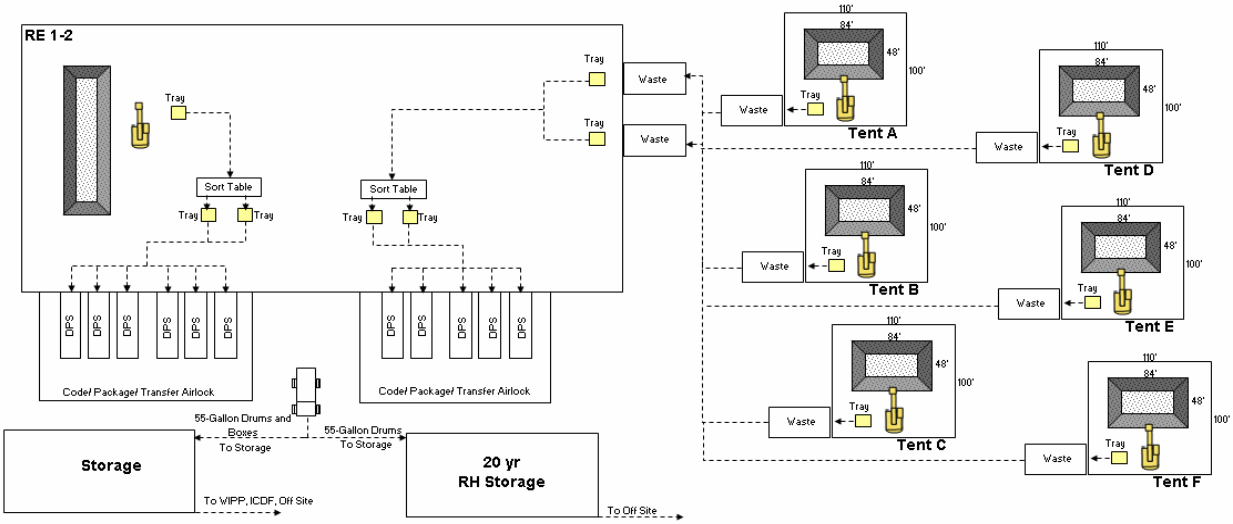

Figure 1-12. Full retrieval process.

Waste is placed in cargo containers for transfer to sorting tables within the central retrieval enclosure and sorted based on disposal path. Retrieved waste is handled in one of several ways:

- Transuranic waste exiting the sorting tables is moved to drum packaging stations for Waste Isolation Pilot Plant-certified visual examination loading into Waste Isolation Pilot Plant-certified drums
- Roaster oxides and other nontransuranic waste meeting waste acceptance criteria are drummed and transferred to the Idaho CERCLA Disposal Facility (or similar on-Site or off-Site facility) for treatment (i.e., grouting) and disposal
- Contact-handled nontransuranic waste is sent off-Site for treatment, if required to satisfy waste acceptance criteria, and permanent disposal
- Remote-handled waste is retrieved using a crane, shielding blocks, and a cask, then sent to a new storage facility within the INL Site for up to 20 years pending future transport to an off-Site facility.

Following retrieval, a simple, two-layer evapotranspiration cover is placed over the entire SDA to reduce infiltration and inhibit transport of residual contamination in the vadose zone. The implementation timeframe for full RTD is approximately 35 years. Long-term maintenance, OCVZ operation, institutional controls, and environmental monitoring also are included and will last approximately 10 years. A preconceptual design of the assembled alternative is shown in Figure 1-13.

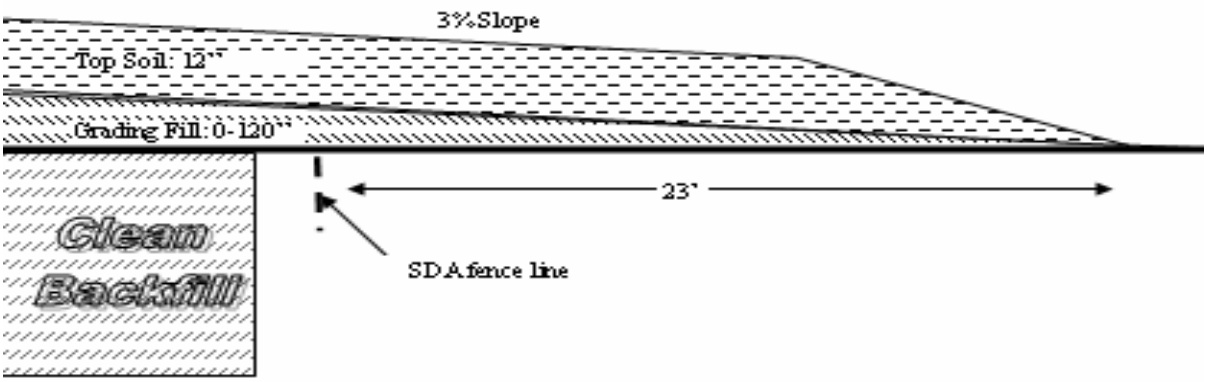

Figure 1-13. Preconceptual design for Alternative 5 – Full retrieval, treatment, and disposal.

1.4 Summary of Selected Modules

Twenty independent remedial modules in various combinations compose the five alternatives. Figure 1-14 shows how the modules compose each of the alternatives. The 20 modules are described in the following paragraphs and in Appendix A.

For each module, the risks associated with radiological, chemical, and industrial and transportation hazards were evaluated for the following three population groups: (1) remediation workers involved in the project, (2) the collocated workers, and (3) the exposed members of the public. These population groups, also called receptors, were identified through the development of a conceptual site model that is presented in Section 3. From the list of the unique events, the sources of risk are identified for each of the three potential receptor populations. Sources of risk expected to be present in this risk assessment include: (1) inhalation of radionuclides, (2) inhalation of volatile organics, (3) inhalation of hazardous chemicals, (4) labor, and (5) transportation of raw materials to the site and disposition of waste packages.

	ALTERNATIVE[1]	COMPONENTS								PROJECT COMPLETION[3]
		Retrieval & Disposal	Pad A	In Situ Treatment	Foundation Preparation	Containment Barrier	Shallow Volatile Organic Compound Removal	Surveillance and Monitoring	Institutional Controls	
1	NO ACTION	NA	NA	NA	NA	NA	NA	YES 19	NA	NA
2a	SURFACE BARRIER[2]	NA	Pad A waste left in place with no steps to address subsidence	NA	Foundation grouting 10	Modified RCRA Type C with biotic barrier 5	Active vapor extraction through shallow extraction wells integrated into existing OCVZ system 6	YES 5,		2012
2b			Pad A waste shipped to active SDA LLW pit without treatment 15		Dynamic compaction 8	Evapotranspiration with biointrusion/gas vent layer 3	Active vapor extraction through transport layer vents integrated into the existing OCVZ system 7	YES 3,		2015
3	IN SITU GROUTING (ISG)	NA	Pad A waste shipped to active SDA LLW pit following ex situ grouting treatment 18	Focused ISG to immobilize Tc-99 and I-129 11	Dynamic compaction 8	Evapotranspiration with biointrusion/gas vent layer 3	Passive vapor extraction through transport layer vents and side burden riprap armor 7	YES 3,		2012
4a	PARTIAL RTD (PRTD)	Two acres (excluding ARP) of targeted RFP-TRU waste will be retrieved, segregated, treated as necessary, and disposed of ; targeted TRU waste shipped to WIPP; non-targeted waste left in place 12	Pad A waste left in place, dynamic compaction applied to address subsidence 9	NA	Proof Rolling 2	Evapotranspiration with biointrusion/gas vent layer and Slurry Cut-Off Wall 3, 1	Passive vapor extraction through transport layer vents and side burden riprap armor 7	YES 3,		2015
4b		Four acres (excluding ARP) of targeted RFP-TRU waste will be retrieved, segregated, treated as necessary, and disposed of ; targeted TRU waste shipped to WIPP; non-targeted waste left in place 13	Pad A waste shipped to ICDF for treatment and disposal 16	NA	Dynamic compaction 8	Evapotranspiration with biointrusion/gas vent layer 3	Passive vapor extraction through transport layer vents and side burden riprap armor 7	YES 3,		2018
5	FULL RTD (FRTD)	All waste within the SDA will be retrieved, segregated, treated as necessary, and disposed of ; TRU waste shipped to WIPP; non-TRU waste shipped to appropriate on- or off-site TSD facilities 14	Pad A waste shipped to an off-site facility for treatment and disposal 17	NA	NA	Evapotranspiration without biointrusion/gas vent layer 4	No volatile organic compound (VOC) removal from the surface barrier or buried waste zone	YES 4,		2035

1. All alternatives, except the No Action alternative, will have a number of common remedial actions to address waste-stream specific issues and achieve RAOs: (1) site preparation suitable for the remedial action, such as removal of temporary structures, (2) pretreatment to mitigate subsidence and provide a stable foundation for a cap, (3) continued operation of the OCVZ vapor extraction system until vadose zone RAOs for OU 7-08 are satisfied, (4) containment by capping (surface barrier), with the robustness of the cap and size of the associated restricted access area dependent on the alternative being evaluated, (5) long-term operations, maintenance, and monitoring, (6) passive institutional control (future land use restricted in perpetuity). The No Action alternative includes costs for long-term monitoring only.

2. Two surface barrier designs will be developed and evaluated: an evapotranspiration cover and a modified RCRA Type C cover. Three approaches to subsidence--dynamic compaction, grouting, and proof rolling will be evaluated as pretreatment to mitigate subsidence.

3. Dates are rough approximations subject to change based on more rigorous development of fully assembled alternatives. For purposes of risk modeling only, effective project completion date for all alternatives is 2010.

= Module

Figure 1-14. Summary of alternatives and the modules that compose each alternative.

- Slurry Cut-Off Wall (Module 1). The slurry cut-off wall consists of a trench dug around the SDA and immediately filled with a bentonite slurry. The slurry wall is designed to prevent migration of shallow perched water into the waste zone. Because the cut-off wall will be outside the SDA, there will be no risk from chemical or radiological constituents; the only risk will be worker injuries and material transportation to the site.

- Proof Rolling (Module 2). Proof rolling consists of mowing and scarifying the SDA; importing, placing, and compacting fill materials; and proof-rolling the SDA for stability. Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste surface; therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.

- Evapotranspiration Surface Barrier (Module 3). The evapotranspiration surface barrier module consists of constructing a cap over the entire SDA that can collect volatile constituents. Several existing probes and wells will need to be relocated to complete this module. Additionally, pre- and post-cap work, such as installing and demolishing roads and fences, extending probes, installing wells, recontouring the SDA, and maintenance will be performed. As part of institutional controls, a perimeter road and fence may be installed after the completion of the cap but the risk associated with this item would be negligible when compared with the other remedial activities because of the shielding provided by the cap and the short timeframe needed to complete the activity. Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste near the surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.

  At the completion of the cap installation, a long term monitoring campaign will commence. Pre-monitoring activities involve installation of wells, lysimeters, vapor ports, and tensiometers. These instruments are monitored at regular intervals to ensure that the waste is not migrating through the environmental media, causing an unacceptable risk. The risk associated with long-term monitoring is not included in this short-term risk assessment.

- Surface Barrier without Vent Layer (Module 4). Pre- and post-cap work for this module is identical to module 3. What distinguishes this module from module 3 is the absence of several cap layers (and therefore a shorter time frame for construction). Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste near the surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.

  The post-cap long term monitoring campaign is identical to that mentioned in module 3. The risk associated with the long-term monitoring is not included in this short-term risk assessment.

- Type C RCRA Cap (Module 5). Pre- and post-cap work for this module is identical to module 3. What distinguishes this module from module 3 is the thickness and composition of the various cap layers. Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste near the surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.

  The post-cap long term monitoring campaign is identical to that mentioned in module 3. The risk associated with the long-term monitoring is not included in this short-term risk assessment.

- Gas Extraction Manifold for the Evapotranspiration Surface Barrier (Module 6). This module will be constructed with Module 3. The gas extraction manifold module consists of placing sections of 12-in. (outside diameter) pipe horizontally within the evapotranspiration cap gas collection layer and connecting the pipe to the OCVZ treatment unit. Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.
- Shallow Gas Extraction Pipe for the RCRA Type C Cap (Module 7). This module will be constructed with Module 5. The shallow gas extraction well consists of placing sections of 12-in. well casing vertically through the RCRA Type C cap, between the waste pits and into the underlining basalt. Following cap completion, the protruding wells will be connected to the organic contamination in the vadose zone treatment units. Because no waste will be released in this module, there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries.
- Dynamic Compaction of Pits (Module 8). Dynamic compaction consists of compacting soil by dropping a heavy weight from a designated height in an engineered pattern. This will prepare the ground for a cap that will be placed over the SDA. No waste is expected to be released in this module so there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.
- Dynamic Compaction of Pad A (Module 9). Dynamic compaction will prepare the ground for a cap that will be placed over Pad A. No waste is expected to be released in this module so there will be no chemical risks; however, the remediation worker may receive a radioactive dose from the buried waste surface. Therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.
- Foundation Grouting (Module 10). Foundation grouting uses a nondisplacement rotary percussion drill to bore holes through the SDA at regular intervals and inject grout to provide a stable base to place a cap. The grouting approach is considered a nondisplacement approach; therefore, the chemical risk has not been quantified because the waste does not have a complete pathway to the surface for release into the environment. Remediation workers may still be exposed to radioactivity from waste beneath the surface; therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.
- Contaminant Grouting (Module 11).This module is similar to foundation grouting (Module 10), except that the columns will be made to fill the entire targeted area with grout, thus encapsulating the waste in the SDA. The grouting approach is considered a nondisplacement approach; therefore, the chemical risk has not been quantified because the waste does not have a complete pathway to the surface for release into the environment. Remediation workers may still be exposed to radioactivity from waste near the surface; therefore, a worker dose was calculated to be conservative. Risk will be present from worker injuries and transporting materials to the site.
- Two-Acre Retrieval, Treatment, and Disposal (Module 12). The two-acre RTD consists of retrieving two acres of targeted waste, sorting and repackaging the waste within a centrally located retrieval enclosure, and transporting the waste to either the Waste Isolation Pilot Project or the Idaho CERCLA Disposal Facility, as appropriate. Because this alternative will actively bring waste to the surface, the potential for chemical and radiological risk is present, along with risk from worker injuries and transporting waste to the disposal area.

- Four-Acre Retrieval, Treatment, and Disposal (Module 13). The four-acre RTD consists of retrieving four acres of targeted waste, sorting and repackaging the waste within a centrally located retrieval enclosure, and transporting the waste to either the Waste Isolation Pilot Plant or Idaho CERCLA Disposal Facility, as appropriate. Because this alternative will actively bring waste to the surface, the potential for chemical and radiological risk is present, along with risk from worker injuries and transporting waste to the disposal area.
- Full Retrieval, Treatment, and Disposal (Module 14).The full RTD option consists of retrieving all the waste, including the higher activity remote-handled (RH) waste, from the SDA, sorting and repackaging the waste within a centrally located retrieval enclosure, and transporting the waste to either the Waste Isolation Pilot Plant, Idaho CERCLA Disposal Facility, or another off-Site disposal facility, as appropriate. Since this alternative will actively bring RH waste to the surface as well as those types of waste recovered in Modules 12 and 13, the potential for the radiological dose administrative limit being exceeded is greater and must be monitored more closely. The potential for chemical risk is also present, along with risk from worker injuries and transporting waste to the disposal area.
- Removing Pad A and Disposing of Waste in the RWMC Low-Level Waste Repository without Treatment (Module 15). This option consists of recontouring the Pad A berm and building an enclosure over the top to be used for retrieving waste stored on Pad A. The waste will be retrieved, sorted, and transferred to the RWMC Low-Level Waste repository without treatment. Available information from Pad A shows that there are no significant volatile chemicals in the Rocky Flats waste and there is limited data for the remainder of Pad A organic and inorganic waste; therefore, there is no chemical risk included in the risk assessment. Risk will be calculated for radiological exposure, worker injuries, and transportation.
- Removing Pad A, and Disposing of and Treating Waste at the Idaho CERCLA Disposal Facility or Similar On-Site Facility (Module 16). This module consists of recontouring the Pad A berm and building an enclosure over the top for retrieving waste stored on Pad A. The waste will be retrieved, sorted, and transferred to the Idaho CERCLA Disposal Facility (or similar facility) for treatment and disposal. Available information from Pad A shows that there are no significant volatile chemicals in the Rocky Flats waste and there is limited data for the remainder of Pad A organic and inorganic waste; therefore, there is no chemical risk included in the risk assessment. Risk will be calculated for radiological exposure, worker injuries, and transportation.
- Removing Pad A, and Disposing of and Treating Waste at Envirocare or Similar Off-Site Facility (Module 17).This module consists of recontouring the Pad A berm and building an enclosure over the top for retrieving waste stored on Pad A. The waste will be retrieved and transferred to Envirocare (or similar facility) for treatment and disposal. Available information from Pad A shows that there are no significant volatile chemicals in the Rocky Flats waste and there is limited data for the remainder of Pad A organic and inorganic waste; therefore, no chemical risk is included in the risk assessment. Risk will be calculated for radiological exposure, worker injuries, and transportation.
- Removing Pad A, and Disposing of and Treating Waste at SDA and in the RWMC Low-Level Waste Repository (Module 18). This module consists of recontouring the Pad A berm and building an enclosure over the top for retrieving waste stored on Pad A. The waste will be retrieved and then treated at the SDA before transferring it to the RWMC Low-Level Waste repository. Available information from Pad A shows that there are no significant volatile chemicals in the Rocky Flats waste and there is limited data for the remainder of Pad A organic and inorganic waste; therefore, no chemical risk is included in the risk assessment. Risk will be calculated for radiological exposure, worker injuries, and transportation.

- Monitoring (Module 19). The monitoring module is a stand-alone option that will not require any additional retrieval or work at the SDA. Wells, lysimeters, vapor ports, and tensiometers will be monitored at regular intervals to ensure that the waste is not migrating through the environmental media, causing an unacceptable risk. Risk will not be calculated for this module since this activity is a long-term activity and not part of the short-term remedial action.
- Organic Contamination in the Vadose Zone Operations and Maintenance (Module 20). This module consists of operating and maintaining the OCVZ and can be used with several of the other modules. Three phases are associated with this module: (1) operating and maintaining the OCVZ treatment units for each five-year period they operate, (2) replacing the OCVZ treatment units each 20 years they are in service, and (3) final shutdown of the OCVZ treatment units at the end of the alternative action. Risk will not be calculated for this module since this activity is a long-term activity and not part of the short-term remedial action.

1.5 Background

The U.S. Atomic Energy Commission established the RWMC in 1952 for the disposal of radioactive waste within the boundaries of what was then the National Reactor Testing Station. The RWMC consisted of two main disposal areas: the Transuranic Storage Area and the Subsurface Disposal Area. From 1952 through 1970, waste from both the National Reactor Testing Station and various off-Site generators was buried in the SDA (Figure 1-2). Waste buried in the SDA consisted of a wide variety of waste types, including radionuclides, toxic metals, inorganics, and organics.

1.6 Report Organization

The remaining sections in this report are as follows:

- Section 2 describes the methodology used in the risk calculations and the associated uncertainty analysis
- Section 3 describes radiological risk analysis
- Section 4 describes the chemical risk analysis
- Section 5 describes the accident and transportation analysis
- Section 6 summarizes the risks associated with each action
- Section 7 lists the references cited throughout this report.

2. RISK ASSESSMENT METHODOLOGY

Consistent with Environmental Protection Agency guidelines (EPA 1989a), this risk assessment contains the following sections:

- Exposure Assessment. An exposure assessment involves identifying the exposure pathways and human receptors and quantifying exposure. Section 2.1, "Exposure Scenarios," evaluates the fate and transport of chemicals and radionuclides in the environment and establishes the routes of exposure for people. This information is used to establish a conceptual site model. Section 2.2, "Modeling Methodology," presents the quantitative methods used to determine exposure point concentrations.
- Toxicity Assessment. The toxicity assessment shows the formulas used to establish risk from chemical constituents. This section also shows the chemical specific risk factors used in determining acute and chronic risk in humans. This information is presented in Section 2.3.
- Risk Characterization. Risk characterization applies the exposure and toxicity assessment information to quantify risk estimates. The risk characterization is provided in Section 2.4.
- Uncertainty Assessment. The uncertainty assessment summarizes both the uncertainty and variability inherent in various risk assessment components. This assessment allows qualitative aspects of the risk assessment to be incorporated into the quantitative risk estimates established in the risk characterization step. The uncertainty assessment is presented in Section 2.5.

This technical approach does not include analyses of life cycle risks as suggested by the *Preliminary Risk Evaluation of Options for Buried Waste Disposition at the Idaho Site* (CRESP 2005). The Preliminary Risk Evaluation report states that previous short-term risk evaluations provide risk estimates for remedial alternatives but does not examine the risks remaining in the SDA or for other sites that receive SDA waste. Examination of residual risk at the SDA or disposal sites is not included in the scope of this assessment. Each of the disposal sites being considered have established waste acceptance criteria, based on the performance assessment for the disposal site. The additional risk from remediation waste from the SDA will not exceed the site-specific performance assessment and therefore, by definition, will not increase risks beyond what has been proposed for the disposal sites at closure of the facility.

2.1 Exposure Scenarios

Both chemical and radiological constituents must come into contact with receptors through complete exposure pathways to create a potential for risk or hazard. Figures 2-1, 2-2, and 2-3 present the conceptual site model for the project and summarize the primary sources, release mechanisms, and exposure pathways that are relevant under all or any one of the remedial modules. The conceptual site model indicates which module may have a probability of exposing either a remediation worker, collocated worker or a member of the public to risk from radiation, chemical exposure or injuries, and fatalities from accidents. The subsections that follow address each aspect of the conceptual site model.

2.1.1 Radiological Inventory and Selection of Chemical Contaminants of Concern

2.1.1.1 **Radiological Waste Sources.** From the conceptual site model, it was determined that radiological sources of concern may be encountered in all the modules. The inventory from each of these sources is described below.

The radionuclide inventories were only used in the analysis of doses and cancer risks to the collocated worker and the public. Worker radiation exposures and cancer risks for retrieval enclosure activities were assumed to be at the administrative dose limit of 600 mrem/yr (i.e., 0.3 mrem/hr based on a 2,000-hour work year) for each worker inside the retrieval enclosure. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure. The maximally exposed individual (MEI) cancer risk for the worker was calculated based on the calculated dose rate of 2,000 hours of exposure per year, a dose-to-risk conversion factor of 8.00E-04 cancers/rem, and are for a specific assemble alternative.

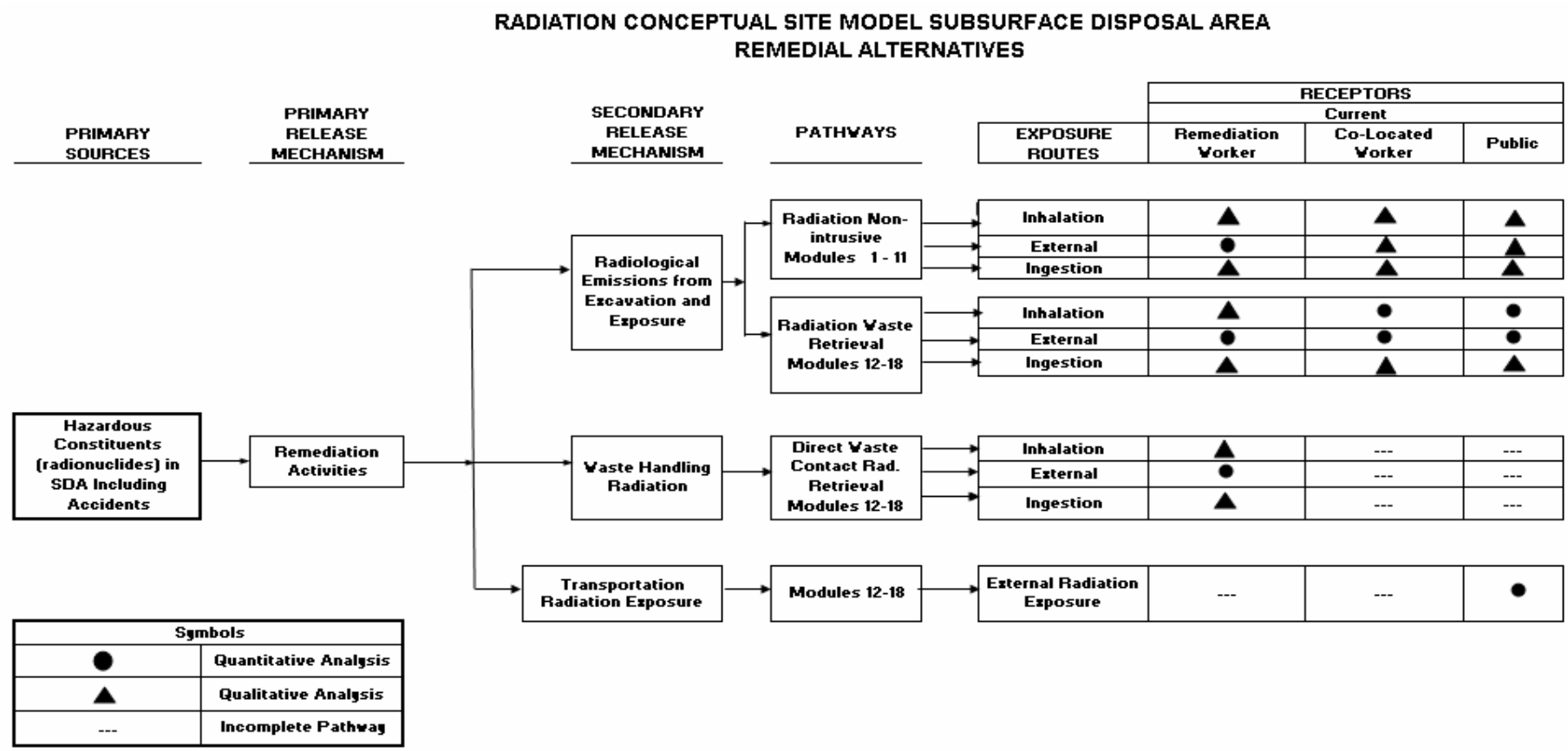

Figure 2-1. Radiological conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex.

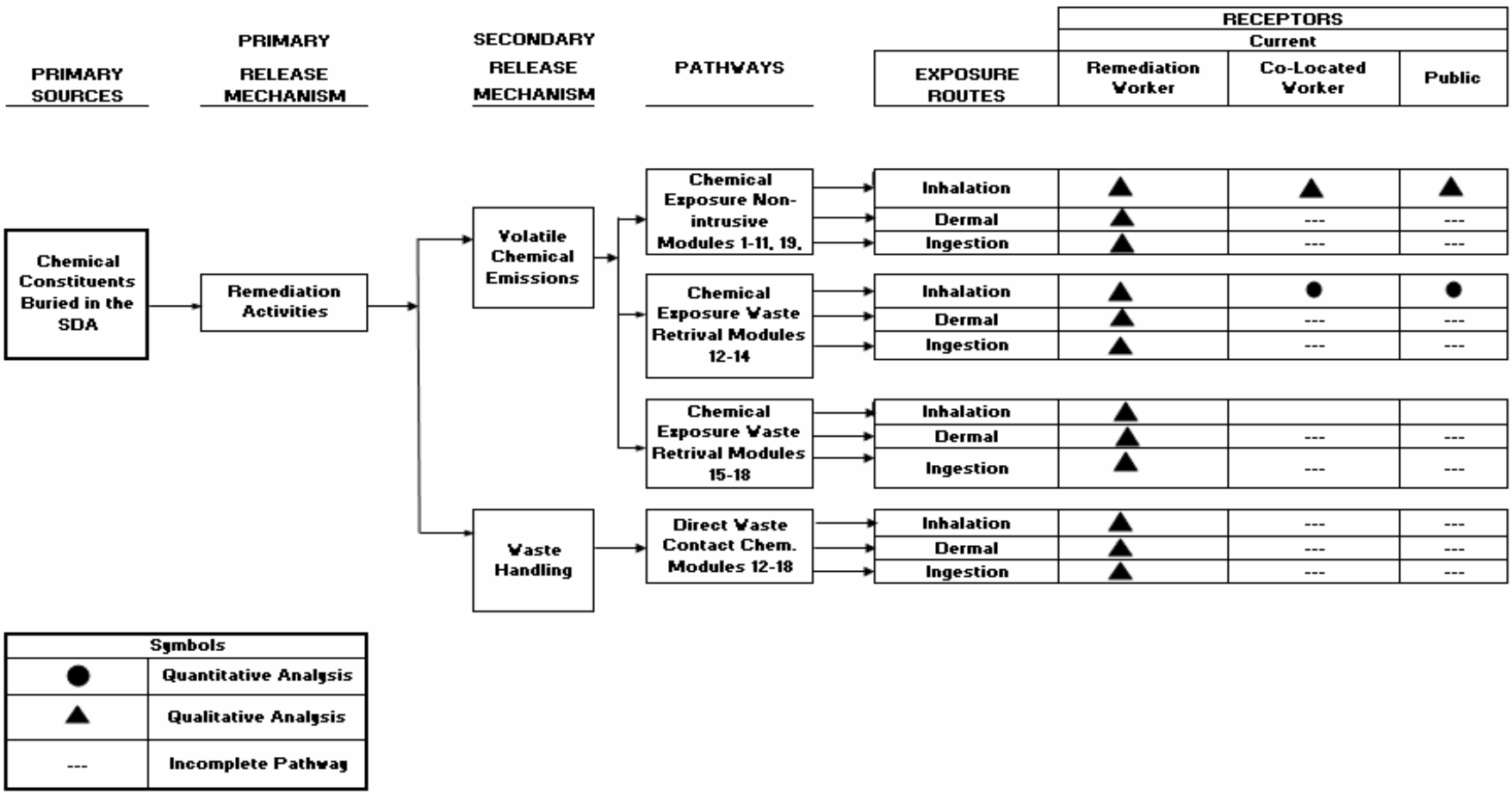

Figure 2-2. Chemical conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex.

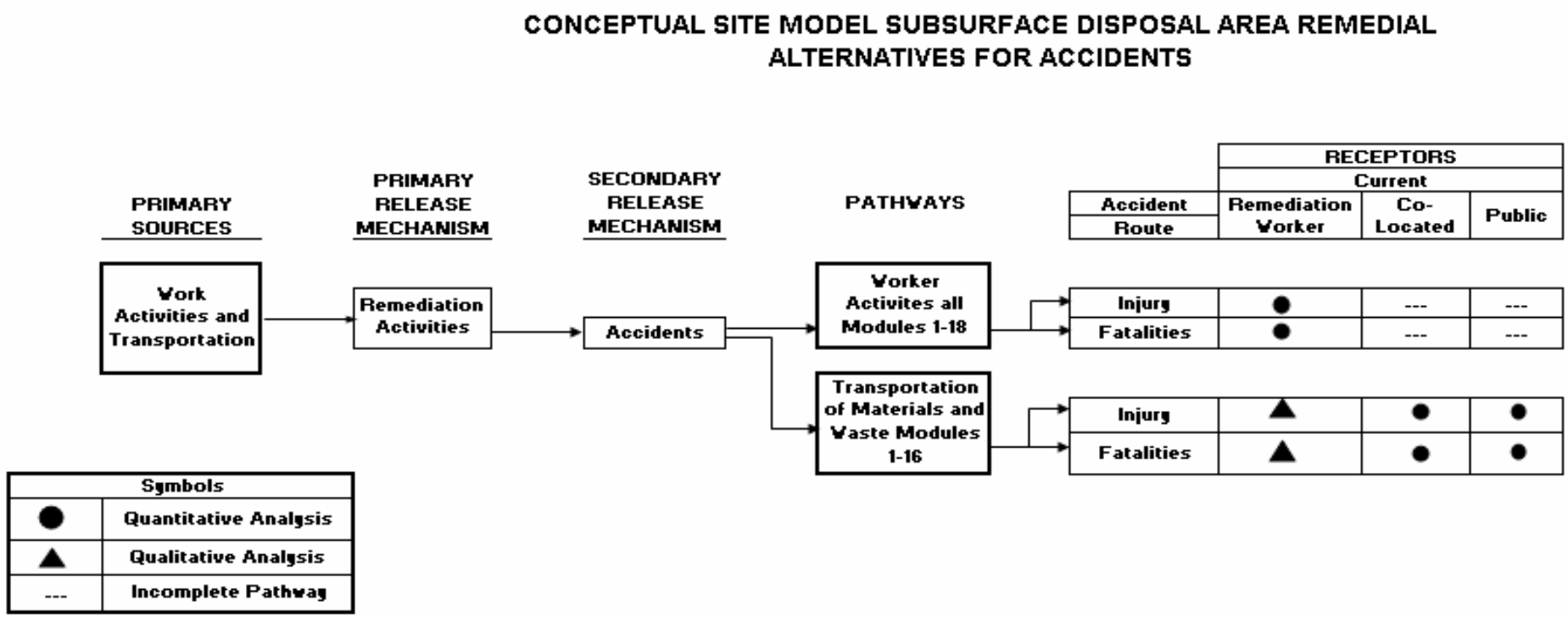

Figure 2-3. Conceptual site model for the short-term risk assessment for the Subsurface Disposal Area at the Radioactive Waste Management Complex.

Workers outside the retrieval enclosures involved in nonwaste retrieval activities were assigned a dose rate of 0.03 mrem/hr based on the Accelerated Retrieval Project area thermoluminescent dosimeter measurements provided in Appendix D, Table D-1. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure. The MEI cancer risk for the worker was calculated based on the calculated dose rate of 2,000 hours of exposure per year, a dose-to-risk conversion factor of 8.00E-04 cancers/rem, and the project duration.

The MEI worker cancer risk for nonwaste retrieval activities is based on a maximum potential dose. The average dose received by the worker population is expected to be less than for the MEI worker risk. The purpose of the short-term risk assessment is to provide a cancer risk for a comparative analysis between alternatives. As such, the MEI cancer risks must be interpreted as the maximum potential risk for a maximally exposed individual and not as a general cancer risk among all workers.

2.1.1.2 Radiological Inventory for Nonintrusive Modules (Modules 1-11 and 19)—The nonintrusive modules (1–11, 19, and 20) will not generate airborne radionuclide material. Therefore, specific radionuclide inventory and material-at-risk calculations were not evaluated for these alternative modules. A complete description of these modules is given in Section 1.4 above. Worker risks were evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr to the worker. This exposure rate was based on area thermoluminescent dosimetry/dosimeter (TLD) exposure rates measured outside retrieval enclosures during the Accelerated Retrieval Project (ARP) project. A control TLD level of 0.01 mrem/hr was subtracted from the average ARP project TLDs. A complete list of the reported TLD exposure rates is presented in Appendix D. This calculation encompasses all of the anticipated exposure pathways to the worker.

2.1.1.3 Radionuclide Inventory for Retrieval Modules 12 and 13—The inventories presented in the short-term risk assessment were based on the waste types targeted for retrieval provided by CWI. However, a nontransuranic (non-TRU) component was added to the two-acre and four-acre inventories (i.e., fission and activation products) to ensure that the cancer risks were not underestimated for the external exposure pathway. The non-transuranic inventory was added by adjusting the volume of the full RTD non-transuranic material to the retrieval volumes for the two-acre and four-acre alternatives. The total radionuclide inventory for those nuclides that comprise the majority of the potential dose is provided in the Section 2 radionuclide inventory tables. The radionuclide inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1988 and 1993). The inventory screening tables are provided in Appendix D. Additional radionuclides that did not pass the screening were added to the inventory tables for analysis to ensure that the external pathway was not underestimated. However, these additional radionuclides did not result in significant dose or cancer risk contributions in the analyses. The main contributors to the cancer risks are the actinides via the inhalation pathway.

2.1.1.3.1 Radionuclide Inventory for Two-Acre Excavation (Module 12) —The radionuclide inventory for the two-acre excavation (Module 12) was based on the information in engineering design file (EDF)-4591, "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4." This EDF provides normalized inventories per drum for each waste category included n the two-acre excavation. The waste categories to be retrieved include Series 741 sludge, Series 742 sludge, Series 743 sludge, filter waste, graphite waste, and roaster oxide waste.

EDF-4591 relied on information from EDF-3374, "Radioassay Data Collected During 3,100 Cubic Meter Project," which documents the data obtained from the assay of thousands of waste drums of various waste types for the 3,100 Cubic Meter Project from 1997 through 2002. The data from EDF-3374 were generated during the late 1970s and 1980s. EDF-3374 developed an average mass per drum for a specific radionuclide based on a fraction of the total number of drums assayed in that waste category. EDF-4591 extrapolated this data and applied it to the total number of drums in each particular waste

category. This information was used to obtain the average radionuclide for each waste category on a volume basis. The waste data from EDF-3374 is reported as being decayed to the midpoint of retrieval in 2010.

EDF-4591 also relied on information from *Content Code Assessments for INEL Contact-Handled Stored Transuranic Wastes* (Clements 1982). This report documents the assayed contents of waste drums generated and stored between 1970 and 1981, as reported by the generator. Clements' data include the average mass per container for each radionuclide assayed at the time of shipment, typically from weapons-grade plutonium and americium-241.

The radionuclide inventories, listed by waste category, are provided in Appendix D for the two-acre excavation module. These inventories are based on the average activity per drum obtained from EDF-4591 and the anticipated volume of waste to be excavated as provided in Table 2-1. The total radionuclide inventory for those nuclides that comprise the majority of the potential dose is provided in Table 2-2. The radionuclide inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1988 and 1993). The radionuclide inventory screening tables are provided in Appendix D.

Table 2-1. Two-acre retrieval waste types and volumes.

Waste Type	Waste Volume (ft^3)	Packaged Drum Equivalents
Series 741 sludge	30,739	8,077
Series 742 sludge	14,593	3,835
Series 743 sludge	29,991	7881
Filter waste	23,336	6,132
Graphite waste	7,036	1,849
Roaster oxide waste	1,829	481

Table 2-2. Two-acre radionuclide inventory.

Nuclide	Ci
Am-241	3.48E+04
Ce-144	3.15E+01
Co-58	2.36E+00
Co-60	5.85E+03
Cs-137	1.77E+02
Ba-137m	1.77E+02
Mn-54	5.99E+00
Np-237	2.76E-01
Pa-234m	2.26E+01
Pu-238	1.21E+02
Pu-239	4.10E+03
Pu-240	9.19E+02
Pu-241	3.60E+03
Sr-90	1.09E+02
Y-90	1.09E+02

2.1.1.3.2 Radionuclide Inventory for Four-Acre Excavation (Module 13) **—**The radionuclide inventory for the four-acre excavation was also based on information in EDF-4591, "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4." The same methodology described previously for the two-acre retrieval option was used for the four-acre retrieval option.

The radionuclide inventories, listed by waste category, are provided in Appendix D for the four-acre retrieval module. These inventories are based on the average activity per drum obtained from EDF-4591 and the anticipated volume of waste to be excavated as provided in Table 2-3. The total radionuclide inventory for those nuclides that compose the majority of the potential dose is provided in Table 2-4. The radionuclide inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993). The radionuclide inventory screening tables are provided in Appendix D.

Table 2-3. Four-acre retrieval waste types and volumes.

Waste Type	Waste Volume (ft^3)	Packaged Drum Equivalents
Series 741 sludge	35,201	9,250
Series 742 sludge waste	20,486	5,383
Series 743 sludge	33,875	8,901
Filter waste	34,581	9,087
Graphite waste	11,086	2,913
Roaster oxide waste	2,559	672

Table 2-4. Four-acre radionuclide inventory.

Nuclide	Ci
Am-241	5.85E+04
Ce-144	4.63E+01
Co-58	3.48E+00
Co-60	8.61E+03
Cs-137	2.60E+02
Ba-137m	2.60E+02
Mn-54	8.82E+00
Np-237	4.45E-01
Pa-234m	3.23E+01
Pu-238	1.93E+02
Pu-239	6.51E+03
Pu-240	1.46E+03
Pu-241	5.89E+03
Sr-90	1.60E+02
Y-90	1.60E+02

2.1.1.4 Radionuclide Inventory for Full Excavation (Module 14)**—**The radionuclide inventory for the full excavation was also based on the information provided in EDF-4591, "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4," as described in the previous sections.

EDF-4591 does not provide information for waste categories designated as (1) other transuranic waste, (2) other nontransuranic waste, and (3) remote-handled waste. The radionuclide inventory for these waste categories was obtained from SDA WILD database (McKenzie et al. 2005). The inventories for these waste categories were based on disposal records and were not decayed because the disposal time for each waste category was unknown.

The radionuclide inventories, listed by waste category, are provided in Appendix D for the full RTD (Module 14). These inventories, other than the three types of waste listed previously, are based on the average activity per drum obtained from EDF-4591, decayed to 2010, and the anticipated volume of waste to be excavated as provided in Table 2-5. The total radionuclide inventory for those nuclides that compose the majority of the potential dose is provided in Table 2-6. The radionuclide inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993). The radionuclide inventory screening tables are provided in Appendix D.

Table 2-5. Full RTD waste types and volumes.

Waste Type	Source Volume (ft^3)	Packaged Drum Equivalents
Series 741 sludge waste	64,141	14,412
Series 742 sludge waste	55,302	12,426
Series 743 sludge waste	63,756	14,325
Filter waste	79,764	17,922
Graphite waste	34,612	7,777
Roaster oxide waste	166,041	37,307

Table 2-6. Full RTD radionuclide inventory.

Nuclide	Ci
Am-241	2.55E+05
Ce-144	5.59E+04
Co-58	2.32E+03
Co-60	4.84E+06
Cs-137	1.71E+05
Ba-137m	1.71E+05
Ni-63	8.86E+05
Mn-54	2.40E+03
Pu-238	1.75E+03
Pu-239	5.73E+04
Pu-240	1.31E+04
Pu-241	2.79E+05
Sr-90	1.33E+05
Y-90	1.33E+05
U-238	1.86E+03

2.1.1.4.1 Radionuclide Inventory for Pad A Retrieval (Modules 15, 16, 17, and 18)—The radionuclide inventory for Pad A was obtained from the SDA WILD databases. The inventories for these waste categories were based on disposal records and were previously decayed to 2010. The radionuclide inventory for the PAD A retrieval modules is provided in Appendix D. The total radionuclide inventory for those nuclides that compose the majority of the potential dose is provided in Table 2-7. The radionuclide inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1988 and 1993). The radionuclide inventory screening table for Pad A is provided in Appendix D.

Table 2-7. Pad A radionuclide inventory.

Nuclide	Ci
Am-241	1.15E+01
Co-60	8.11E-03
Cs-137	4.23E-01
Ba-137m	4.23E-01
Eu-152	2.15E-05
Eu-154	2.24E-03
Pu-238	5.54E-01
Pu-239	1.80E+01
Pu-240	3.44E+00
Pu-241	1.85E+00
Pu-242	2.50E-02
Sr-90	3.05E-01
Y-90	3.06E-01
U-234	4.23E+00
U-235	2.99E-01
U-236	1.42E-02
U-238	2.47E+01

2.1.1.5 Chemical Waste Sources and Selection of Contaminants of Concern. Each proposed remediation module varies in terms of its relevant constituent fate and transport pathways. The chemicals of concern are contained within waste drums that have been buried in trenches or cells throughout the SDA. The locations of the trenches and cells are shown on Figure 1-4.

SDA chemical inventories in EDF-3543 are used to establish the concentrations of chemicals at the project site. This EDF is augmented by using the emissions calculation in EDF-5942. Other existing engineering design files were also reviewed to establish a list of constituents that are known to exist or may reasonably be expected to exist at the SDA.

2.1.1.5.1 Organic Compounds of Interest—Section 5 of the draft *Remedial Investigation Baseline Risk Assessment* (Holdren et

al. 2006) provides a description of the organic chemicals expected to be present in any major concentration in the SDA. By evaluating these compounds with respect to their potential for release (volatility), their relative mass in the SDA, and the relative risk factors for each chemical (toxicity), it was determined that the compounds listed in Table 2-8 would be considered for quantitative evaluation in the risk assessment. Table 2-8 also lists the mass of each compound expected to be encountered during the two-acre, four-acre, and full retrieval processes. The values in Table 2-8 were based on the initial inventory and take into account the 50% loss expected due to volatilization (Sondrup et al. 2004). All of the chemicals listed in Table 2-8 are known to be present in the Rocky Flats Plant waste targeted for retrieval during the two-acre, four-acre, and full retrieval modules and, as such, have a high potential for release. A description of the method used to determine the mass of each compound is given in Tables B1–B3 in Appendix B.

Table 2-8. Volatile organic compounds of interest used for the risk assessment.

Compound	Chemical Formula	Expected Mass Two-Acre Retrieval (g)	Expected Mass Four-Acre Retrieval (g)	Expected Mass Full Retrieval (g)
Carbon tetrachloride	CCl_4	1.85E+08	2.09E+08	3.63E+08
Tetrachloroethylene	C_2Cl_4	2.32E+07	2.62E+07	4.56E+07
Trichloroethylene	C_2HCl_3	2.32E+07	2.62E+07	4.56E+07
Chloroform	$CHCl_3$	3.32E+06	3.75E+06	6.52E+06
Methylene chloride	CH_2Cl_2	3.32E+06	3.75E+06	6.52E+06

Other organic compounds considered but not included in the rigorous calculations are listed in Table 2-9. While all of these compounds are known to be present in the SDA, their relative toxicity is such that they would not contribute to the overall effect of this risk assessment when compared to the risk associated with the compounds already identified in Table 2-8.

Table 2-9. Volatile organic compounds not included in risk assessment.

Compound	Chemical Formula
1,1,1 Trichloroethane	$C_2H_3Cl_3$
Methyl isobutyl ketone	$C_6H_{12}O$
Xylene	$C_{24}H_{30}$
1,1,2-Trichloro-1,2,2-trifluoroethane	$C_2Cl_3F_3$

2.1.1.5.2 Inorganic Compounds of Interest—Table 2-10 lists some of the known toxic inorganic compounds in the SDA. It is expected that all of the compounds listed in Table 2-10 have the potential to be present during any of the RTD and Pad A retrieval processes presented in Modules 12–18. Due to the lack of specific concentrations and locations of the constituents listed in the Table 2-10, no quantitative release/risk assessments can be made. A qualitative estimate of the risks of beryllium and asbestos was made. In addition while nitrate salts and uranium are known to be present in the RFP Series 745 evaporator salts they were not considered as a likely risk potential since they only present a dermal or oral hazard, which will be negated by the PPE of the remediation workers and will not be of consequence to co-located workers and the general public because of the release factor for particulates, the HEPA filtration, and the deposition of particles in the atmosphere before reaching another receptor.

Table 2-10. Possible inorganic toxic compounds of concern.

Compound	Estimated Mass[a] (g)	Chemical Form	Source
Beryllium	2.1E+07	Unknown	Reactor Technology Complex, Test Area North
Asbestos	4.6E+07	Unknown	Idaho Nuclear Technology and Engineering Center, Test Reactor Area
Chromium	1.8E-06	Unknown	RFP 745 evaporator salts
Lead	6.7E+08	Elemental	10% Rocky Flats, 90% INL Site
Nitrate	2.4E+08	Salt	RFP 745 evaporator salts
Uranium	3.4E+06	Unknown	RFP 745 evaporator salts

[a] WILD database (McKenzie et al. 2005)

The quantitative risk assessment assumes that the compounds listed in Table 2-10 are present in either the solid or particulate form. Based on 40 CRF 61 Appendix D, the release factor for these compounds into the retrieval enclosure would be 1E-03 to 1E-06 of original inventory. In addition, any of the material that is released into the enclosure would further be reduced before release to the environment by the high-efficiency particulate air filtration system of each of the enclosures. Using a 0.5% leak rate from the filters and the enclosure an overall release of 5E-6 to 5E-9 of the initial material is assumed.

To determine the qualitative risk for the compounds in Table 2-10, a comparison was made between carbon tetrachloride (the major volatile organic compound), asbestos, and beryllium using the Idaho Acceptable Ambient Concentrations for Carcinogens (AACC) as a basis (lead does not have an AACC value and was not compared). For this comparison it was assumed that both beryllium and asbestos were present in the more releasable particulate form. This comparison is shown in Table 2-11 below.

Table 2-11. Comparison of AACC concentrations between CCl_4 and selected inorganic compounds.

Compound of Interest	Relative Release Factor Based on Unity	Idaho AACC (ug/m^3)	Relative Qualitative Risk
Carbon tetrachloride	1.0	6.7E-02	14.4E+01
Beryllium (particulate)	5.0E-06	4.2E-03	1.2E-03
Asbestos (friable)	5.0E-06	4.0E-06	1.2E+01
Chromium (VI)	5E-06	8.3E-05	6.0E-02

From Table 2-11 it can be concluded that beryllium and chromium pose an insignificant risk compared to that associated with carbon tetrachloride and while risk from asbestos is low it should be considered if further information regarding exact location and concentration becomes available.

2.1.2 Radiological and Chemical Release Mechanisms

2.1.2.1 Radionuclide Release Mechanisms. Radionuclide emissions from the retrieval enclosures were based on the total radionuclide inventory to be excavated, duration of the excavation, airborne release fraction, high-efficiency particulate air (HEPA) filtration, and HEPA by-pass loss rates.

The radionuclides were assumed to be released over the duration of each module. In all cases, the duration of the modules of interest (Modules 12–18) was at least one year. An airborne release fraction for particulate matter based on 40 CFR 61, Appendix D (i.e., 1.0E-03) was applied to the inventory to determine the radionuclide release rate into the retrieval enclosure.

The majority of the radionuclide releases into the retrieval enclosure are assumed to exit through a HEPA-filtered ventilation system. However, EDF-4825 estimated a leakage rate from the retrieval enclosure at 0.5%, which exits the enclosure without HEPA filtration. These factors were applied to the radionuclide release calculations by assuming that 99.5% of the emissions exited through the HEPA filtration system and that 0.5% of the emissions exited without HEPA filtration. The HEPA filtration system was assumed to be 99.97% effective, resulting in a release fraction of 3E-04 for the HEPA system. The remainder of the radionuclide releases from the retrieval enclosure were assumed to be released unabated.

The radionuclide release rates for each retrieval option are provided in Appendix D.

2.1.2.2 Chemical Release Mechanisms. The potential for release of chemicals into the environment strongly depends upon the nature of the remediation activities. A list and brief description of the remediation modules is provided in Section 1.2, and a description of each remediation module is provided in Appendix A. Only the RTD modules (12–14) and the Pad A retrieval modules (15–18) provide for the retrieval of buried waste within the trenches, vaults, and pits. The remaining modules do not have complete pathways for chemical waste to reach the surface and be dispersed through the environment. In these modules, the available information indicates that the potential for exposure to chemicals is limited. Although the retrieval of Pad A will allow waste to reach the surface and be dispersed into the environment, the available quantifiable information regarding the location, chemical form, and volume of the waste that was buried there is limited. Therefore, a quantitative chemical risk analysis was not performed for Pad A. Quantitative risks are determined only for the RTD modules (12–14).

Upon excavation and removal, the content of the drums may be accidentally spilled. Some drums may have released chemicals into subsurface soils prior to excavation. As the soils in the SDA are excavated, the chemical constituents in the waste may be released to the environment. The RTD excavations are to be conducted inside tent enclosures; therefore, there will be no appreciable off-Site transport of particulate matter. Exposure to the collocated workers and the off-Site population is restricted to volatile organic chemicals. As stated in the draft *Remedial Investigation Baseline Risk Assessment* (Holdren et al. 2006), it is expected that only 50% of the original inventory of the volatile organic compounds remains in the buried Rocky Flats Plant waste. This reduction in the inventory was used as the basis for the organic inventory as stated in Table 2-8. It was assumed that once the retrieval process began, a very conservative estimate of the volatile organic release would be used to calculate risks to the collocated workers and members of the public. Therefore, the chemical release mechanism used assumed that 100% of the volatiles were released at a constant rate during each of the retrieval modules. This release rate was then combined using the chemical release model described in Section 2.2 to determine releases.

2.1.3 Exposure Pathways and Receptors

2.1.3.1 Radiological Exposure

2.1.3.1.1 Remediation Worker Radiological Receptor—Radiation exposures to workers are assumed to occur during remediation activities. The worker doses for retrieval enclosure activities were assumed to be at the administrative dose limit of 600 mrem/yr (i.e., 0.3 mrem/hr based on a 2,000-hour work year) for each worker. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure.

Workers outside the retrieval enclosures involved in nonwaste retrieval activities were assigned a dose rate of 0.03 mrem/hr based on the Accelerated Retrieval Project area thermoluminescent dosimeter measurements listed in Appendix D. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure.

2.1.3.1.2 Collocated Worker Radiological Receptors—Radionuclide releases during remediation activities were assumed to impact two receptors: collocated workers and members of the public. The collocated worker was assumed to be located at the point of the highest modeled dose using the CAP88-PC atmospheric dispersion and dose computer code (EPA 1990). The worker was assumed to be exposed for 2,000 hours per year to releases from the retrieval enclosures. The collocated worker was assumed to be exposed to airborne radioactive contaminants through the inhalation, air immersion, and external ground deposition exposure.

2.1.3.1.3 Off-Site/Public Radiological Receptors—The off-Site public member was assumed to be located at the southern Site boundary, which is 5,900 m from remedial activities. The member of the public was assumed to be exposed for 24 hours a day and 350 days per year (8,400 hours per year). The member of the public was assumed to be located at the point of the highest modeled dose using the CAP88-PC atmospheric dispersion and dose computer code (EPA 1990). The member of the public was assumed to be exposed to airborne radioactive contaminants through the inhalation and external ground deposition exposure.

2.1.3.2 Chemical Exposure

2.1.3.2.1 Remediation Worker Chemical Exposure—Remediation workers will be located on-Site during remediation activities. Remediation workers may be exposed to chemicals in the soil or air. However, this risk assessment assumes that occupational exposures during remediation will be controlled by site-specific health and safety plans. Because on-Site remediation workers will be equipped with the appropriate personal protective equipment and are required to use appropriate engineering controls, their risk should be managed at an acceptable level for each remediation module. Therefore, risks to remediation workers are not quantitatively evaluated.

2.1.3.2.2 Collocated Workers Chemical Exposure—Chemicals released during remediation activities may contact both collocated workers, as well as members of the pubic. The conceptual site model identifies receptors that represent a range of reasonable maximum exposures. The identification of these reasonable maximum exposure scenarios precludes the need to assess risks for all possible scenarios under which other people may be exposed.

The collocated workers in the administrative and operations areas of Waste Area Group 7 are distinguished by the following features:

- Exposure via air (volatiles assessed quantitatively) and dust (assessed qualitatively)
- Potentially exposed for a normal, full-time work schedule (10 hours/day, 4 days/week, and 200 days per year) throughout the duration of the remediation effort
- Exposure concerns encompass both acute and chronic hazards
- The collocated worker is located at the point of maximum concentration.

2.1.3.2.3 Off-Site Receptors Chemical Exposure—Off-Site receptors consist of people who may be traveling or stopping near the remediation area and those living at the Site boundary. Those traveling or stopping include people who may visit Experimental Breeder Reactor I (a historic monument) or members of the public who may stop at the rest area on U.S. Highway 20/26 near where the Big Lost River intersects the highway. Off-Site receptors are distinguished by the following features:

- Exposure via air (volatiles assessed quantitatively) and dust (assessed qualitatively)
- Exposure concerns encompass both acute and chronic hazards.

The general public is represented by a diverse range of potential exposure conditions. Two exposure scenarios were developed for use across the various remediation modules. For the acute exposure scenario a member of the public was assumed to be present at Experimental Breeder Reactor I (EBR-I) while the peak one-hr exposure concentration was being released. For the chronic noncarcenogenic and carcinogenic exposure scenarios the maximum exposed individual was assumed to be an adult living at the southern Site boundary 5,600 m from the SDA. The exposure assessment calculations are provided in Appendix B.

2.2 Modeling Methodology

2.2.1 Radiological Release Modeling

The CAP88-PC computer assessment code (EPA 1990) was used to determine the effective dose equivalent (in mrem/yr) from radionuclide emissions from each module. Emissions were modeled from a 29-ft stack with a diameter of 2.7 ft (DWG-631026) and a flow rate of 10,000 acfm. Although there are two stacks with different flow rates, it cannot be determined through the available data which stack will have the greatest rate of release of radiological materials. This stack was chosen for all modeling in the radiological risk assessment because it yields the highest ground-level concentrations and thus will produce conservative results.

The meteorological input file was a ten-year joint frequency file developed from the 1994–2003, 15-m high Central Facilities Area meteorological tower data by the National Oceanic and Atmospheric Administration office in Idaho Falls, Idaho. Wind data from Central Facilities Area were used because a reliable long-term data set does not exist for the Radioactive Waste Management Complex. The National Oceanic and Atmospheric Administration data incorporate calm hours into the lowest wind-speed class.

2.2.2 Chemical Release Modeling

Air modeling for the risk assessment was performed using the Environmental Protection Agency-approved SCREEN 3 Version 96043 model to determine the ambient air concentrations of volatile chemicals at probable human receptor locations. Characteristics of the emission sources associated with the site activities, meteorological data, topography, and appropriate receptor locations were entered into the model to generate a conservative, yet realistic, ambient air concentration to the exposed public and collocated workers.

SCREEN 3 requires several inputs for control options for release parameters, meteorological conditions, and topography. Data from the preliminary engineering design were used where available; otherwise, conservative assumptions were made for the input data. Two types of stacks were modeled, one for the larger retrieval building and another for the smaller portable tents. The larger retrieval building has a stack diameter of 2.7 ft, stack height of 29 ft, and a flow rate of 20,000 acfm (EDF-4692). The smaller, portable tents have a stack diameter of 2.7 ft, a stack height of 29 ft, and a flow rate of 10,000 acfm. The stack and ambient air temperature were set at 293 K (68ºF) for both stacks. Meteorological conditions, including wind speed, mixing height, direction, and atmospheric stability, were set to the default, which calculates the worst-case scenario for downwind concentrations. By setting the ambient air and off-gas release temperatures the same, the plume rise is limited, making it a conservative assumption. Building downwash calculations were not considered in the model run because it is expected that the design of the stack will meet good engineering practices, which eliminates cavitation from building downwash. Also, eliminating building downwash keeps the downwind concentrations conservative. No terrain elevations were input because the facility and surrounding area is relatively flat, with little or no changes in elevation for several thousand meters in each direction. The receptor height was set to 1 meter to approximate the air intake of an adult or child at the receptor location.

2.3 Toxicity Assessment

The collocated worker receptor is an adult worker in the administrative and operations areas of Waste Area Group 7. The maximum public receptor for the short-term risk assessment is a visitor to Experimental Breeder Reactor I. These receptors may be exposed under both acute and chronic exposures. The toxicity factors used must be consistent with the duration of exposure. For acute exposures, one important distinction is that carcinogenic effects are not considered. Rather, aspects of toxicity that are known to have immediate and potentially irreversible effects with short-term exposure are emphasized in the development of acute toxicity factors.

Risks from exposure to noncarcinogens may be evaluated using acute and subchronic reference doses (both oral and inhaled). Acute exposure is defined as up to two weeks in duration, and subchronic exposure is defined as two weeks to seven years in duration. Chronic exposure generally assumes lifetime exposure (defined as 30 years for noncarcinogens and 70 years for carcinogens). However, there is little guidance on the application of chronic toxicity factors for less than lifetime exposure durations.

The exposure durations for the remedial alternatives are: 3.5 years for two-acre excavation, 6 years for four-acre excavation, and 25 years for full excavation. To minimize report complexity and meet the objective of providing comparable risks across remediation alternatives, this assessment applies both acute and chronic toxicity factors.

Risks from exposure to carcinogens will be evaluated using inhalation reference doses and inhalation slope factors established by the Environmental Protection Agency. Where values were not available from the Environmental Protection Agency, toxicity values were obtained from the U.S. Department of Energy (DOE). The toxicity values selected are presented in Table 2-12.

Table 2-12. Reference doses and slope factors for compounds of interest.

Parameter	Inhalation Reference Dose (µg/kg-dy)	Inhalation Slope Factor $(ug/kg\text{-}dy)^{-1}$
Carbon tetrachloride	7.00E-01[a]	5.25E-05[d]
Chloroform	9.00E+00[a]	8.05E-05[d]
Methylene chloride	8.57E+02[b]	1.65E-06[d]
Tetrachloroethylene	1.71E+02[c]	2.07E-05[e]
Trichloroethylene	1.14E+01[f]	4.0E-04[f]

a. EPA Integrated Risk Information System. Reference doses used because inhalation reference doses were not available.
b. EPA Health Effects Assessment Summary Table values obtained from DOE Risk Assessment Program.
c. Provisional value that should be used for DOE-ORR projects, established by the DOE Risk Assessment Program.
d. EPA Integrated Risk Information System. The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
e. Provisional slope factor per California EPA and EPA Region 9, as published by the DOE Risk Information System.
f. *Trichloroethylene Health Risk Assessment: Synthesis and Characterization* (External Review Draft). USEPA EPA/600/P-01/002A, 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC, *EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX select? Select =nrad*).

2.3.1 Chronic Reference Doses

All toxic effects other than cancer are evaluated using a reference dose approach. Unlike the cancer slope factor, for the reference dose there is a threshold concentration below which no toxic effects are known to occur. Reference doses are developed based on both acute and chronic exposure. Generally, as the exposure period increases, the value of the chronic reference dose decreases relative to the acute reference dose. Reference doses are intended to be protective of the most sensitive receptor.

2.3.2 Cancer Slope Factors

A cancer slope factor is the upper-bound estimate of the probability of a cancer response per unit intake of a constituent averaged over a lifetime. It is derived based on the relationship of exposure (dose) to cancer rates (response) in laboratory studies using animals or epidemiological studies of human exposure. Various statistical regression methods are used to evaluate the dose-versus-cancer-rate data and calculate the slope factor. Once established, the slope factors are used to extrapolate the observations in experimental studies to lower levels of exposure typically observed in environmental investigations such as this one.

2.3.3 Acute Chemical Exposure

Short-term exposures to chemicals in air are evaluated using available standards. Using established guidance standards, a hierarchy of sources for selecting air standards can be used to assess acute risk to workers and the general population.

The Environmental Protection Agency suggests a method of using established exposure criteria to determine risk to the public from emissions (EPA 2005). As stated by the Agency:

> Acute inhalation exposure guidelines and criteria are (1) designed to protect a variety of exposure groups including occupational workers, and the general public, (2) based on varying exposure durations up to 24 hours in length, and (3) intended to protect against a

variety of toxicity endpoints ranging from discomfort or mild adverse health effects to serious, debilitating, and potentially life-threatening effects, up to and including death.

This document recommends using a hierarchy of established exposure criteria. They are presented in order of preference:

1. Cal/EPA Acute Reference Exposure Limit (RELs). An acute reference exposure limit represents the concentration in air at or below which no adverse health effects are anticipated in the general population, including sensitive individuals, for a specified exposure period.
2. Acute Inhalation Exposure Guidelines (AEGL-1). An acute inhalation exposure guideline value represents "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."
3. Level 1 Emergency Planning Guidelines (ERPG-1). A Level 1 emergency planning guideline value represents "the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor."
4. Temporary Emergency Exposure Limits (TEEL-1). A temporary emergency exposure limit value represents "the maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined odor."

The acute toxicity factors used in this assessment are shown in Table 2-12. A more detailed summary of available toxicity data is provided in Appendix B.

Table 2-12. Summary of acute toxicity factors.

Parameter	Acute Criteria ($\mu g/m^3$)	Average Time (hr)	Source[a]
Carbon tetrachloride	1.90E+03	7	Reference exposure limit
Chloroform	1.50E+02	7	Reference exposure limit
Methylene chloride	1.40E+04	1	Reference exposure limit
Tetrachloroethylene	2.37E+05	1	Acute inhalation exposure guideline
Trichloroethylene	7.10E+05	1	Acute inhalation exposure guideline

a. Highest one-hour modeled concentration for worst-case receptor, includes consideration of upset conditions.

In order of preference selected:

- "Reference exposure limit (REL) Air Toxics Hot Spots Program Risk Assessment Guidelines," Part 1, *The Determination of Acute Reference Exposure Levels for Airborne Toxicants*, California EPA, 1999.
- *Acute Inhalation Exposure Guidelines (AEGL-1) Level 1 Acute Exposure Guidelines*, National Advisory Committee, 1997.
- *Level 1 Emergency Planning Guidelines (ERPG-1) Level 1 Emergency Response Planning Guidelines Levels*, Subcommittee on Consequence Assessment and Protective Guidelines, 1997.
- *Temporary Emergency Exposure Limits (TEEL-1) Level 1 Temporary Emergency Exposure Limits*, Subcommittee on Consequence Assessment and Protective Guidelines, 1997.

2.4 Risk Characterization

This section of the report presents the methodology used to calculate risks.

2.4.1 Radiological Risk

Estimating the potential risk from radiation exposures requires applying dose-to-risk conversion factors to an estimate of dose. It is common practice to multiply the calculated total effective dose equivalent by a risk-to-dose factor. The most recent guidance on dose-to-risk conversion factors is provided by the Interagency Steering Committee on Radiation Standards, which issued a technical report entitled *A Method for Estimating Radiation Risk from TEDE* (ISCORS 2002). The total effective dose equivalent-to-risk factor provided by ISCORS (2002) in Technical Report 1 is based upon a static population with characteristics consistent with the U.S. population. The ISCORS (2002) guidance recommends a conversion factor of 8E-04 cancers per rem for morbidity (incidence) when estimating risk from radiation exposure to members of the general public. Due to the uncertainties in the risk estimates, the public conversion factor of 8E-04 will also be applied to workers, as recommended by DOE guidance (DOE 2003).

ISCORS (2002) notes that the recommended risk coefficients used with the total effective dose equivalent dose estimates generally produce conservative radiation risk estimates. The approach of converting total effective dose equivalent to risk based on this conversion factor is considered appropriate due to the uncertainties in the risk estimates and the fact that the resulting risk estimates are only being used to compare remedial modules to each other (DOE 2002).

The MEI cancer risk (i.e., probability of cancer incidence for the person who receives the highest dose over the project duration) was determined as follows:

$$MEI\ cancer\ risk = (DR)(CRF)(PD) \tag{2-1}$$

where:

DR = MEI annual dose rate (rem/yr)

CRF = dose to cancer risk conversion factor (8.0E-04 cancers/rem)

PD = project duration (years).

2.4.1.1 Worker Radiological Risks. Radiation exposures to workers are assumed to occur during remediation activities. The worker doses for retrieval enclosure activities were assumed to be at the administrative dose limit of 600 mrem/yr (i.e., 0.3 mrem/hr based on a 2,000-hour work year) for each worker. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure. The MEI cancer risk for the worker was calculated based on the calculated dose rate, 2,000 hours of exposure per year, dose-to-risk conversion factor of 8.00E-04 cancers/rem, and the project duration.

Workers outside the retrieval enclosures involved in nonwaste retrieval activities were assigned a dose rate of 0.03 mrem/hr based on the Accelerated Retrieval Project area thermoluminescent dosimeter measurements provided in Appendix D. This dose rate includes all potential pathways, including inhalation, ingestion, and external exposure. The MEI cancer risk for the worker was calculated based on the calculated dose rate, 2,000 hours of exposure per year, dose-to-risk conversion factor of 8.00E-04 cancers/rem, and the project duration.

The MEI worker cancer risk for nonwaste retrieval activities is based on the maximum potential dose. The average dose received by the worker population is expected to be less than for the MEI worker risk. The purpose of the short-term risk assessment is to provide an estimate of cancer risk for a comparative analysis between the implementation of the alternatives. As such, the MEI cancer risks must be interpreted as an estimate of the maximum potential risk for a maximally exposed individual and not as a general cancer risk among all workers.

The MEI worker total cancer risk, for a given alternative, was determined by summing the alternative module cancer risks. This is a conservative estimate of the cancer risk for the alternative because the same worker may not be involved in all of the given alternative modules.

In all cases, the cancer risks presented are for an MEI worker. The MEI cancer risk may be the same for a given alternative module task and does not capture the total number of cancers expected in the worker population. Another measure of risk would be the total number of cancers within the worker population. The total number of cancers in the worker population can be determined by multiplying the MEI cancer risk for each alternative module by the number of workers involved in the work activity.

2.4.1.2 Collocated Worker Radiological Risks. The collocated worker doses were based on the results of the CAP88-PC atmospheric dispersion computer model (EPA 1990). Collocated worker doses were evaluated for the average annual releases from the retrieval operations. The collocated worker is an MEI. The MEI cancer risk for the MEI collocated worker was calculated based on the CAP88-PC dose rate (rem/yr), 2,000 hours of exposure per year, dose-to-risk conversion factor of 8.00E-04 cancers/rem, and the project duration (years). The MEI collocated worker total cancer risk, for a given alternative, was determined by summing the alternative module cancer risks.

2.4.1.3 Public Risks. The public receptor doses were also based on the results of the CAP88-PC atmospheric dispersion computer model. The public receptor doses were evaluated for the average annual releases from the retrieval operations. The MEI cancer risk for the MEI member of the public was calculated based on the CAP88-PC dose rate (rem/yr), 8,400 hours of exposure per year, dose-to-risk conversion factor of 8.00E-04 cancers/rem, and the project duration (years). The total cancer risk for a MEI member of the public, for a given alternative, was determined by summing the alternative module cancer risks.

2.4.1.4 Synergistic Effects. Risks from individual constituents are summed to determine the total risk. The total risk is provided as a measure of the potential synergistic effects resulting from exposure to multiple constituents. This approach is believed to be conservative, as indicated by a recent Presidential/Congressional Commission on Risk Assessment and Risk Management (1997):

> The combined effects of exposure to constituents in a mixture are determined by how individual components of the mixture affect the biological processes involved in toxicity. Components of a mixture can affect biological processes in many ways. For example, anything that affects the absorption, distribution, metabolism, or elimination of a constituent will affect the amount of that constituent that is available to react with DNA or other cellular targets. Because interactions leading to synergism or antagonism are the result of reactions of many molecules at many cellular sites, a mathematical dose-response model of a synergistic or antagonistic response that depends on such mechanisms is most likely nonlinear at low doses. Such logic strongly suggests that any disease process that depends on such interactions is only marginally important at low exposure levels. Only at high doses of one or more mixture components—such as cigarette smoke, alcohol, and some substances in occupational exposures—is the combined effect likely to be detectably greater than the sum of the individual effects.

2.4.2 Chemical Risks

2.4.2.1 Chemical Carcinogenic Risk. The mathematical approach used to quantify risks from chronic exposure to carcinogens is different from the approach used to quantify other types of hazards. For carcinogenic constituents, an estimated excess lifetime cancer risk is calculated using:

$$\text{Risk} = I \times SF \tag{2-2}$$

where:

I = chemical intake, the estimated exposure level in mg/kg/day averaged over a lifetime.

SF = slope factor, the upper bound estimate of the probability of a cancer response per unit intake of a constituent averaged over a lifetime in 1/(mg/kg/day).

2.4.2.2 Chemical Acute and Chronic Noncarcinogenic Hazards

The potential for adverse health effects from acute and chronic exposures to noncarcinogens is determined by comparing estimated intake values with reference doses, both expressed in units of mg/kg/day. The reference doses are threshold levels below which no adverse effects are expected to occur. This relationship is mathematically described as follows:

$$\text{Hazard quotient} = I/RfD \tag{2-3}$$

where:

I = intake value

RfD = reference dose.

If intake exceeds the reference dose, the hazard quotient will exceed 1.0, indicating a potential for adverse health effects. For simultaneous exposure to multiple constituents with similar toxic effects, a hazard index is calculated as the sum of constituent-specific hazard quotients. The hazard index is intended as an estimate of the synergistic effects from exposure to multiple constituents. Summing all hazard quotients provides a simple but likely overstated assessment of the potential synergistic hazards.

Noncancer hazard values are interpreted differently from cancer risk values. Noncancer hazards are based on threshold levels of exposure below which no adverse health effect is known to exist. This contrasts sharply with a cancer risk value, which is expressed as a probability. While cancer risk values are expressed on a linear scale that may be compared in quantitative terms, hazard quotients cannot. All hazard quotients less than 1 are equal because there is no toxic effect. Also, a hazard quotient of 2 does not imply twice as much toxicity as a hazard quotient of 1. The reference dose used to determine the hazard index (and hazard quotients) does not address the types of effects and the magnitude of the effects associated with exposure above the reference dose level.

2.5 Uncertainty Analysis

Uncertainty is inherent in every model input factor used in this and other risk assessments to varying degrees. Some elements of uncertainty cannot be addressed on a project-specific basis, while uncertainty for other variables can be reduced with increased information. These issues are addressed in the subsections that follow. Importantly, by adhering to an agency-approved methodology while accounting for site-specific factors where possible, the results of this assessment may be compared across the various proposed modules and alternatives. In this manner, this risk assessment is intended to provide a consistent basis for understanding risks and making decisions. Moreover, because the emphasis in this assessment is on the comparability of the risks across the different remediation modules, a detailed consideration of uncertainty and variability is less important than the consistent use of assumptions across the various remediation modules.

2.5.1 Uncertainty Associated with Emission Inventory

Substantial uncertainty is associated with estimating the concentrations of each contaminant and radionuclide that may be released during the remediation. For this risk assessment, the exact inventory of chemicals and radionuclides, their location, and the rate at which they will be released are generally unmeasured. Thus, determining a source term for use in dispersion modeling is difficult. The inventory was determined using process knowledge of the waste types and volumes at the SDA. Preliminary design estimates as to the rate of retrieval and emission estimates were used to approximate a source term.

The fate and transport of chemicals and radionuclides are approximated using Environmental Protection Agency guidance and approved screening-level modeling software. For chemicals, screening-level software is used to approximate a worst-case scenario using worst-case meteorological conditions. It assumes that the contaminants are not taken out of the air due to deposition from moisture or other natural causes. Thus, the highest possible downwind concentration is calculated, which is conservative because it is likely that the worst-case meteorological conditions will not frequently occur and that deposition will occur due to moisture and other forces. For radionuclides, a meteorological data file is required to approximate conditions at the site.

2.5.2 Uncertainty Associated with Chemical Risk Assessment

2.5.2.1 Uncertainty Associated with Exposure Assessment. To minimize the extent of compounding conservatism throughout the emission inventory and risk assessment, the exposure assessment uses many average values for model inputs. The body weight values are the average for the U.S. adult population. The inhalation rates are the average for all activities. Also, in calculating exposure concentration over multiple subunits within a remediation module, the average air concentration was used to estimate chronic exposure rather than an upper confidence limit estimate of the mean, which could not be calculated due to an insufficient number of data points.

This exposure assessment requires estimating the frequency and duration of public use of EBR-I and the US 20/26 rest area. Therefore, a plausible exposure scenario was established and applied uniformly in the evaluation of exposure resulting from each remediation module such that the resulting risk estimates are comparable.

2.5.2.2 Uncertainty Associated with Toxicity Assessment. There are many unknowns regarding the biological processes that control carcinogenic risk at low concentrations. The Environmental Protection Agency policy in this regard has been to conservatively estimate cancer slope factors for use in risk assessments based on what is scientifically known, allowing a margin of safety for the unknown. Importantly, the slope factors are generally intended to apply to chronic exposures. There is

little information or guidance concerning the application of slope factors for evaluating risks from subchronic (less than 10 years) durations.

Assessing acute, subacute, and chronic hazards is complicated by the selection of exposure duration. For example, toxicity values for acute exposure can vary by as much as an order of magnitude depending on whether a 10-minute or 8-hour exposure duration is used in the assessment. Moreover, a higher standard can be applied if mild or transient health effects are acceptable.

Uncertainty may occur in assuming that the risk from each contaminant is additive in nature. This assumption may be either conservative or underestimated in risk. Some contaminants may have a synergistic effect, such as lead and asbestos in the lungs, leading to a much greater risk when both are present than the total from calculating the risk of each separately and adding the risk together. However, at low concentrations, it is generally believed that there is substantially lower potential for synergistic effects to occur.

Summing the individual hazard indexes into a hazard quotient can only be performed with surety if the chemical is known to affect the same target organ at the anticipated exposure concentration. Also, for several chemicals, the oral reference dose is used because an inhalation reference dose is not available. Using the oral reference dose has merit because the critical effect is not at the point of exposure to the body but is the effect within the body; however, there may be some differences in the absorption and distribution of a specific chemical when exposed orally versus via inhalation.

2.5.2.3 Uncertainty Associated with Radiological Risk Characterization. Estimating the potential risk from radiation exposures requires applying dose-to-risk conversion factors to an estimate of dose. It is common practice to multiply the calculated total effective dose equivalent by a risk-to-dose factor of 8.00E-04 cancers/rem. The most recent guidance on dose-to-risk conversion factors is provided by the Interagency Steering Committee on Radiation Standards, which issued a technical report entitled *A Method for Estimating Radiation Risk from TEDE* (ISCORS 2002). The total effective dose equivalent-to-risk factor provided by ISCORS (2002) in Technical Report 1 is based upon a static population with characteristics consistent with the U.S. population.

Estimating the potential risk from low levels of ionizing radiation requires applying dose-to-risk conversion factors to an estimate of the dose. The Environmental Protection Agency, in coordination with other federal agencies involved in radiation protection, has issued *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999). This document is a compilation of risk factors for doses from external gamma radiation and internal intakes of radionuclides. It is the basis of the radionuclide risk coefficients used in the Health Effects Assessment Summary Tables (EPA 2001).

DOE and other agencies regularly conduct dose assessments with models and codes that calculate radiation dose from exposure or intake using dose conversion factors (Figure11 in EPA 1988 and Figure 12 in EPA 1993) and do not compute risk directly. In cases where it is necessary or desirable to estimate risk for comparative purposes (e.g., comparing the risk associated with alternative actions), it is common practice to simply multiply the calculated total effective dose equivalent by a risk-to-dose factor. DOE previously recommended total effective dose equivalent-to-fatal cancer risk factors of 5E-04 rem for the public and 4E-04 rem for working-age populations. These values were based upon recommendations from the former Committee on Interagency Radiation Research and Policy Coordination (CIRRPC 1992). The ISCORS (2002) guidance supersedes the CIRRPC (1992) guidance and recommends that agencies use a conversion factor of 6E-04 fatal cancers per total effective dose equivalent (rem) for mortality and 8E-04 cancers per TEDE rem for morbidity when making qualitative or semiquantitative estimates of risk from radiation exposure to members of the general public.

ISCORS (2002) notes that the recommended risk coefficients used with total effective dose equivalent estimates generally produce conservative radiation risk estimates (i.e., they overestimate risk). When comparing the ingestion pathway of 11 radionuclides, risks would be overestimated compared to the EPA (1999) values for about eight radionuclides and significantly overestimated (by up to a factor of six) for four of these. The DOE Office of Environmental Policy and Guidance also compared the total effective dose equivalent × conversion factor approach to EPA (1999) for the inhalation pathway and found a bias toward overestimation of risk, although it was not as severe as for ingestion. For 16 radionuclides/chemical states evaluated, seven were significantly overestimated (by more than a factor of two), five were significantly underestimated, and the remainder agreed within about a factor of 2. Generally, these differences are within the uncertainty of transport and uptake portions of dose or risk modeling, and, therefore, the approach recommended by ISCORS (2002) is considered acceptable for comparative assessments.

2.5.3 Uncertainty Associated with Accident and Fatality Rates

Uncertainties in the projections of injuries and fatalities from the alternatives result from uncertainties in three kinds of data: 1) the estimates of labor hours required to complete the modules that are the basic building blocks of the alternatives and the types of labor that are required for each module, 2) the number of truck-miles required to move materials to complete each module, and 3) experience-based incidence rates (fatalities and injuries) taken from various databases. The first kind of data (estimates of labor hours and types of labor) was used to calculate estimates of fatalities and injuries that might be experienced by workers from industrial-type accidents; the estimates of truck-miles, along with the expected routes to be taken by the trucks, were used to calculate estimates of fatalities and injuries due to transportation accidents by both workers and the public from transporting materials.

This section deals primarily with the uncertainties in the incidence rates and the choices of sources for those rates. While there may be uncertainties in the estimates of labor hours, labor types, and truck-miles that were used to calculated possible injuries and fatalities, those estimates were developed on a consistent basis and are valid for comparing the alternatives.

2.5.3.1 Industrial Accident Injuries. DOE's Computerized Accident Incident Reporting System database (CAIRS 2006) was used to develop incidence rates for industrial injuries. The Computerized Accident Incident Reporting System presently lists numbers of injuries for all significant DOE agencies, contractors, and subcontractors per quarter year, for the year 2000 through the first half of 2005. The data are also broken down into 10 "operation types," most of which are closely related to the labor types for which the labor estimates were made for each of the modules that make up the remedial alternatives. In total, the Computerized Accident Incident Reporting System database represents over 1.5 billion hours of work performed for DOE.

The "injury and labor hours worked" information in the Computerized Accident Incident Reporting System for the years 2001 through 2004 were used to calculate injury incidence rates for each labor type. The smallest number of labor hours used to get these incident rates for a particular labor type was more than two million. The total number of labor hours during the period was almost 44 million, and 360 injuries were recorded. Based on this volume of data, the relative uncertainty is assumed to be relatively low.

Injuries presented in this risk assessment are classified as recordable cases. Recordable cases include all work related illnesses and injuries which result in a loss of consciousness, days away from work, restricted work activity or job transfer, or medical treatment beyond first aid.

2.5.3.2 Industrial Accident Fatalities. Two databases were reviewed for information on industrial fatalities—Computerized Accident Incident Reporting System and the U.S. Bureau of Labor Statistics.

The entire Computerized Accident Incident Reporting System database, covering from the year 2000 through the first half of 2005, shows five fatalities over 300 million work hours. Oddly, none of those fatalities occurred in the operations codes involving construction, which is arguably the most likely of the remediation activities to cause fatalities. The five fatalities are attributed to service, security (two), research, and oil and gas activities. About 125 million hours of construction labor are recorded in the Computerized Accident Incident Reporting System database.

The Bureau of Labor Statistics database provides fatality information for the years 2003 and 2004 for a wide range of activity types. The number of hours worked in those activities are not provided in many cases, which makes it impossible to develop estimates of fatalities per hour worked for different kinds of work that are representative of the activities that occur during remediation. Both kinds of data are provided for a number of construction-related activities, including the broad category "Heavy and Civil Engineering Construction," which represents the type of construction work performed during remediation. Approximately 3.6 billion labor hours were recorded for that category during 2003 and 2004, the period for which such data were available. Using the information on hours worked and fatalities for those two years, a fatality rate of approximately 4.5 per 30 million hours was calculated, which is an order of magnitude higher than for all activities in the Computerized Accident Incident Reporting System database.

If the Computerized Accident Incident Reporting System fatality rate of five per 300 million hours for all activities is applied to the 125 million construction hours in the Computerized Accident Incident Reporting System database, about two fatalities due to construction would be expected. If the Bureau of Labor Statistics "Heavy and Civil Engineering Construction" fatality rate of 4.5 per 30 million hours is applied to 125 million construction hours, about 19 fatalities would be expected. The fact that there are no fatalities recorded in the Computerized Accident Incident Reporting System for 125 million work hours in construction is arguably a tribute to DOE and its contractor's efforts to protect its workers.

Neither database is ideal for estimating fatalities for the short-term risk assessment. This is due largely to the infrequent nature of fatalities and to the evident success of DOE procedures in reducing such events well below the level experienced in similar activities outside DOE facilities. It was decided to use the Computerized Accident Incident Reporting System fatality rate of five per 300 million hours for all activities in the short-term risk assessment, in spite of not being able to discriminate among different activities during remediation and apparently being based on relatively spurious events. The most striking result of using the Computerized Accident Incident Reporting System database is the dependence of the fatality estimates only on projected hours worked for each alternative, regardless of the kind of work performed.

The uncertainty in the incidence rates used to project fatalities from industrial accidents is considered to be relatively high. Furthermore, the inability to use incidence rates that distinguish among the different labor types is unfortunate.

2.5.3.3 Transportation Injuries and Fatalities. The Computerized Accident Incident Reporting System database did not prove to be useful in determining incidence rates, in this case injuries or fatalities per mile traveled, for transportation accidents. The U.S. Department of Transportation maintains databases (DOT 2005) on accidental injuries and fatalities for a variety of vehicles, such as highway motor vehicles in general, trucks, and aircraft. The only database that contained incidence rates for trucks, the primary means of transport for all of the remediation modules, was for occupants of trucks, not all

persons involved in truck accidents. It was decided to use a Department of Transportation database that covers motor vehicles in general. That database contains injury and fatality incidence rates that are broken down into those for collocated workers and members of the public.

For this study, it was determined that speeds of 55 mph were on public highways and, as such, affect only members of the general public. While speeds of less than 55 mph were listed, only on-Site collocated workers would be affected. Average incidence rates for 2002 and 2003, the latest two years for which there were data, were used. Figures for three road types in the Department of Transportation database were used: interstate travel, travel on other principal arterials and minor arterials, and local travel.

Unfortunately, no breakdown of injury frequencies similar to those for fatalities was found in the Department of Transportation database. Only the annual number of motor vehicle accident injuries is available. Those annual injury totals and the total miles driven for 2002 and 2003 were used to determine an injury incidence rate for projecting transportation injuries for the short-term risk assessment.

The incidence rates taken from the Department of Transportation database represent over 800 trillion miles traveled. It is felt that there is little uncertainty in the incidence rates, based on both the miles of travel represented and the year-to-year variations in those rates in the Department of Transportation data. While low, some uncertainty is added by assigning the fatality rates for different speeds of travel and, in two cases, destinations, and by using a gross injury rate regardless of the kind of travel required.

3. RADIOLOGICAL ANALYSIS RESULTS

3.1 Dose and Risk Estimates for Remediation Workers

As stated in Section 2.1.3.1, the dose to workers was evaluated by applying a standard dose rate to each worker involved in a specified activity. The MEI worker's total cancer risk (i.e., probability of cancer incidence for the person who receives the highest dose over the project duration) for a given alternative module, was determined by summing the module tasks, providing the highest risk that a worker would likely be involved in over the alternative module duration. For example, in the full RTD retrieval, the MEI worker is assumed to be involved in waste excavation and deactivation, decontamination, and decommissioning (DD&D) activities, not in assay, storage, and treatment tasks, because these tasks all take place at the same time as the waste retrieval and DD&D tasks. The MEI worker's total cancer risk (i.e., probability of cancer incidence for the person who receives the highest dose over the project duration) for each alternative module task and alternative module are provided in Appendix D, Tables 3-1 and 3-2. MEI worker cancer risks are not provided for modules and tasks deemed to provide a low dose to workers. Activities such as construction, surveying, and security will not provide dose levels above those already encountered by workers at the SDA and would provide little information in terms of the overall risk of the modules.

3.2 Dose and Risk Estimates for a Collocated Worker

The dose and cancer risk (i.e., probability of cancer incidence for the person who receives highest dose over the project duration) to the collocated worker were evaluated for the modules that have significant releases to the environment. These modules include the two-acre retrieval (Module 12), four-acre retrieval (Module 13), full retrieval, treatment, and disposal (Module 14), and Pad A retrievals (Modules 15–18). The following tables provide the dose and risk associated with each module of interest. The dose and cancer risks are broken out by the fraction of releases from the high-efficiency particulate air filtration system and enclosure releases that are not filtered by the high-efficiency particulate air system. The module dose and risk tables reported for each radionuclide of concern are provided in Appendix D. A summary of that data is presented in Tables 3-3 and 3-4.

3.3 Dose and Risk Estimates for a Member of the Public

The dose and cancer risk (i.e., probability of cancer incidence for the person who receives highest dose over the project duration) to a member of the public at the site boundary were evaluated for the modules that have significant releases to the environment. These modules include the two-acre retrieval (Module 12), four-acre retrieval (Module 13), full retrieval, treatment, and disposal (Module 14), and Pad A retrievals (Modules 15–18). Table 3-1 and Tables 3-2 through 3-6 provide the dose and cancer risks associated with each module of interest. The doses and risks are broken out by the fraction of releases from the high-efficiency particulate air filtration system and enclosure releases that are not filtered by the high-efficiency particulate air system. The module dose and risk tables reported for each radionuclide of concern are provided in Appendix D. A summary of that data is provided in Tables 3-5 and 3-6

Table 3-1. MEI remediation worker cancer risks by alternative.

Alternative	Module	Total MEI Cancer Risk for Project Duration
1. No Action	Monitoring (19)	--
	Sum for Alternative 1	
2a. Surface Barrier - RCRA Type C Cap	RCRA Type C Cap (5)	1.9E-04
	Shallow Extraction Pipe (7)	4.8E-05
	Foundation Grouting (10)	4.8E-05
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	--
	Sum for Alternative 2a	**2.9E-04**
2b. Surface Barrier - Evapotranspiration Cap	Evapotranspiration Cap (3)	1.7E-04
	Gas Vent Layer Extraction Pipe (6)	4.8E-05
	Dynamic Compaction of Pits (8)	4.8E-05
	Pad A Removal, w/o Treatment, Shipped to Low-Level Waste Pit (15)	5.0E-04
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	---
	Sum for Alternative 2b	**7.6E-4**
3. In Situ Grouting	Evapotranspiration Cap (3)	1.7E-04
	Gas Vent Layer Extraction (6)	4.8E-05
	Dynamic Compaction of Pits (8)	4.8E-05
	Contaminant Grouting (11)	7.2E-05
	Pad A Removal, Treat and Ship to Low-Level Waste Pit (18)	7.4E-04
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	---
	Sum for Alternative 3	**1.1E-03**
4a. Two-acre RTD	Slurry Cut-Off Wall (1)	---
	Proof Rolling (2)	2.4E-05
	Evapotranspiration Cap (3)	1.7E-04
	Gas Vent Layer Extraction (6)	4.8E-05
	Dynamic Compaction Pad A (9)	4.8E-05
	Two-acre Excavation (12)	2.4E-03
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	---
	Sum for Alternative 4a	**2.6E-03**

Alternative	Module	Total MEI Cancer Risk for Project Duration
4b. Four-acre RTD	Evapotranspiration Cap (3)	1.7E-04
	Gas Vent Layer Extraction (6)	4.8E-05
	Dynamic Compaction of Pits (8)	4.8E-05
	Four-acre Excavation (13)	3.0E-03
	Pad Removal Ship to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	7.4E-04
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	---
	Sum for Alternative 4b	**4.0E-03**
5. Full RTD	Evapotranspiration Cap w/o Gas Vent Layer (4)	7.2E-05
	Full Excavation (14)	1.2E-02
	Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	7.4E-04
	Organic Contamination in Vadose Zone Maintenance and Operations (20)	---
	Sum for Alternative 5	**1.3E-02**

Table 3-2. Summary of MEI remediation worker cancer risks by alternative.

Alternative	Total MEI Cancer Risk for Project Duration
1. No Action	----
2a. Surface Barrier	**2.0E-04**
2b. Surface Barrier	**7.7E-4**
3. In Situ Grouting	**1.1E-03**
4a. Partial RTD (2 Acre)	**2.7E-03**
4b. Partial RTD (4 Acre)	**4.4E-03**
5. Full RTD	**1.3E-02**

Table 3-3. Module radionuclide dose to a collocated worker.

Module	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Two-Acre Retrieval	2.2E+00	3.7E+01	3.9E+01
Four-Acre Retrieval	2.1E+00	3.6E+01	3.8E+01
Full RTD Retrieval	2.8E+00	4.8E+01	5.0E+01
Pad A Retrieval	4.3E-03	7.1E-02	7.5E-02

a. 99.5% of releases assumed to be through high-efficiency particulate air filtration.
b. 0.5% of releases assumed to be lost from enclosure without high-efficiency particulate air filtration.

Table 3-4. Module radionuclide cancer risk[a] to a collocated worker.

Module	HEPA[b]	0.5% Loss [c]	Total
Two-Acre Retrieval	6.1E-06	1.0E-04	1.1E-04
Four-Acre Retrieval	1.0E-05	1.7E-04	1.8E-04
Full RTD Retrieval	5.7E-05	9.5E-04	1.0E-03
Pad A Retrieval	5.1E-09	8.5E-08	9.0E-08

a. Risk = mrem/yr x 1 rem/1,000 mrem x 8E-4 risk/rem x duration (duration = 3.5 yr two-acre, 6 yr four-acre, 25 yr full and 1.5 yr Pad A removal.

b. 99.5% of releases assumed to be through high-efficiency particulate air filtration.

c. 0.5% of releases assumed to be lost from enclosure without high-efficiency particulate air filtration.

Table 3-5. Radionuclide dose to a public member at site boundary.

Module	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Two-Acre Retrieval	3.1E-04	5.2E-03	5.5E-03
Four-Acre Retrieval	3.0E-04	5.1E-03	5.4E-03
Full RTD Retrieval	4.0E-04	6.7E-03	7.1E-03
Pad A Retrieval	6.0E-07	1.0E-05	1.1E-05

a. 99.5% of releases assumed to be through high-efficiency particulate air filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table 3-6. Radionuclide risk[a] to a public member at site boundary.

Module	HEPA[b]	0.5% Loss[c]	Total
Two-Acre Retrieval	2.13E-07	3.56E-06	3.77E-06
Four-Acre Retrieval	3.55E-07	5.97E-06	6.33E-06
Full RTD Retrieval	1.42E-06	3.31E-05	3.46E-05
Pad A Retrieval	2.13E-07	3.56E-06	3.77E-06

a. Risk = mrem/yr x 1 rem/1,000 mrem x 8E-4 risk/rem x duration (duration = 3.5 yr two-acre, 6 yr four-acre, 25 yr full and 1.5 yr Pad A removal.

b. 99.5% of releases assumed to be through high-efficiency particulate air filtration.

c. 0.5% of releases assumed to be lost from enclosure without high-efficiency particulate air filtration.

3.4 Transportation Dose to Members of the Public

Three of the proposed alternatives (two-acre RTD, four-acre RTD, and full RTD) will require shipping radioactive waste to off-Site facilities, including the Waste Isolation Pilot Plant in Carlsbad, New Mexico, and Envirocare in Clive, Utah. During these shipments, members of the public who reside in or are sharing the transportation corridors through which the shipments travel will be exposed to very low levels of radiation. Extensive studies and modeling have been performed in support of the Waste Isolation Pilot Plant to determine the radiological impacts along the transportation corridors based on estimated transuranic waste volumes, number of shipments, radiation levels of the shipments, and population densities along the approved routes (DOE 1997). Tables E-12 and E-13 in the Supplemental Environmental Impact Statement (DOE 1997) summarize the population doses per shipment of

contact-handled transuranic waste (E-12) and remote-handled transuranic waste (E-13) from each of the DOE origination sites with the following results:

- Total nonoccupational dose from contact-handled transuranic for INL Site waste—0.1 person-rem
- Total nonoccupational dose from remote-handled transuranic for INL Site waste—0.2 person-rem.

Using the nonoccupational doses listed above, the alternatives were evaluated for dose to members of the public based on the projected waste volumes. Calculations of dose were based on the dose per shipment times the number of shipments. As outlined in Appendix E of the Supplemental Environmental Impact Statement (DOE 1997), the dose rates for contact-handled transuranic waste (4 mrem/hr) and remote-handled transuranic waste (10 mrem/hr) were used to calculate the off-Site shipment exposure to the maximally exposed member of the public. In this case, the MEI is defined as a state safety inspector who is assumed to be involved in 20% of the shipments over 10 years, spending one hour at an average exposure distance of one meter (3.3 feet). Exposure for the Envirocare shipments used the remote-handled exposure rate of 10 mrem/hr at 1 meter (3.3 feet), which is conservative when compared to the estimated contact dose rate of 5.2 mrem/hr on a 55-gal drum of transuranic waste and soil (Schofield 2002). Based on the risk calculation explained in section 2.4.1, the estimated incremental lifetime cancer risk to the maximum exposed member of the public by alternative is: two-acre RTD, 4.3E-04; four-acre RTD, 5.4E-04; full RTD, 3.8E-02, as shown in Table 3-7.

Table 3-7. Total dose to public for alternatives.

Alternative	Module	Waste Volume (55-gal drums)	Number of Drums per Shipment	Number of Shipments	Dose Rate Per Shipment (mrem/hr)	Total Dose to MEI per Alternative (mrem)	Risk to MEI
Two-acre RTD	Two-acre excavation	27,773	42[a]	662	4	532	4.3E-04
Four-acre RTD	Four-acre excavation	35,534	42[a]	847	4	680	5.4E-04
Full RTD	Full excavation	241,474	42[a]	5,750	4	4,600	3.7E-03
	Full excavation	20,840	3[b]	6,947	10	13,900	1.1E-02
	Full excavation	1,173,468	80[c]	14,669	10	29,340	2.3E-02
	Pad A removal and ship off-Site	564 Sea-Land Containers	3 containers[d]	188	10	380	3.0E-04
	Total for Full RTD						3.8E-02

a. Contact-handled transuranic waste, 0.1 person-rem per shipment, 14 drums/TRUPACT-II, 3 TRUPACT-IIs per shipment.

b. Remote-handled transuranic waste, 0.2 person-rem per shipment, three 55-gal drums per RH-72B shipping cask, one RH-72B per shipment.

c. Off-Site shipment of waste to Envirocare, 80 drums per truck, 0.2 person-rem per shipment, mileage to Envirocare 22% of mileage to Waste Isolation Pilot Plant (based on information in the Supplemental Environmental Impact Statement (DOE 1997).

d. Sea-Land containers transported via rail, three containers per dedicated train, factor of 1.5 applied for additional rail mileage and slower transport speed, 0.2 person-rem per container, mileage to Envirocare 22% of mileage to Waste Isolation Pilot Plant (based on information in the *Waste Isolation Pilot Plant Supplemental Environmental Impact Statement* (DOE 1997).

4. CHEMICAL ANALYSIS RESULTS

Risk from chemicals can take the form of a carcinogenic lifetime risk or a hazard as measured by a hazard quotient. The carcinogenic risk is expressed as the probability of the MEI contracting cancer after 30 years of contact with the reported concentration. For example, a risk of 4.3E-05 would mean that 43 out of 1 million individuals as the maximum exposure would contract cancer during their lifetime from the proposed project. A hazard index is measured as a noncarcinogenic hazard that can occur either over a lifetime of exposure or exposure for a short duration. In this risk assessment, both the chronic and acute hazards are presented. Sections 2.4.1.1 and 2.4.2 discuss the carcinogenic and noncancer risks in greater detail. It should also be noted here that there is no risk from chemicals in transportation. The chemicals will be transported in containers that will eliminate the potential for escape into the atmosphere, except in the rare off-normal event that an accident breaches one of the containers and releases the contents to the environment.

4.1 Risk Estimates for a Remediation Worker

As stated previously (Section 2.1.3.2), this risk assessment assumes that occupational exposures during remediation will be controlled by site-specific health and safety plans. Additionally, engineering controls will be utilized to minimize the exposure of remediation workers. Finally, job-specific personal protective equipment will be required for all remediation workers that are inside the tents or handling waste in any form. In general, personal protective equipment will include a Tyvek suit, boots, gloves, and supplied air. This level of engineering controls and personal protective equipment should be adequate to protect workers from chemical hazards. Except in the case of failure of personal protective equipment and/or noncompliance with INL Site health and safety procedures, risks to workers will be mitigated and will not vary significantly among the different remediation modules.

4.2 Risk Estimates for a Collocated Worker

Total carcinogenic risk levels and hazard indexes for the collocated worker are shown in Table 4-1. The noncancer chronic and acute hazards are less than 1 for each of the alternatives, indicating that there is no hazard. Because no waste will be disturbed and released during the no action and RCRA Type C cap alternatives, the overall risk was qualitatively judged to be extremely low to none. Some chemical releases are expected during the evapotranspiration cap alternative and from the in situ grouting from Pad A removal; however, the risk associated with these alternatives was qualitatively determined to be insignificant because of a lack of volatile organic compounds in the Pad A inventory.

Table 4-1. Chemical risks and hazard indexes to the collocated worker.

Alternative	Cancer Risk	Noncancer Chronic Hazard Index	Noncancer Acute Hazard Index
1. No Action	__[a]	__[a]	__[a]
2a. Surface Barrier	__[a]	__[a]	__[a]
2b. Surface Barrier	__[a]	__[a]	__[a]
3. In Situ Grouting	__[a]	__[a]	__[a]
4a. Partial RTD (2 Acre)	1.1E-05	0.35	0.35
4b. Partial RTD (4 Acre)	1.3E-05	0.40	0.37
5. Full RTD	2.7E-05	0.86	0.32

a. Risk assessed qualitatively and considered extremely low.

4.3 Risk Estimates for a Member of the Public

Total carcinogenic risk levels and hazard indexes for the members of the public are shown in Table 4-2. The noncancer chronic hazard is less than 1 for each of the alternatives, indicating that there is no hazard. The noncancer acute hazard is also less than 1 for all of the RTD alternatives and, as previously noted, the hazard index is not a linear function and any result that is less than 1 indicates no hazard. Because no waste will be disturbed and released during the no action and RCRA Type C cap alternatives, the overall risk was qualitatively judged to be extremely low to none. Some chemical releases are expected during the evapotranspiration cap alternative and from the in situ grouting from Pad A removal; however, the risk associated with these alternatives was qualitatively determined to be insignificant because of a lack of volatile organic compounds in the Pad A inventory.

Table 4-2. Chemical risks and hazard indices to members of the public.

Alternative	Cancer Risk	Noncancer Chronic Hazard Index	Noncancer Acute Hazard Index
1. No Action	—[a]	—[a]	—[a]
2a. Surface Barrier	—[a]	—[a]	—[a]
2b. Surface Barrier	—[a]	—[a]	—[a]
3. In Situ Grouting	—[a]	—[a]	—[a]
4a. Partial RTD (2 Acre)	1.3E-05	0.40	0.20
4b. Partial RTD (4 Acre)	1.4E-05	0.45	0.21
5. Full RTD	2.9E-05	0.92	0.18

a. Risk assessed qualitatively and considered extremely low.

5. ACCIDENT AND TRANSPORTATION ANALYSIS

This section presents the projected injuries and fatalities from industrial and transportation accidents for the Operable Unit 7-13/14 short-term risk assessment. Those injuries and fatalities are separate from any consequences of the fact that radioactive materials are involved in most of the remediation activities. They result from unanticipated mechanical injuries that can be typical of those occurring in any industrial setting where functions similar to those during remediation and postremediation are performed.

5.1 Industrial Injuries and Fatalities

All accidents, other than transportation accidents, are covered by this category. Projections of injuries and fatalities for each alternative are calculated and presented in this section. All of the accidents are assumed to involve only workers assigned to remediation activities; collocated workers and the public are assumed not to experience any consequences from these accidents.

Section 2.5.3 discussed the sources of accident data and uncertainties in the information used to make these projections. In brief, the DOE Computerized Accident/Incident Reporting System database was used to develop incidence rates, expressed as injuries per hour worked and fatalities per hour worked, based on information from DOE sites.

The incidence rates for injuries were expressed in terms of different types of labor and matched to activities during the Operable Unit 7-13/14 remediation. Labor-hour estimates for those activities were then multiplied by the appropriate incidence rates to get a total projected number of injuries for each activity. Those projections were summed for the various modules, and the projections for the appropriate modules were summed to calculate a projection for each alternative.

It was not possible to calculate fatality incidence rates for different types of labor because of the very low rate of occurrence of fatalities recorded in the Computerized Accident/Incident Reporting System and the lack of availability of robust statistics in other databases. Consequently, a single fatality incidence rate was used for all activities in the Operable Unit 7-13/14 remediation, and the fatality projections for each alternative depends only on the number of work hours estimated and not the kind of work being performed.

The most complete exposition of the calculation of projected industrial injuries and fatalities is contained in Table C-1 of Appendix C. In that table, details of the injury and fatality projections for each of the 20 modules that make up the components of all of the alternatives are shown. The roadmap linking modules to the different alternatives is given in Section 1.4.

Table 5-1 shows the buildup of the projections of nontransportation injuries and fatalities from those calculated for the various modules. Injuries and fatalities were not considered for monitoring and OCVZ maintenance and operations (modules 19 and 20) because they are considered over a long period of time and this is a short-term risk assessment for a comparison of remedial actions.

Table 5-2 consolidates the information from Table 5-1 to easily compare the projected injuries and fatalities for the remedial alternatives. The projected number of injuries increases monotonically as the alternative number increases. The same pattern is observed for the projected number of fatalities, except for the RCRA Type C cap alternative where the number reaches a local peak. The reason for this anomaly in the general trend is the long duration of organic contamination in the vadose zone operations in that alternative.

Table 5-1. Projected industrial injuries and fatalities calculated from module projections.

Alternative	Module	Projected Injuries	Projected Fatalities
1. No Action	Monitoring (19)	-	-
	Sum for Alternative 1	**-**	**-**
2a. Surface Barrier – RCRA Type C Cap	RCRA Type C Cap (5)	4	<<1
	Shallow Extraction Pipe (7)	<1	<<1
	Foundation Grouting (10)	<1	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 2a	**5**	**<<1**
2b. Surface Barrier – Evapotranspiration Cap	Evapotranspiration Cap (3)	3	<<1
	Gas Vent Layer Extraction Pipe (6)	<1	<<1
	Dynamic Compaction of Pits (8)	<1	<<1
	Pad A Removal, w/o Treatment, Shipped to Low-Level Waste Pit (15)	3	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 2b	**7**	**<<1**
3. In Situ Grouting	Evapotranspiration Cap (3)	3	<<1
	Gas Vent Layer Extraction (6)	<1	<<1
	Dynamic Compaction of Pits (8)	<1	<<1
	Contaminant Grouting (11)	1	<<1
	Pad A Removal, Treat & Ship to Low-Level Waste Pit (18)	7	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 3	**12**	**<<1**
4a. Two-acre RTD	Slurry Cut-Off Wall (1)	<<1	<<1
	Proof Rolling (2)	<<1	<<1
	Evapotranspiration Cap (3)	3	<<1
	Gas Vent Layer Extraction (6)	<1	<<1
	Dynamic Compaction Pad A (9)	<<1	<<1
	Two-acre Excavation (12)	29	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 4a	**32**	**<<1**

Table 5-1. (continued).

Alternative	Module	Projected Injuries	Projected Fatalities
4b. Four-acre RTD	Evapotranspiration Cap (3)	3	<<1
	Gas Vent Layer Extraction (6)	<1	<<1
	Dynamic Compaction of Pits (8)	<1	<<1
	Four-acre Excavation (13)	44	<<1
	Pad Removal Ship to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	9	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 4b	**56**	**<<1**
5. Full RTD	Evapotranspiration Cap w/o Gas Vent Layer (4)	2	<<1
	Full Excavation (14)	611	<1
	Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	3	<<1
	Organic Contamination in Vadose Zone Maintenance & Operations (20)	-	-
	Sum for Alternative 5	**616**	**<1**

Table 5-2. Summary of projected injuries and fatalities from industrial accidents, by alternative.

Alternative	Projected Injuries	Projected Fatalities
1. No Action	0	0
2a. Surface Barrier	5	<<1
2b. Surface Barrier	7	<<1
3. In Situ Grouting	12	<<1
4a. Partial RTD (2 Acre)	32	<<1
4b. Partial RTD (4 Acre)	56	<<1
5. Full RTD	616	<1

Table 5-1 shows that the lone module associated with the no action alternative—monitoring—while requiring a large number of labor hours, involves labor types that have low injury incidence. Also, even though the labor hour count is high for this module, it is the only module connected to the no action alternative; therefore, the total number of hours for this alternative is relatively small. Because the projected fatality count depends only on the number of hours, not the labor types, that count is relatively low too.

For full RTD, Table 5-1 shows that full excavation (Module 14) dominates the projections of industrial risks. Table C-1 in Appendix C shows that the module includes a large number of labor hours, and most of those hours are associated with labor types that have relatively high injury incidence rates. The total number of labor hours involved in this alternative also results in an increased projected fatality rate.

5.2 Transportation Injuries and Fatalities

Projections were made of injuries and fatalities that might result from significant transportation activities associated with the different modules and alternatives. Incidence rates are expressed in terms of injuries and fatalities per mile traveled. This information is presented in this section and in Appendix C. In contrast with the information about industrial accidents, it was possible to assign fatality incidence rates to travel at different speeds and on different kinds of roads, but only one incidence rate could be found for injuries. Section 2.5.3 discusses the assignment of fatality information in the reference to different travel speeds and destinations that are shown in Table C-2 in Appendix C for those modules that involve significant transportation activities.

The most complete exposition of the calculation of projected risks from transportation associated with the Operable Unit 7-13/14 remediation is in Table C-2 in Appendix C. That table shows the projected travel miles, speeds, and road types for those modules that involve moving materials to and from Operable Unit 7.

Table 5-3 shows the buildup of the projected transportation risk for the alternatives, as calculated from the modules. Only modules that have non-zero risks in Table C-2 are listed in Table 5-3.

Table 5-3. Projected transportation injuries and fatalities to the member of the public.

Alternative	Module	Projected Injuries	Projected Fatalities
1. No Action		0	0
2a. Surface Barrier – RCRA Type C Cap	RCRA Type C Cap (5)	<1	<<1
	Foundation Grouting (10)	<<1	<<1
	Sum for Alternative 2a	**<1**	**<<1**
2b. Surface Barrier – Evapotranspiration Cap	Evapotranspiration Cap (3)	1	<<1
3. In Situ Grouting	Evapotranspiration Cap (3)	1	<<1
	Contaminant Grouting (11)	<1	<<1
	Sum for Alternative 3	**1**	**<<1**
4a. Two-acre RTD	Slurry Cut-Off Wall (1)	<<1	<<1
	Proof Rolling (2)	<<1	<<1
	Evapotranspiration Cap (3)	1	<<1
	Two-acre Excavation (12)	2	<<1
	Sum for Alternative 4a	**4**	**<<1**
4b. Four-acre RTD	Evapotranspiration Cap (3)	1	<<1
	Four-acre Excavation (13)	3	<<1
	Pad A Removal and Ship to Idaho CERCLA Disposal Facility to Treat and Dispose (16)	<<1	<<1
	Sum for Alternative 4b	**4**	**<<1**
5. Full RTD	Evapotranspiration Cap w/o Vent Layer (4)	<1	<<1
	Full Excavation (14)	30	<1
	Pad Removal and Ship Off-Site to Treat and Dispose (17)	<1	<<1
	Sum for Alternative 5	**30**	**<1**

The no action alternative has no projected transportation risk because no activities require significant movement of materials. RCRA Type C cap requires transporting materials for the cap, as well as grout. Table C-2 shows that each successive alternative uses more truck miles of material hauling and causes the projected injuries and fatalities to increase. The alternatives that involve shipping transuranic waste to the Waste Isolation Pilot Plant are associated with the highest transportation miles, and even though the fatality incidence rates are lowest for travel over interstate highways, the projected resultant fatalities are highest for that alternative. In the case of projected injuries, where highway-specific data were not available, the increased truck miles for those three alternatives result in increased projected risks.

Table 5-4 consolidates the information in Table 5-3 for easy comparison of the projected injuries and fatalities for each of the alternatives.

Table 5-4. Summary of projected injuries and fatalities from transportation accidents to the public, by alternative.

Alternative	Projected Injuries	Projected Fatalities
1. No Action	0	0
2a. Surface Barrier	<1	<<1
2b. Surface Barrier	1	<<1
3. In Situ Grouting	1	<<1
4a. Partial Retrieval, Treatment, and Disposal	4	<<1
4b. Partial Retrieval, Treatment, and Disposal	4	<<1
5. Full Retrieval, Treatment, and Disposal	30	<1

Table 5-5 summarizes the projected injuries and fatalities for each alternative for remediating Operable Unit 7-13/14. The table shows that the projected risks, in terms of both injuries and fatalities, range over more than two orders of magnitude. The lowest risks are for the no action alternative and the highest risks are for the full RTD.

Table 5-5. Total projected injuries and fatalities from industrial and transportation accidents.

Alternative	Injuries	Fatalities
1. No Action	0	0
2a. Surface Barrier	5	<<1
2b. Surface Barrier	8	<<1
3. In Situ Grouting	13	<<1
4a. Partial RTD (2 Acre)	36	<<1
4b. Partial RTD (4 Acre)	60	<<1
5. Full RTD	646	<1

6. SUMMARY OF RESULTS

This document briefly described the alternatives, methodology for performing a risk assessment, sources of data, and intermediate results of the risk assessment. This section summarizes the risks for each alternative and presents the information in tabular form for easy viewing. Sections 6.1, 6.2, and 6.3 present the risks for each alternative—radiological risk, chemical risk, and risk from industrial accidents and transportation. Section 6.4 then discusses and presents the risk associated with each module that composes an alternative. Finally, Section 6.5 presents a table that includes all the risks calculated by alternative so decision-makers can easily compare them side-to-side.

6.1 Risk Levels for the Radiological Risk Evaluation

Cancer incidence risks for radiological exposures were evaluated for each of the alternatives. These risks provide a measure of the potential excess cancer incidence risk for the receptor of interest. The radiological cancer incidence risk for each alternative is summarized in Table 6-1.

Table 6-1. Radiological cancer incidence risk for each alternative.

Alternative		Worker Risk	Collocated Worker Risk	Member of the Public Risk	Risk to Public from Transportation
1.	No Action	—[a]	—[a]	—[a]	—[a]
2a.	Surface Barrier	2.9E-04	—[a]	—[a]	—[a]
2b.	Surface Barrier	7.6E-04	9.0E-08	3.2E-09	—[a]
3.	In Situ Grouting	1.1E-03	9.0E-08	3.2E-09	—[a]
4a	Partial RTD (2 Acre)	2.6E-03	1.1E-04	3.8E-06	4.3E-04
4b.	Partial RTD (4 Acre)	4.0E-03	1.8E-04	6.3E-06	5.4E-04
5.	Full RTD	1.3E-02	1.0E-03	3.5E-05	3.8E-02

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

6.2 Risk Levels and Hazard Indexes for the Chemical Risk Evaluation

Risks from carcinogenic and noncarcinogenic hazards were evaluated for each of the alternatives. The cancer risk from chronic exposure during each alternative is summarized in Table 6-2, the chronic noncancer hazard is summarized in Table 6-3, and the acute noncancer hazard is summarized in Table 6-4. It will be noted that for the chemical cancer risk and the chronic noncancer hazard, the risk to the member of the public is greater than that to the collocated worker even though the concentration of the chemical in the atmosphere is greater for the collocated worker. This is a result of the MEI of the public being exposed for more than four times as many hours each year as compared to the collocated worker.

Table 6-2. Chemical cancer risk for each alternative.

Alternative	Worker Risk	Collocated Worker Risk	Member of the Public Risk
1. No Action	—[a]	—[a]	—[a]
2a. Surface Barrier	—[a]	—[a]	—[a]
2b. Surface Barrier	—[a]	—[a]	—[a]
3. In Situ Grouting	—[a]	—[a]	—[a]
4a Partial RTD (2 Acre)	—[a]	1.1E-05	1.3E-05
4b. Partial RTD (4 Acre)	—[a]	1.3E-05	1.4E-05
5. Full RTD	—[a]	2.7E-05	2.9E-05

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

Table 6-3. Chemical noncancer chronic hazard for each alternative.

Alternative	Worker Risk	Collocated Worker Risk	Member of the Public Risk
1. No Action	—[a]	—[a]	—[a]
2a. Surface Barrier	—[a]	—[a]	—[a]
2b. Surface Barrier	—[a]	—[a]	—[a]
3. In Situ Grouting	—[a]	—[a]	—[a]
4a Partial RTD (2 Acre)	—[a]	0.35	0.40
4b. Partial RTD (4 Acre)	—[a]	0.40	0.45
5. Full RTD	—[a]	0.86	0.92

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

Table 6-4. Chemical noncancer acute hazard for each alternative.

Alternative	Worker Risk	Collocated Worker Risk	Member of the Public Risk
1. No Action	—[a]	—[a]	—[a]
2a. Surface Barrier	—[a]	—[a]	—[a]
2b. Surface Barrier	—[a]	—[a]	—[a]
3. In Situ Grouting	—[a]	—[a]	—[a]
4a Partial RTD (2 Acre)	—[a]	0.35	0.20
4b. Partial RTD (4 Acre)	—[a]	0.37	0.21
5. Full RTD	—[a]	0.32	0.18

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

6.3 Industrial and Transportation Injuries and Fatalities

The risks associated with industrial accidents involving worker activities and transporting materials to and from the site were evaluated for each of the alternatives. These risks provide a measure of the potential injuries and fatalities for each alternative. The risks of injuries and fatalities are summarized in Tables 6-5 through 6-7. All injuries and fatalities are reported to the nearest whole number. The calculations and results are found in Appendix C. The risks generally rise with the complexity associated with each alternative.

Table 6-5. Total projected injuries and fatalities from industrial accidents for remediation workers.

	Alternative	Injuries	Fatalities
1.	No Action	0	0
2a.	Surface Barrier	5	<<1
2b.	Surface Barrier	7	<<1
3.	In Situ Grouting	12	<<1
4a	Partial RTD (2 Acre)	32	<<1
4b.	Partial RTD (4 Acre)	56	<<1
5.	Full RTD	616	<1

Table 6-6. Total projected injuries and fatalities from transportation accidents for collocated workers.

	Alternative	Injuries	Fatalities
1.	No Action	0	0
2a.	Surface Barrier	<<1	<<1
2b.	Surface Barrier	<1	<<1
3.	In Situ Grouting	<1	<<1
4a	Partial RTD (2 Acre)	<1	<<1
4b.	Partial RTD (4 Acre)	<1	<<1
5.	Full RTD	<1	<1

Table 6-7. Total projected injuries and fatalities from transportation accidents for members of the public.

	Alternative	Injuries	Fatalities
1.	No Action	0	0
2a.	Surface Barrier	<1	<<1
2b.	Surface Barrier	1	<<1
3.	In Situ Grouting	1	<<1
4a	Partial RTD (2 Acre)	4	<<1
4b.	Partial RTD (4 Acre)	4	<<1
5.	Full RTD	30	<1

The risks are based on industrial accident incidence rates (injuries and fatalities per hour worked) derived from the U.S. Department of Energy's Computerized Accident Incident Reporting System. Transportation accident incidence rates (injuries and fatalities per transport mile) were taken from a U.S. Department of Transportation database. The projected risks from industrial accidents are only to workers at the site. The projected risks from transportation accidents are assumed to be entirely to collocated workers at the site and the public. See Sections 2.5.3 and 5.0 for details.

6.4 Summary of Risks by Alternative

The following subsections discuss the risk for each alternative. The sections are separated by radiological risk, nonradiological risk, and risk from accidents and injury. Each section gives the rationale for either qualitatively or quantitatively summarizing the risk. Appendixes A through D contain the technical background information, such as emission estimates, modeling runs, tables, and risk calculations, that were used to substantiate the risk assessment.

6.4.1 No Action – Alternative 1

6.4.1.1 Radiological Risk (No Action). The only activity in this alternative is monitoring (module 19), which includes long-term groundwater sampling, lysimeter sampling sampling, and vapor port sampling. Because the monitoring is considered a long-term future event, the radiological risk is not evaluated quantitatively in this short-term risk assessment.

6.4.1.2 Chemical Risk (No Action). The only activity in this alternative is monitoring (module 19), which includes long-term groundwater sampling, lysimeter sampling, and vapor port sampling. Because the monitoring is considered a long-term future event, the chemical risk is not evaluated quantitatively in this short-term risk assessment.

6.4.1.3 Industrial and Transportation Injuries and Fatalities (No Action). The only activity in this alternative is monitoring (module 19), which includes long-term groundwater sampling, lysimeter sampling, and vapor port sampling. Because the monitoring is considered a long-term future event, accidents and fatalities are not evaluated quantitatively in this short-term risk assessment.

6.4.2 Surface Barrier (RCRA Type C Cap) – Alternative 2a

6.4.2.1 Radiological Risk (RCRA Type C Cap). The radiological risk from the implementation of the surface barrier alternative (Alternative 2a) was evaluated quantitatively and qualitatively. This surface barrier alternative involves RCRA Type C cap (Module 5), shallow extraction pipe (Module 7), foundation grouting (Module 10), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-8. Since no radioactive material is removed during any of the modules in alternative 2a, the radiological risk associated with transportation is assumed to be negligible.

Table 6-8. Summary of radiological risk for the RCRA Type C cap alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
RCRA Type C Cap (5)	1.9E-04	—[a]	—[a]
Shallow Extraction Pipe (7)	4.8E-05	—[a]	—[a]
Foundation Grouting (10)	4.8E-05	—[a]	—[a]
From Transport			
RCRA Type C Cap (5)	—[a]	—[a]	—[a]
Shallow Extraction Pipe (7)	—[a]	—[a]	—[a]
Foundation Grouting (10)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The RCRA Type C cap (5) will involve earth work that is largely restricted to materials brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of four years. This resulted in a cancer risk of 1.92E-04 for the MEI worker.

Installing the shallow extraction pipe (7) does not involve disturbing waste materials. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.80E-05 for the MEI worker.

Foundation grouting (10) is not anticipated to generate airborne radioactive material. The radioactive waste remains in the ground and under the soil cover during grouting. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.80E-05 for the MEI worker.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after the completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.2.2 Chemical Risk (RCRA Type C Cap). The chemical risk from the implementation of this surface barrier alternative (Alternative 2a) is evaluated qualitatively. This surface barrier alternative involves RCRA Type C cap (Module 5), shallow extraction pipe (Module 7), foundation grouting (Module 10), organic contamination in the vadose zone maintenance and operations (Module 20), and long-term monitoring and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-9.

Table 6-9. Summary of chemical risks and hazards for the RCRA Type C cap alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
RCRA Type C Cap (5)	—[a]	—[a]	—[a]
Shallow Extraction Pipe (7)	—[a]	—[a]	—[a]
Foundation Grouting (10)	—[a]	—[a]	—[a]
Organic Contamination in Vadose Zone Maintenance and Operations (20)	—[a]	—[a]	—[a]
Chronic Hazard Index			
RCRA Type C Cap (5)	—[a]	—[a]	—[a]
Shallow Extraction Pipe (7)	—[a]	—[a]	—[a]
Foundation Grouting (10)	—[a]	—[a]	—[a]
Acute Hazard Index			
RCRA Type C Cap (5)	—[a]	—[a]	—[a]
Shallow Extraction Pipe (7)	—[a]	—[a]	—[a]
Foundation Grouting (10)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The chemical risk for the RCRA Type C cap (5) shallow extraction pipe and the organic contamination in the vadose zone maintenance and operations modules is considered negligible for the worker, collocated worker, and member of the public. These activities will not result in significant releases of chemicals to the environment. The RCRA Type C cap will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The shallow extraction pipe (7) consists of placing sections of 12-in. O.D well casing vertically through the RCRA Type C cap, between the waste pits, and into the underlining basalt. The well will then be connected to the OCVZ treatment unit. This module does not disturb waste materials; therefore, chemical exposures are considered negligible.

Foundation grouting (10) is not anticipated to generate airborne chemicals. The grouting approach is considered nondisplacement, meaning that the chemical waste remains in the ground and under the soil cover during grouting. Therefore, the risk to the worker, collocated worker, and member of the public is considered negligible for this alternative module.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the

vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.2.3 Industrial and Transportation Injuries and Fatalities (RCRA Type C Cap). The risks due to industrial accidents and transportation from the implementation of the surface barrier alternative (Alternative 2a) were evaluated based on worker-hours and mileage. This surface barrier alternative involves RCRA Type C cap (Module 5), shallow extraction pipe (Module 7), foundation grouting (Module 10), and organic contamination in the vadose zone maintenance and operations (Module 20). A summary of the accident and injuries by module for this alternative is included in Table 6-10. As can be seen in this table, not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways resulting in no public component. In the case of the slurry cut-off wall, most of the material is delivered using only public highways so the co-located worker component is negligible. Modules with no transportation accidents listed indicates that all transportation is done within the remediation area.

Table 6-10. Summary of industrial and transportation injuries and fatalities for the RCRA Type C cap alternative.

	Industrial Accidents[a]	Transportation Accidents[b]		
Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
RCRA Type C Cap (5)	4	<<1	<1	<1
Shallow Extraction Pipe (7)	<1	—[c]	—[c]	—[c]
Foundation Grouting (10)	<1	<<1	<<1	<<1
Number of Fatalities				
RCRA Type C Cap (5)	<<1	<<1	<<1	<<1
Shallow Extraction Pipe (7)	<<1	—[c]	—[c]	—[c]
Foundation Grouting (10)	<<1	<<1	<<1	<<1

a. Industrial accidents only apply to those performing remediation work on-Site.
b. Transportation accidents are only considered off-Site and do not apply to the remediation workers.
c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The projected total injuries and fatalities for the RCRA Type C cap (5) are 4 injuries and <<1 fatality for industrial accidents and <1 injury and <<1 fatality for transportation accidents. The rates for the shallow extraction pipe (7) are <1 injury and <<1 fatality from industrial accidents; there is no transportation component for the shallow extraction pipe module. For the foundation grouting (10), industrial accidents are projected to cause <1 injury and <<1 fatality. Transportation accidents are expected to cause <<1 injury and <<1 fatality. The largest contributor to injuries and fatalities in the surface barrier, RCRA Type C cap alternative, is the installation of the RCRA Type C cap module. Total projected injuries and fatalities for the RCRA Type C cap are given in Table 6-10.

6.4.3 Surface Barrier (Evapotranspiration Cap) – Alternative 2b

6.4.3.1 Radiological Risk (Evapotranspiration Cap). The radiological risk from the implementation of this surface barrier alternative (Alternative 2b) was evaluated quantitatively and qualitatively. This surface barrier alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), Pad A removed without treatment and shipped to Low-Level Waste Pit (Module 15), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-11.

Table 6-11. Summary of radiological risk for the evapotranspiration cap alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
Evapotranspiration Cap (3)	1.7E-04	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	4.8E-05	—[a]	—[a]
Dynamic Compaction of Pits (8)	4.8E-05	—[a]	—[a]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	5.0E-04	9.0E-08	3.15E-09
From Transport			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

Construction of the evapotranspiration cap (3) will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 3.5 years. This resulted in a cancer risk of 1.7E-04 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to either the remediation worker, collocated worker or members of the public.

Gas vent layer extraction pipe (6) involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not disturb waste materials. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during

this module there is no radiological risk from transportation to either the remediation worker, collocated worker or members of the public.

Dynamic compaction of pits (8) is not anticipated to generate airborne radionuclide material. Therefore, risk to a collocated worker and a member of the public is not assessed. However, the worker is anticipated to be exposed to negligible radioactive material when the waste is exposed due to void space compaction and from external exposures to buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module there is no radiological risk from transportation to either the remediation worker, collocated worker or members of the public.

Pad A removed without treatment and shipped to Low-Level Waste Pit (15) is anticipated to generate airborne radioactive material. Therefore, the risks to workers, a collocated worker, and a member of the public were evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of one year and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 0.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 5.0E-04. The MEI cancer risk to a collocated worker and a member of the public was estimated as 9.0E-08 and 3.15E-09, respectively.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.3.2 Chemical Risk (Evapotranspiration Cap). The chemical risk from the implementation of this surface barrier alternative (Alternative 2b) is evaluated qualitatively. This surface barrier alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), Pad A removed without treatment and shipped to Low-Level Waste Pit (Module 15), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-12.

The risks for the evapotranspiration cap (3) and gas vent layer extraction pipe are considered negligible for the worker, collocated worker, and member of the public. These activities will not result in significant releases of chemicals to the environment.

The evapotranspiration cap will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. Gas vent layer extraction pipe involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not disturb waste materials. Organic contamination in the vadose zone maintenance and operations involves sampling of the vadose zone organic contaminants and maintenance of treatment units. Significant releases of chemical contaminants are not expected from this sampling alternative.

Dynamic compaction of pits (8) is not anticipated to generate airborne chemical material. Therefore, risk to workers, collocated workers, and members of the public are not assessed.

Pad A removal without treatment and shipment to the Low-Level Waste Pit (15) is not anticipated to generate significant airborne chemical material. Based on a qualitative evaluation of the types of chemicals likely present, it was determined that the risk from the Pad A treatment option would be significantly less than the risk determined quantitatively for any of the retrieval options. Therefore, risks to workers, collocated workers, and members of the public are considered negligible for these modules.

Table 6-12. Summary of chemical risks and hazards for the evapotranspiration cap alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	—[a]	—[a]	—[a]
Chronic Hazard Index			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	—[a]	—[a]	—[a]
Acute Hazard Index			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	—[a]	—[a]	—[a]
Organic Contamination in Vadose Zone Maintenance and Operations (20)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.3.3 Industrial and Transportation Injuries and Fatalities (Evapotranspiration Cap).

The risk due to Industrial and Transportation Injuries and Fatalities from the implementation of the surface barrier alternative (Alternative 2b) was evaluated based on worker-hours and mileage. This surface barrier alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), Pad A removal without treatment and shipment to the Low-Level Waste Pit (Module 15), and organic contamination in the vadose zone maintenance and operations (Module 20). A summary of the accident and injuries by module for this alternative is included in Table 6-13. As can be seen in this table, not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways resulting in no public component. In the case of the slurry cut-off wall, most of the material is delivered using only public highways and the co-located worker component is negligible. Modules with no transportation accidents listed indicates that all transportation is done within the remediation area.

Table 6-13. Summary of industrial and transportation injuries and fatalities for the evapotranspiration cap alternative.

	Industrial Accidents[a]	Transportation Accidents[b]		
Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
Evapotranspiration Cap (3)	3	<1	1	1
Gas Vent Layer Extraction Pipe (6)	<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<1	—[c]	—[c]	—[c]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	3	—[c]	—[c]	—[c]
Number of Fatalities				
Evapotranspiration Cap (3)	<<1	<<1	<1	<1
Gas Vent Layer Extraction Pipe (6)	<<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<<1	—[c]	—[c]	—[c]
Pad A Removal w/o Treatment and Shipped to Low-Level Waste Pit (15)	<<1	—[c]	—[c]	—[c]

a. Industrial accidents only apply to those performing remediation work on-Site.

b. Transportation accidents are only considered off-Site and do not apply to the remediation workers.

c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The industrial accident risks for the evapotranspiration cap (3) are 3 injuries and <<1 fatality; for transportation accidents they are 1 injury and <<1 fatality. The risks for the gas vent layer extraction pipe (6) are <1 injury and <<1 fatality from industrial accidents only because there is no transportation component for this module. Injuries and fatalities for the dynamic compaction of the pits (8) are <1 and

<<1 respectively, and injuries and fatalities for Pad A removal without treatment and shipment to Low-Level Waste Pit (15) are 3 and <<1.

The largest contributor to injuries and fatalities in the evapotranspiration cap alternative is the evapotranspiration cap module. The total projected injury and fatality risks for the evapotranspiration cap alternative are given in Table 6-13. Both of them are larger than for no action and the RCRA Type C cap but smaller than the remainder of the alternatives.

6.4.4 In Situ Grouting – Alternative 3

6.4.4.1 Radiological Risk (In Situ Grouting). The radiological risk from the implementation of this in situ grouting alternative (Alternative 3) was evaluated quantitatively and qualitatively. The in situ grouting alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), contaminant grouting (Module 11), Pad A removed with treatment and shipped to the Low-Level Waste Pit (Module 18), organic contamination in the vadose zone maintenance and operations (Module 20), and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-14.

Table 6-14. Summary of radiological risk for the in situ grouting alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
Evapotranspiration Cap (3)	1.7E-04	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	4.8E-05	—[a]	—[a]
Dynamic Compaction of Pits (8)	4.8E-05	—[a]	—[a]
Contaminant Grouting (11)	7.2E-05		
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	7.4E-04	9.0E-08	3.15E-09
From Transport			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Contaminant Grouting (11)			
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

Construction of the evapotranspiration cap (3) will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 3.5 years. This resulted in a cancer risk of 1.7E-04 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Gas vent layer extraction pipe (6) involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not disturb waste materials. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Dynamic compaction of pits (8) is not anticipated to generate airborne radionuclide material. Therefore, risk to a collocated worker and a member of the public is not assessed. However, the worker is anticipated to be exposed to negligible radioactive material in which the waste is exposed due to void space compaction and from external exposures to buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Contaminant grouting (11) is not anticipated to generate airborne radioactive material. The radioactive waste remains in the ground and under the soil cover during grouting. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 1.5 years. This resulted in a cancer risk of 7.2E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Pad A removed with treatment and shipped to the Low-Level Waste Pit (18) is anticipated to generate airborne radioactive material. Therefore, the risk to workers, a collocated worker, and a member of the public was evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of 1.5 years and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 0.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 7.4E-04. The MEI cancer risk to a collocated worker and a member of the public was estimated as 9.0E-08 and 3.15E-09, respectively.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuited for evaluation for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.4.2 Chemical Risk (In Situ Grouting). The chemical risk from the implementation of this in situ grouting alternative (Alternative 3) was evaluated qualitatively. The in situ grouting alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic

compaction of pits (Module 8), contaminant grouting (Module 11), Pad A removal with treatment and shipped to the Low-Level Waste Pit (Module 18), and organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-15.

Table 6-15. Summary of chemical risks and hazards for the in situ grouting alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
Evapotranspiration Cap (3)	__[a]	__[a]	__[a]
Gas Vent Layer Extraction Pipe (6)	__[a]	__[a]	__[a]
Dynamic Compaction of Pits (8)	__[a]	__[a]	__[a]
Contaminant Grouting (11)	__[a]	__[a]	__[a]
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	__[a]	__[a]	__[a]
Chronic Hazard Index			
Evapotranspiration Cap (3)	__[a]	__[a]	__[a]
Gas Vent Layer Extraction Pipe (6)	__[a]	__[a]	__[a]
Dynamic Compaction of Pits (8)	__[a]	__[a]	__[a]
Contaminant Grouting (11)	__[a]	__[a]	__[a]
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	__[a]	__[a]	__[a]
Acute Hazard Index			
Evapotranspiration Cap (3)	__[a]	__[a]	__[a]
Gas Vent Layer Extraction Pipe (6)	__[a]	__[a]	__[a]
Dynamic Compaction of Pits (8)	__[a]	__[a]	__[a]
Contaminant Grouting (11)	__[a]	__[a]	__[a]
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	__[a]	__[a]	__[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The risk for the evapotranspiration cap (3) and gas vent layer extraction pipe (6) is considered negligible for the worker, collocated worker, and member of the public. These activities will not result in significant releases of chemicals to the environment. The evapotranspiration cap will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. Gas vent layer extraction pipe involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not involve the disturbance of waste materials. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units. Significant releases of chemical contaminants are not expected from this sampling alternative. Since no radioactive

material is removed during this module there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Dynamic compaction of pits (8) is not anticipated to generate airborne chemical material. Therefore, risk to workers, collocated workers, and members of the public are not assessed. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Pad A removal with treatment and shipment to the Low-Level Waste Pit (18) is not anticipated to generate significant releasable airborne chemical material. Based on a qualitative evaluation of the types and physical properties of the chemicals present, it was determined that the risk from the Pad A treatment option would be significantly less than the risk determined quantitatively for any of the retrieval options (see Sections 6.4.5, 6.4.6 and 6.4.7). Therefore, risks to workers, collocated workers, and members of the public are considered negligible for this module.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.4.3 Industrial and Transportation Injuries and Fatalities (In Situ Grouting). The risk due to industrial and transportation injuries and fatalities from the implementation of the in situ grouting (Alternative 3) was evaluated based on worker-hours and mileage. The in situ grouting alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), contaminant grouting (Module 11), Pad A removal with treatment and shipment to the Low-Level Waste Pit (Module 18), and organic contamination in the vadose zone maintenance and operations (Module 20). A summary of the accident and injuries by module for this alternative is included in Table 6-16. As can be seen in this table, not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways, resulting in no public component. In the case of the slurry cut-off wall, most of the material is delivered using only public highways and the co-located worker component is negligible. Modules with no transportation accidents listed indicates that all transportation is done within the remediation area.

Table 6-16. Summary of industrial and transportation injuries and fatalities for the in situ grouting alternative.

Module Name (Number)	Industrial Accidents[a]	Transportation Accidents[b]		
	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
Evapotranspiration Cap (3)	3	<1	1	1
Gas Vent Layer Extraction Pipe (6)	<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<1	—[c]	—[c]	—[c]
Contaminant Grouting (11)	1	<<1	<1	<1
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	7	—[c]	—[c]	—[c]
Number of Fatalities				
Evapotranspiration Cap (3)	<<1	<<1	<<1	<<1
Gas Vent Layer Extraction Pipe (6)	<<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<<1	—[c]	—[c]	—[c]
Contaminant Grouting (11)	<<1	<<1	<<1	<<1
Pad A Removal w/Treatment and Shipped to Low-Level Waste Pit (18)	<<1	—[c]	—[c]	—[c]

a. Industrial accidents only apply to those performing remediation work on-Site.
b. Transportation accidents are only considered off-Site and do not apply to the remediation workers.
c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The injury and fatality rates for the evapotranspiration cap (3) were 3, <<1 and 1, <<1 for industrial and transportation, respectively. The rates for gas vent layer extraction pipe (6) were <1 for injuries and <<1 fatalities from industrial only because there was no transportation component for this module. Injuries and fatalities for dynamic compaction of pits (8) and Pad A removal with treatment and shipment to the Low-Level Waste Pit (18) are for industrial accidents only because no transportation was involved. These are <1 and 7 for injuries and <<1 and <<1 for fatalities respectively. Injuries and fatalities for contaminant grouting (11) were 1 and <<1 for industrial accidents and <1 and <<1 for transportations accidents.

6.4.5 Two-Acre Retrieval, Treatment, and Disposal – Alternative 4a

6.4.5.1 Radiological Risk (Two-Acre Retrieval, Treatment, and Disposal). The radiological risk from the implementation of this two-acre RTD alternative (Alternative 4a) was evaluated quantitatively and qualitatively. The two-acre RTD alternative involves the slurry cut-off wall (Module 1), proof rolling (Module 2), evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction Pad A (Module 9), two-acre excavation (Module 12), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-17.

Table 6-17. Summary of radiological risk for the two-acre RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
Slurry Cut-Off Wall (1)	—[a]	—[a]	—[a]
Proof Rolling (2)	2.4E-05	—[a]	—[a]
Evapotranspiration Cap (3)	1.7E-04	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	4.8E-05	—[a]	—[a]
Dynamic Compaction of Pad A (9)	1.2E-05	—[a]	—[a]
Two-acre Excavation (12)	2.4E-03	1.1E-04	3.77E-06
From Transport			
Slurry Cut-Off Wall (1)	—[a]	—[a]	—[a]
Proof Rolling (2)	—[a]	—[a]	—[a]
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pad A (9)	—[a]	—[a]	—[a]
Two-acre Excavation (12)	—[a]	—[a]	4.3E-04

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The slurry cut-wall (1) consists of digging a trench around the SDA and immediately filling the trench with bentonite slurry. Since all of the activity involved in this module is external to the SDA, no contaminated material will be disturbed and the risk to the collocated worker and member of the public is considered negligible for this module. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Proof rolling (2) will not disturb waste material and involves negligible disturbance of the surface soils in the upper few inches. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 0.5 years. This resulted in a cancer risk of 2.4E-05 for the MEI worker. Since no

radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Constructing the evapotranspiration cap (3) will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 3.5 years. This resulted in a cancer risk of 1.7E-04 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Installing the gas vent layer extraction pipe (6) involves installing gas vents and distribution lines into the new evapotranspiration surface barrier system. This module does not involve the disturbance of waste materials. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Dynamic compaction of Pad A (9) is not anticipated to generate airborne radionuclide material. Therefore, risk to a collocated worker and a member of the public was not assessed. However, the worker is anticipated to be exposed to negligible radioactive material in which the waste is exposed due to void space compaction and from external exposure to buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 0.5 years. It was assumed that no additional dose rate would be encountered when the compaction occurred. This resulted in a cancer risk of 1.2E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Two-acre excavation (12) is anticipated to generate airborne radioactive material. Therefore, the risk to workers, collocated workers, and members of the public was evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of 3.5 years, and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 1.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 2.4E-03. The MEI cancer risk to a collocated worker and a member of the public was estimated as 1.1E-04 and 3.77E-06, respectively. A transportation dose to the MEI member of the public was calculated and found to be 4.3E-04. Transportation doses to the remediation worker and collocated worker are negligible.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.5.2 Chemical Risk (Two-Acre Retrieval, Treatment, and Disposal). The chemical risk from the implementation of this two-acre RTD alternative (Alternative 4a) is evaluated quantitatively and qualitatively. The two-acre RTD alternative involves the slurry cut-off wall (Module 1), proof rolling (Module 2), evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction Pad A (Module 9), two-acre excavation (Module 12), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-18.

The risk for the slurry cut-off wall (1), proof rolling (2), evapotranspiration cap (3), and gas vent layer extraction pipe (6), is considered negligible for the workers, collocated workers, and members of the public. These activities will not result in significant releases of chemicals to the environment. Proof rolling will not disturb waste material and involves the negligible disturbance of the surface soils in the upper few inches. The evapotranspiration cap module will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The slurry cut-off wall involves trenching and bentonite slurry activities outside of the waste zone. Gas vent layer extraction pipe involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This alternative module does not involve the disturbance of waste materials.

Dynamic compaction of Pad A (9) is not anticipated to generate significant airborne chemical material. Therefore, risks to workers, collocated workers, and members of the public were not assessed.

The two-acre excavation (12) is anticipated to generate airborne chemical material. The remediation workers are expected to be protected through the proper use of site safety controls and personal protective equipment. Therefore the risks to the remediation workers was considered negligible. However, the risks to collocated workers and members of the public were evaluated quantitatively. The cancer risks are presented in Table 6-18. The chronic and acute hazard indexes, also presented in Table 6-18, for the co-located worker and the members of the public are less than 1, indicating that there is no hazard from acute or chronic hazards.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

Table 6-18. Summary of chemical risks and hazards for the two-acre RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
Slurry Cut-Off Wall (1)	—[a]	—[a]	—[a]
Proof Rolling (2)	—[a]	—[a]	—[a]
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pad A (9)	—[a]	—[a]	—[a]
Two-acre Excavation (12)	—[a]	1.1E-05	1.3E-05
Chronic Hazard Index			
Slurry Cut-Off Wall (1)	—[a]	—[a]	—[a]
Proof Rolling (2)	—[a]	—[a]	[a]
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pad A (9)	—[a]	—[a]	—[a]
Two-acre Excavation (12)	—[a]	0.35	0.40
Acute Hazard Index			
Slurry Cut-Off Wall (1)	—[a]	—[a]	—[a]
Proof Rolling (2)	—[a]	—[a]	—[a]
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pad A (9)	—[a]	—[a]	—[a]
Two-acre Excavation (12)	—[a]	0.35	0.20

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

6.4.5.3 Industrial and Transportation Injuries and Fatalities (Two-Acre Retrieval, Treatment, and Disposal). The industrial accident and transportation risks from the implementation of this two-acre RTD alternative (Alternative 4a) were evaluated based on the slurry cut-off wall (Module 1), proof rolling (Module 2), evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of Pad A (Module 9), and two-acre excavation (Module 12). As can be seen from Table 6-19 not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways, resulting in no public component. In the case of the slurry cut-off wall, most of the material is delivered using only public highways and the co-located worker component is negligible. Modules with no transportation accidents listed indicates all transportation is done within the remediation area. A summary of the accident and injuries by module for this alternative is included in Table 6-19.

Table 6-19. Summary of industrial and transportation injuries and fatalities for the two-acre RTD alternative.

Module Name (Number)	Industrial Accidents[a]	Transportation Accidents[b]		
	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
Slurry Cut-Off Wall (1)	<<1	—[c]	<<1	<<1
Proof Rolling (2)	<<1	<<1	—[c]	<<1
Evapotranspiration Cap (3)	3	<1	1	1
Gas Vent Layer Extraction Pipe (6)	<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pad A (9)	<<1	—[c]	—[c]	—[c]
Two-acre Excavation (12)	29	<<1	2	2
Number of Fatalities				
Slurry Cut-Off Wall (1)	<<1	—[c]	<<1	<<1
Proof Rolling (2)	<<1	<<1	—[c]	<<1
Evapotranspiration Cap (3)	<<1	<<1	<<1	<<1
Gas Vent Layer Extraction Pipe (6)	<<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pad A (9)	<<1	—[c]	—[c]	—[c]
Two-acre Excavation (12)	<<1	<<1	<<1	<<1

a. Industrial accidents only apply to those performing remediation work on-Site.
b. Transportation accidents are only considered off-Site and do not apply to the remediation workers.
c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The injury risks due to industrial accidents for the slurry cut-off wall (1), proof rolling (2), evapotranspiration cap (3), gas vent layer extraction pipe (6), dynamic compaction of Pad A (9), and two-acre excavation (12) are <<1, <<1, 3, <1, <<1, and 29 respectively. For fatalities, they are <<1, <<1, <<1, <<1, <<1, and <<1 respectively.

The only modules in this alternative that have significant transportation activities are the slurry cut-off wall, proof rolling, evapotranspiration cap, and two-acre excavation. The injury risks from transportation from these modules are projected to be <<1, <<1, 1, and 2, respectively. For fatalities, the projected risks are <<1, <<1, <<1, and <<1, respectively. The injury risks from transportation from these modules are projected to be <<1, <<1, 1, and 2, respectively. For fatalities, the projected risks are <<1, <<1, <<1, and <<1, respectively.

The largest contributor to injury risks for this alternative is the two-acre excavation module. The largest contributors to fatalities are the evapotranspiration cap and two-acre excavation modules. Both of these modules make their largest contribution through transportation accidents because they involve hauling large amounts of materials to form the cap and transporting transuranic waste over long distances to the Waste Isolation Pilot Plant. Total injury and fatality risks for two-acre RTD are given in Table 6-5. Both of them are smaller than the corresponding risk for four-acre and full RTD, but larger than for the other alternatives.

6.4.6 Four-Acre Retrieval, Treatment, and Disposal – Alternative 4b

6.4.6.1 Radiological Risk (Four-Acre Retrieval, Treatment, and Disposal). The radiological risk from the implementation of this four-acre RTD alternative (Alternative 4b) was evaluated quantitatively and qualitatively. The four-acre RTD alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), four-acre excavation (Module 13), Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (Module 16), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-20.

Table 6-20. Summary of radiological risk for the four-acre RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
Evapotranspiration Cap (3)	1.7E-04	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	4.8E-05	—[a]	—[a]
Dynamic Compaction of Pits (8)	4.8E-05	—[a]	—[a]
Four-acre Excavation (13)	3.0E-03	1.8E-04	6.33E-06
Pad A Removal and Ship to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	7.4E-04	9.0E-08	3.15E-09
From Transport			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	[a]
Four-acre Excavation (13)	—[a]	—[a]	5.4E-04
Pad A Removal and Ship to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The evapotranspiration cap (3) will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of 3.5 years. This resulted in a cancer risk of 1.7E-04 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

The gas vent layer extraction pipe (6) involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not involve the disturbance of waste materials. Therefore, the risk to the collocated worker and member of the public is considered

negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Dynamic compaction of pits (8) is not anticipated to generate airborne radionuclide material. Therefore, risk to a collocated worker and a member of the public was not assessed. However, the worker is anticipated to be exposed to negligible radioactive material in which the waste is exposed due to void space compaction and from external exposures to buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 4.8E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Four-acre excavation (13) is anticipated to generate airborne radioactive material. Therefore, the risk to workers, collocated workers, and members of the public was evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of six years and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of two years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 3.0E-03. The MEI cancer risk to a collocated worker and a member of the public was estimated as 1.8E-04 and 6.33E-06, respectively. The cancer risk to the MEI member of the public due to waste transportations was calculated to be 5.4E-04. The risk to the remediation worker and collocated worker was assumed to be negligible

Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (16) is anticipated to generate airborne radioactive material. Therefore, the risk to workers, collocated workers, and members of the public was evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of 1.5 years and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 0.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 7.4E-04. The MEI cancer risk to a collocated worker and a member of the public was estimated as 9.0E-08 and 3.15E-09, respectively. Since no waste is transported off-Site from this alternative the cancer risk to the MEI member of the public is assumed to be zero and negligible to the remediation and collocated workers.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.6.2 Chemical Risk (Alternative 4b). The chemical risk from the implementation of this four-acre RTD alternative (Alternative 4b) is evaluated quantitatively and qualitatively. The partial RTD alternative involves evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), four-acre excavation (Module 13), Pad A removal and shipment

to Idaho CERCLA Disposal Facility for treatment and disposal (Module 16), organic contamination in the vadose zone maintenance and operations (Module 20), and long-term monitoring and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-21.

The risk for the evapotranspiration cap (3) and gas vent layer extraction pipe (6) are considered negligible for the workers, collocated workers, and members of the public. These activities will not result in significant releases of chemicals to the environment. The evapotranspiration cap module will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. Gas vent layer extraction pipe involves installing gas vents and distribution lines into the newly installed evapotranspiration surface barrier system. This module does not involve the disturbance of waste materials.

Dynamic compaction of pits (8) is not anticipated to generate airborne chemical material. Therefore, risk to workers, collocated workers, and members of the public are not assessed.

Four-acre excavation (13) is anticipated to generate airborne chemical material. Therefore, the risks to collocated workers and members of the public were evaluated quantitatively. The remediation workers are expected to be protected through the proper use of site safety controls and personal protective equipment. Therefore the risk to the remediation workers was considered negligible. The cancer risks for the co-located workers and public, presented in Table 6-21, are within levels generally believed to be negligible. The chronic and acute hazard indices, also presented in Table 6-21 for the co-located worker and the members of the public are less than 1, indicating that there is no hazard from acute or chronic hazards.

Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (16) is not anticipated to generate significant airborne chemical material. Based on a qualitative evaluation of the types of chemicals likely present, it was determined that the risk from the Pad A removal option will be less than the risk determined quantitatively for the full retrieval option. Therefore, risk to the worker, collocated worker, and a member of the public is assumed to be negligible

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time, making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated

Table 6-21. Summary of chemical risks and hazards for the four-acre RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Four-acre Excavation (13)	—[a]	1.3E-05	1.4E-05
Pad A Removal and Shipment to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	—[a]	—[a]	—[a]
Chronic Hazard Index			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Four-acre Excavation (13)	—[a]	0.40	0.45
Pad A Removal and Shipment to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	—[a]	—[a]	—[a]
Acute Hazard Index			
Evapotranspiration Cap (3)	—[a]	—[a]	—[a]
Gas Vent Layer Extraction Pipe (6)	—[a]	—[a]	—[a]
Dynamic Compaction of Pits (8)	—[a]	—[a]	—[a]
Four-acre Excavation (13)	—[a]	0.37	0.21
Pad A Removal and Shipment to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

6.4.6.3 Industrial and Transportation Injuries and Fatalities (Alternative 4b). The industrial accident and transportation risks from the implementation of this four-acre RTD alternative (Alternative 4b) were evaluated based on the evapotranspiration cap (Module 3), gas vent layer extraction pipe (Module 6), dynamic compaction of pits (Module 8), four-acre excavation (Module 13), and Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (Module 16). A summary of the accident and injuries by module for this alternative is included in Table 6-22. As can be seen from Table 6-20 not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways resulting in no public component. Modules with no transportation accidents listed indicates that all transportation is done within the remediation area.

Table 6-22. Summary of industrial and transportation injuries and fatalities for the four-acre retrieval, treatment, and disposal alternative.

	Industrial Accidents[a]	Transportation Accidents[b]		
Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
Evapotranspiration Cap (3)	3	<1	1	1
Gas Vent Layer Extraction Pipe (6)	<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<1	—[c]	—[c]	—[c]
Four-acre Excavation (13)	44	<<1	3	3
Pad A Removal and Shipment to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	9	<<1	—[c]	<<1
Number of Fatalities				
Evapotranspiration Cap (3)	<<1	<<1	<<1	<<1
Gas Vent Layer Extraction Pipe (6)	<<1	—[c]	—[c]	—[c]
Dynamic Compaction of Pits (8)	<<1	—[c]	—[c]	—[c]
Four-acre Excavation (13)	<<1	<<1	<<1	<<1
Pad A Removal and Shipment to Idaho CERCLA Disposal Facility for Treatment and Disposal (16)	<<1	<<1	—[c]	—[c]

a. Industrial hazards only apply to those performing remediation work on-Site.

b. Transportation hazards are only considered off-Site and do not apply to the remediation workers.

c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The injury risks due to industrial accidents for the evapotranspiration cap (3), gas vent layer extraction pipe (6), dynamic compaction of pits (8), four-acre excavation (13), and Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (16) are 3, <1, <1, 44, and 9, respectively. For fatalities they are <<1, <<1, <<1, <<1, and <<1, respectively.

The injury and fatality risks from transportation accidents are only from the evapotranspiration cap (3), four-acre excavation (13), and Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (16). For injuries, they are 1, 3, and <<1, respectively, and for fatalities <<1, <<1, and <<1, respectively.

The largest contributor to injuries for the four-acre RTD alternative is the four-acre excavation module, primarily through industrial accidents. That module is also the largest contributor to fatalities, through both industrial and transportation accidents. It involves excavating a relatively large volume of material and transporting transuranic waste long distances to the Waste Isolation Pilot Plant. The evapotranspiration cap module also contributes significantly to transportation fatality risk because of the large amount of material that is brought to the site to form the cap.

Total injury and fatality risks for the four-acre RTD are given in Table 6-5. Those risks are larger than for all other alternatives, except for full RTD.

6.4.7 Full Removal, Treatment, and Disposal – Alternative 5

6.4.7.1 Radiological Risk (Full Removal, Treatment, and Disposal). The radiological risk from the implementation of the full RTD alternative (Alternative 5) was evaluated quantitatively and qualitatively. The full RTD alternative involves evapotranspiration cap without gas vent layer (Module 4), full excavation (Module 14), Pad A removal and ship off-Site for treatment and disposal (Module 17), organic contamination in the vadose zone maintenance and operations (Module 20) and long-term monitoring and cap maintenance. A summary of the radiological risks by module for this alternative is included in Table 6-23.

Table 6-23. Summary of radiological risk for the full RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
From Remediation			
Evapotranspiration Cap w/o Gas Vent Layer (4)	7.2E-05	—[a]	—[a]
Full Excavation (14)	1.2E-02	1.0E-03	3.5E-05
Pad A Removal and Shipment Off-Site for Treatment and Disposal (17)	7.4E-04	9.0E-08	3.2E-09
Organic Contamination in Vadose Zone Maintenance and Operations (20)	—[a]	—[a]	—[a]
From Transport			
Evapotranspiration Cap w/o Gas Vent Layer (4)	—[a]	—[a]	—[a]
Full Excavation (14)	—[a]	—[a]	3.8E-02
Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	—[a]	—[a]	3.0E-04

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The risk for the evapotranspiration cap extraction without gas vent layer (4) will involve earth work that is largely restricted to materials being brought on-Site to support cap construction. The radioactive waste remains in the ground and under the soil cover during cap construction. Therefore, the risk to the collocated worker and member of the public is considered negligible for this module. However, the worker is assumed to be exposed to external radiation from the buried waste. The MEI worker cancer risk over the project duration was evaluated quantitatively based on an assumed exposure rate of 0.03 mrem/hr, a 2,000-hour working year, and total project duration of one year. This resulted in a cancer risk of 7.2E-05 for the MEI worker. Since no radioactive material is removed during this module, there is no radiological risk from transportation to the remediation worker, collocated worker or members of the public.

Full excavation (14) is anticipated to generate airborne radioactive material. Therefore, the risk to collocated workers and members of the public was evaluated quantitatively. The remediation workers are expected to be protected through the proper use of site safety controls and personal protective equipment. Therefore the risks to the remediation workers was considered negligible. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of 25 years and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 5.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 1.2E-02. The MEI cancer risk to a collocated worker and a member of the public was estimated as 1.0E-03 and 3.5E-05, respectively. The cancer risk to the remediation work and collocated worker from transportation was assumed to be negligible. The Risk from transportation to the MEI member of the public was calculated to be 3.8E-02.

Pad A removal and shipment off-Site for treatment and disposal (17) are anticipated to generate airborne radioactive material. Therefore, the risk to workers, collocated workers, and members of the public were evaluated quantitatively. The MEI worker cancer risk over the project duration was evaluated based on assumed exposure rates of 0.3 mrem/hr for the waste retrieval activities for a duration of 1.5 years and 0.03 mrem/hr for decontamination and decommissioning activities for a duration of 0.5 years. The worker was assumed to be exposed for 2,000 hours per year. This resulted in a MEI worker cancer risk of 7.4E-04. The MEI cancer risk to a collocated worker and a member of the public was estimated as 9.0E-08 and 3.2E-09, respectively. The cancer risk to the remediation work and collocated worker from transportation was assumed to be negligible. The risk from transportation to the MEI member of the public was calculated to be 3.0E-04.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time making this module unsuitable to evaluate for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated

6.4.7.2 Chemical Risk (Full Removal, Treatment, and Disposal). The chemical risk from the implementation of the full RTD alternative (Alternative 5) was evaluated quantitatively and qualitatively. The full RTD alternative involves evapotranspiration cap without gas vent layer (Module 4), full excavation (Module 14), Pad A removal and ship off-Site for treatment and disposal (Module 17), organic contamination in the vadose zone maintenance and operations (Module 20), and long-term monitoring

and cap maintenance. A summary of the chemical risks and hazards by module for this alternative is included in Table 6-24.

Table 6-24. Summary of chemical risks and hazards for the full RTD alternative.

Module Name (Number)	Remediation Worker	Collocated Worker	Member of Public
Cancer Risk			
Evapotranspiration Cap w/o Gas Vent Layer (4)	—[a]	—[a]	—[a]
Full Excavation (14)	—[a]	2.7E-05	2.9E-05
Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	—[a]	—[a]	—[a]
Chronic Hazard Index			
Evapotranspiration Cap w/o Gas Vent Layer (4)	—[a]	—[a]	—[a]
Full Excavation (14)	—[a]	0.86	0.92
Pad A Removal and Shipment Off-Site for Treatment and Disposal (17)	—[a]	—[a]	—[a]
Acute Hazard Index			
Evapotranspiration Cap w/o Gas Vent Layer (4)	—[a]	—[a]	—[a]
Full Excavation (14)	—[a]	0.32	0.18
Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	—[a]	—[a]	—[a]

a. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

The risk for the evapotranspiration cap without gas vent layer (4) is considered negligible for the workers, collocated workers, and members of the public. This activity will not result in significant releases of chemicals to the environment. Evapotranspiration cap without gas vent layer will involve earth work that is largely restricted to materials being brought on-Site to support cap construction.

Full excavation (14) is anticipated to generate airborne chemical material. The remediation workers risk is assumed to be negligible because the workers are expected to be protected through the proper use of site safety controls and personal protective equipment. However, the risk to collocated workers and members of the public was evaluated quantitatively. The cancer risk from full RTD, presented in Table 6-24, is higher than for the other alternatives. The chronic and acute hazard indexes, also presented in Table 6-24 for the co-located worker and the members of the public, are less than 1, indicating that there is no hazard from acute or chronic hazards.

Pad A removal and shipment to Idaho CERCLA Disposal Facility for treatment and disposal (17) is not anticipated to generate significant airborne chemical material. Based on a qualitative evaluation of the types of chemicals likely present, it was determined that the risk from the Pad A removal option will be less than the risk determined quantitatively for the full retrieval option. Therefore, risk to the worker, collocated worker, and a member of the public is assumed to be negligible.

The risk for organic contamination in the vadose zone maintenance and operations (20) was not considered for the worker, collocated worker, and member of the public. The organic contamination in the vadose zone maintenance and operations module involves sampling of the vadose zone organic contaminants and maintenance of treatment units over an extended period of time making this module unsuited for evaluation for the short-term risk assessment.

Long-term monitoring activities involving groundwater sampling, lysimeter sampling, and vapor port sampling will continue for 100 years after completion project. Since the long-term nature of this task is outside the scope of a short-term risk assessment, risks were not evaluated.

6.4.7.3 Industrial and Transportation Injuries and Fatalities (Full Removal, Treatment, and Disposal). The industrial accident and transportation risks from the implementation of the full RTD alternative (Alternative 5) were evaluated based on evapotranspiration cap without gas vent layer (Module 4), full excavation (Module 14), and Pad A removal and shipment off-Site for treatment and disposal (Module 17). A summary of the accident and injuries by module for this alternative is included in Table 6-25.

As can be seen in Table 6-25, not all modules have an associated transportation injury or fatality. This is due to the nature of the material being moved since some material is delivered without using public highways, resulting in no public component. Modules with no transportation accidents listed indicates that all transportation is done within the remediation area.

The projected injury risks due to industrial accidents for the evapotranspiration cap without gas vent layer (4), full excavation (14), and Pad A removal and shipment off-Site for treatment and disposal (17), are 2, 611, and 3, respectively. The corresponding fatality risks are <<1, <1, and <<1, respectively.

The injury risks from transportation for the evapotranspiration cap without gas vent layer, full excavation, and Pad A removal and shipment off-Site for treatment and disposal modules are <1, 30, and <1, respectively, and the corresponding fatality risks are <<1, <1, and <<1, respectively. There are no transportation risks from organic contamination in the vadose zone maintenance and operations.

The projected injury risk for full RTD is dominated by those from industrial accidents in the full excavation module. The fatality risk is also dominated by this module, but with similar parts from industrial and transportation accidents. Total injury and fatality risks for full RTD are given in Table 6-5. They are the largest such risks for all of the remedial alternatives considered and are almost an order of magnitude higher than from any other alternative.

Table 6-25. Summary of industrial and transportation injuries and fatalities for the full RTD alternative.

Module Name (Number)	Industrial Accidents[a]	Transportation Accidents[b]		
	Remediation Worker	Collocated Worker	Member of Public	Total Accidents
Number of Injuries				
Evapotranspiration Cap w/o Gas Vent Layer (4)	2	<<1	<1	<1
Full Excavation (14)	611	<<1	30	30
Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	3	<1	—[c]	<1
Number of Fatalities				
Evapotranspiration Cap w/o Gas Vent Layer (4)	<<1	<<1	<<1	<<1
Full Excavation (14)	<1	<<1	<1	<1
Pad A Removal and Ship Off-Site for Treatment and Disposal (17)	<<1	<<1	—[c]	<<1

a. Industrial hazards only apply to those performing remediation work on-Site.

b. Transportation hazards are only considered off-Site and do not apply to the remediation workers.

c. Risk assessed qualitatively and is either 1) negligible based on qualitative analysis or 2) not assessed based on absence of contaminant generator.

6.5 Comparison of Risk by Remedial Alternatives

The risk from each module that composes an alternative was summed, where possible, to provide a side-by-side risk comparison for each alternative. Table 6-26 shows the risk and hazards from each alternative for the remediation worker, collocated worker, and members of the public for radionuclide risk, chemical carcinogenic risk and hazards, and injuries and fatalities from accidents.

In addition to the activities that have been identified and quantified, as part of institutional controls a perimeter road and fence may be installed in association with and after the building of a surface barrier. However, the radiological, chemical, and industrial risks associated with this activity would be negligible when compared with the other remedial activities due to the shielding provided by the surface barrier and the short timeframe needed to complete the activity.

6.5.1 No Action – Alternative 1

There is no risk associated with alternative 1 since all of the work involved in this alternative has been defined as long-term maintenance.

Table 6-26. Summary of risks for each alternative.

	Criterion	No Action 1.00	Surface Barrier: Modified RCRA C 2a	Surface Barrier: Evapotranspiration 2b	In Situ Grouting 3	Retrieval, Treatment, and Disposal: 2 Acre 4a	Retrieval, Treatment, and Disposal: 4 Acre 4b	Retrieval, Treatment, and Disposal: Full 5
Radiological Risk	**Cancer Risk-*Remediation***							
	Remediation Worker	△	2.9E-04	7.6E-04	1.1E-03	2.6E-03	4.0E-03	1.3E-02
	Collocated Worker	△	○	9.0E-08	9.0E-08	1.1E-04	1.8E-04	1.0E-03
	Public	△	○	3.2E-09	3.2E-09	3.8E-06	6.3E-06	3.5E-05
	Cancer Risk-*Transport*							
	Remediation Worker	△	○	○	◒	●	●	●
	Collocated Worker	△	○	○	○	●	●	●
	Public	△	○	○	○	4.3E-04	5.4E-04	3.8E-02
Chemical Risk	**Cancer Risk**							
	Remediation Worker	△	○	○	◒	●	●	●
	Collocated Worker	△	○	○	○	1.1E-05	1.3E-05	2.7E-05
	Public	△	○	○	○	1.3E-05	1.4E-05	2.9E-05
	Chronic Hazard Index							
	Remediation Worker	△	○	○	◒	●	●	●
	Collocated Worker	△	○	○	○	0.35	0.40	0.86
	Public	△	○	○	○	0.40	0.45	0.92
	Acute Hazard Index							
	Remediation Worker	△	○	○	◒	●	●	●
	Collocated Worker	△	○	○	○	0.35	0.37	0.32
	Public	△	○	○	○	0.20	0.21	0.18
Industrial and Transportation Injuries and Fatalities	**Number of Injuries**							
	Remediation Worker[a]	△	5.00	7.00	12.00	32.00	56.00	616.00
	Collocated Worker[b]	△	<1	<1	<1	<1	<1	<1
	Public[b]	△	<1	1.00	1.00	4.00	4.00	30.00
	Number of Fatalities							
	Remediation Worker[a]	△	<<1	<<1	<<1	<<1	<<1	<1
	Collocated Worker[b]	△	0.00	0.00	0.00	0.00	<<1	<<1
	Public[b]	△	<<1	<<1	<<1	<<1	<<1	<1

a Industrial accidents only
b Transportation accidents only

Not Evaluated △

Qualitatively Evaluated Risk
● Very low risk
◒ Extremely low risk
○ No risk

Quantatively Evaluated Risk
1E-4<Risk — High risk
1E-6<Risk<1E-4 — Moderate risk
Risk<1E-6 — Low risk

6.5.2 Surface Barrier RCRA Type C Cap – Alternative 2a

Table 6-26 compares risk among the remedial alternatives. The risk from the implementation of the surface barrier—RCRA Type C cap—is small compared with the retrieval alternatives. The risk is greater than that of the no action alternative because of an increased number of worker hours required to install the cap, and the preparation and site work that goes along with cap installation. The risk is based on the administrative dose limit per year that will be allowed for remedial workers and historical background

dosimetry readings at the SDA. Also, because of additional man hours involved in transporting materials to make the cap, the number of injury occurrences from transportation accidents to the collocated worker and public has increased from Alternative 1 because of the proximity of workers to buried waste.

The number of injuries and fatalities to the remediation and collocated workers is due to man hours required for this installation. The transportation of the materials to the site and on the site is responsible for those injuries and fatalities to the remediation workers. The public injuries are estimated at 5 to the remediation worker and <1 to the general public.

6.5.3 Surface Barrier Evapotranspiration Cap – Alternative 2b

The implementation of the surface barrier evapotranspiration cap has similar radiological and chemical risks to the RCRA Type C cap. The risk of injuries to the remediation worker public is increased in this alternative, compared to alternatives 2a, because more time is required in the SDA due to the number of labor hours and the type of labor required to retrieve the waste, the amount of transport needed to transport materials, and the time it takes to construct the evapotranspiration cap. Also, there is a low risk to the collocated worker and the public from radiation due to the removal of Pad A. Injuries are estimated at 7 to the remediation worker and 1 to the general public.

6.5.4 In Situ Grouting – Alternative 3

The radiological and chemical risk from the implementation of in situ grouting is slightly higher overall than the radiological and chemical risk from the evapotranspiration cap. The radiological risk to the collocated worker and the public is low. Radiological risk to the remediation worker is a high risk for the in situ grouting alternative due to the time required to complete the task. Chemical risk is assumed to be relatively consistent with risk in alternative 2a and 2b assuming some minimum exposure of VOC through the surface of the SDA. The additional hours needed to transport the supply grout also increases the number of injuries by a small margin from alternative 2b. Injuries are estimated at 12 to the remediation worker and 1 to the general public.

6.5.5 Two-Acre Removal, Treatment, and Disposal – Alternative 4a

The implementation of the RTD alternatives has a higher risk than alternatives 2a, 2b, and 3 discussed previously. The risk associated with the RTD alternatives increases with the additional volume of retrieval, since more retrieval means more time to retrieve the waste and more shipments, leading to more transportation accidents and also radiological risk from transporting radioactive materials off-Site. The two-acre RTD has a higher radiological risk to the remediation worker, the collocated worker, and the public than the surface barrier and grouting alternatives because of the volume of material being retrieved and the relative potential for this material to be dispersed outside of the retrieval area. The two-acre RTD is the first alternative to have a radiological transportation risk to the public.

A quantifiable chemical risk is first introduced in the two-acre RTD alternative because of the volatile organic compounds that are unearthed during the retrieval process. Remediation workers are protected from the chemical risk by proper use of personal protective equipment, including respirators. The collocated worker, however, may not be wearing a respirator and would be susceptible to a moderate chemical risk. The public also is at risk, but dispersion to the nearest off-Site receptor makes that risk low. The hazard index for chronic and acute hazards was calculated, but was less than 1, meaning there is no hazard.

The risk of injuries to the remediation worker and the public is increased in this alternative, as compared to alternatives 2a, 2b, and 3, because of the number of labor hours and the type of labor

required to retrieve the waste, and the amount of transport needed to dispose of the waste. Injuries are estimated at 32 to the remediation worker and 4 to the general public. While there is some chance of fatality to the workers or the public, the injuries are still <<1.

6.5.6 Four-Acre Removal, Treatment, and Disposal – Alternative 4b

The implementation of the four-acre RTD has radiological risk from the same sources as the two-acre alternative, but the four-acre retrieval takes more time and more transportation to dispose of the waste. The increase in time yields a higher radiological risk to the worker, collocated worker, and the general public, although risk to the public is still very low.

Chemical risk is also present in the four-acre RTD alternative because of the volatile organic compounds that are unearthed during the retrieval process. The chemical risk from the four-acre RTD is slightly higher than in the two-acre RTD due to the increase in the volatile organics released. The hazard index for chronic and acute hazards is still considerably lower than 1, meaning there is no hazard.

The risk of injuries to the remediation worker and the public is increased in this alternative compared to alternatives 2a, 2b, and 3 because of the number of labor hours and the type of labor required to retrieve the waste and the amount of transport needed to dispose of the waste. Injuries to the remediation worker are estimated at 56, which is 24 more than in the two-acre RTD alternative due to the increased number of hours that are worked in order to retrieve the additional two acres. Injuries to the general public are not significantly higher due to transportation. While there is some chance of fatality to the workers or the public, the fatalities are still <<1.

6.5.7 Full Removal, Treatment, and Disposal – Alternative 5

The implementation of the full RTD has the most radiological and chemical risk of any of the chosen alternatives. The full RTD requires the most time to retrieve the waste and has the highest volume of waste to be retrieved and disposed of. The increase in time yields a higher radiological risk to the worker, collocated worker, and the general public, although risk to the public is still low. The radiological risk to the public through transportation increases significantly for this retrieval alternative because of the increased number of containers and shipments that must be taken off-Site.

Chemical risk to the collocated worker and the public is nearly twice as high for the full retrieval as it is for either of the other retrieval alternatives, although the risk to the public is still low. While the hazard index from chronic hazards approaches 1, it is still less than 1, meaning there is no hazard.

The risk of injuries to the remediation worker and the public is increased in this alternative as compared to alternatives 2a, 2b, and 3 because of the number of labor hours and the type of labor required to retrieve the waste, and the amount of transport needed to dispose of the waste. Injuries to the remediation worker are estimated at 616, while the next highest alternative only estimates 56 injuries. Also, injuries to the public are estimated at 30, while the next highest alternative estimates 4 injuries. Fatalities from accidents and transportation are still estimated at < 1 for both the remediation worker and the public, as opposed <<1 for the other retrieval alternatives.

6.6 Off-Normal Events

This report has focused on the risks from the implementation of events that are expected to occur as remedial actions associated with each remedial alternative. In addition to the expected events, there may be some off-normal events, which are events that are not planned or expected to occur but may occur as a result of unexpected events. Such events may occur due to, but not limited to, equipment failure,

unexpected field conditions, or errors made by the remedial workers. An infinite number of off-normal events could be presented; however, in this report the number of off-normal events is limited to those that are associated with the implementation of the remedial actions that are listed in the Safety Analysis Report for the ARP (INEEL 2002) and the PSDA for in-situ grouting (INEEL 2004), that have a greater than 'extremely unlikely' chance of occurring and that the consequences would be greater than negligible. The generalized summary of these events is listed below with likelihood of occurrence category, consequence category and affected population listed in parenthesis:

- High pressure grouting system fails generating a projectile or releasing high-pressure grout (anticipated, medium risk, remediation worker)
- Mechanical failure exposes remediation workers to radioactive/hazardous materials (anticipated, medium-to-high risk, remediation worker)
- PPE becomes damaged, is not working properly, or is not worn properly (anticipated, high radiological risk, low chemical risk, remediation worker)
- Heavy equipment falls into the excavation pit or through a subsidence in the cap (anticipated, high radiological risk, low chemical risk, remediation worker)
- A fire occurs in the retrieval enclosure, storage enclosure, or up to eight drums of waste during retrieval activities (anticipated, low-medium radiological risk, remediation workers)
- An accident causes up to 50 drums to catch fire during transportation (unlikely, medium radiological/chemical risk to remediation workers, low radiological/chemical risk to collocated workers).

As can be seen from the events listed above there are several realistic possibilities for off-normal events to occur during the implementation of the remedial actions. For those events that are anticipated to occur, there will be administrative and engineering controls to minimize the potential risk to those that may be affected. For example, in the case of PPE failure, administrative controls will limit the stay times of each employee and industrial health and radiological control personnel will be on-Site to assist in minimizing both the exposure duration and dose received.

In conclusion, while off-normal events have the potential to present measurable risks to remediation workers, it is anticipated that proper safety measures and controls will both limit the occurrence of off-normal events and keep the overall magnitude of these risks much lower than the risks associated with the planned remedial actions. Additionally, of the off-normal events identified none of the scenarios presented a greater than negligible risk to the public and only one scenario identified a low risk to collocated workers.

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Appendix A

Summary of Information Used for the Technical Approach to the Short-Term Risk Assessment

Appendix A

Summary of Information for the Technical Approach to the Short-term Risk Assessment

The following summarizes the information used to prepare the technical approach for the Short-term Risk Assessment (STRA). This summary should be used to confirm assumptions and provide a basis for preparation of the STRA. When some pathways or additional considerations are not shown, it may be because the risk from the remedial alternative module is thought to be minimal. For example, in the cut-off wall alternative module, exposure to workers is expected to be minimal because of required personal protective equipment. A worker may be subject to inhalation of particulates if there is a respiratory failure, but it would be unlikely that the same worker would ingest particulates or be exposed to dermal absorption because of the required personal protective equipment, yet collocated workers may be included for consideration. Members of the public are not included because significant exposure to emissions from the cut-off wall, while possible, will not be meaningful to the STRA. In this example, exposure to members of the public will be treated in a qualitative manner. Each of the remedial alternative modules will have associated construction activities. The construction activities are not noted because construction is assumed for each module.

The pathways presented in this appendix are based on the expected relative level of risk at this point. During the risk assessment, it may be determined that pathways believed to be minimal and qualitatively discussed may pose a more significant risk and will be examined quantitatively. Conversely, through the quantitative analysis, some pathways may be deemed insignificant and thus qualitatively discussed. The pathways discussed here are not expected to change but may be subject to change.

A-1. REMEDIAL ALTERNATIVE MODULE 1 – SLURRY CUT-OFF WALL

The cut-off wall will lie outside the buried waste zone and beneath the cap toe, and will extend from ground surface to the first basalt layer. It will be of bentonite emplaced using a conventional in-trench construction method.

A-1.1 Six-Month Construction Schedule

The cut-off wall will be outside the waste zone of the Subsurface Disposal Area (SDA). An additional hazard is the presence of silica in bentonite.

A-2. REMEDIAL ALTERNATIVE MODULE 2 – PROOF ROLLING

Proof rolling of the base grade will minimize superficial subsidence and provide overall surface stability for the SDA. The base grade will help control surface water run-off.

A-2.1 Six-Month Construction Schedule

The activities for this action include:

- Hauling fill
- Compact surface.

The pathways considered for this action are ingestion and inhalation of vapors and particulates. Compacting the surface may release contaminants of potential concern from the waste during minor subsidence events or may create paths in the soil for small amounts of waste to be released.

A-3. REMEDIAL ALTERNATIVE MODULE 3 – EVAPOTRANSPIRATION SURFACE BARRIER WITH BIOTIC BARRIER AND GAS VENT LAYER

The evapotranspiration surface barrier provides storage capacity sufficient to optimize evapotranspiration of groundwater to the atmosphere and limit migration through the buried waste zone. An integrated biotic barrier and gas transport layer minimizes the risk of terrestrial exposure and protects surface vegetation from volatile organic compounds and volatile radionuclides. After the surface is compacted and fill is added to grade, the waste is farther removed from the worker than previously. The activities shown in the schedule associated with the cost estimate include many of the activities that would be necessary for site preparation, including the proof rolling for surface compaction. These activities will be included in the surface compaction module. At the completion of the ET surface barrier cap installation, wells, lysimeters, vapor ports, and tensiometers will be installed and monitored at regular intervals to ensure that the waste is not migrating through the environmental media, causing an unacceptable risk. The risk associated with this activity is not included in the STRA due to the long-term nature of this activity.

A-3.1 Five-Year Construction Schedule

The activities for the ET cap include the following:

- Demolish or relocate environmental monitoring equipment and utilities
- Install water storage tank
- Install new SDA perimeter gravel road
- Install new SDA perimeter fence and demolish old SDA perimeter fence
- Abandon or extend existing wells
- Extend existing OCVZ wells and temporarily relocate OCVZ treatment units
- Install grading fill
- Install 24-in. cobble layer
- Install 12-in. gravel layer and 12-in. sand layer
- Install 48-in. fine soil layer
- Install 12-in. topsoil layer and plant vegetation
- OCVZ abovegrade piping to wells
- Install armor layers
- Install six sampling wells outside the SDA
- Recontour southern and eastern ends of SDA for drainage.

A-4. REMEDIAL ALTERNATIVE MODULE 4 – EVAPOTRANSPIRATION SURFACE BARRIER (WITHOUT BIOTIC BARRIER OR GAS VENT LAYER)

The evapotranspiration surface barrier will be installed after the Full Retrieval Alternative module has been implemented. The primary contaminant sources will be removed prior to instituting this action. The ET surface barrier without biotic barrier or gas vent layer minimizes groundwater migration through the fill replacing retrieved wastes, minimizing the potential for transport of soluble contaminants that may have migrated beyond the first basalt interface. This action will take place after wastes have been removed. The risk associated with this action from chemicals and radionuclides would be bound by the evapotranspiration surface barrier action. After the waste is removed, exposures would be minimal. It would be difficult to estimate exposure when the source of the waste is reduced significantly to an unknown quantity. Backfilling the empty pits is the only action that is not included in the evapotranspiration cap alternative module. Some exposures could occur during this activity, but they would be expected to be bound by the evapotranspiration cap action because of the significantly reduced waste inventory. At the completion of the evapotranspiration surface barrier cap installation, wells, lysimeters, vapor ports, and tensiometers will be installed and monitored at regular intervals to ensure that the waste is not migrating through the environmental media, causing an unacceptable risk. The risk associated with this activity is not included in the STRA due to the long-term nature of this activity.

A-4.1 4-1/2-Year Construction Schedule

Activities for the ET cap installed after full retrieval include the following:

- Demolish or relocate environmental monitoring equipment and utilities
- Install water storage tank
- Install new SDA perimeter gravel road
- Install new SDA perimeter fence and demolish old SDA perimeter fence
- Abandon or extend existing wells
- Extend existing OCVZ wells, and temporarily relocate OCVZ treatment units
- Install grading fill
- Install 12-in. topsoil layer and plant vegetation
- OCVZ abovegrade piping to wells
- Install six sampling wells outside the SDA
- Recontour southern and eastern ends of SDA for drainage.

A-5. REMEDIAL ALTERNATIVE MODULE 5 – MODIFIED RCRA TYPE C SURFACE BARRIER

The modified RCRA Type C surface barrier with biotic barrier will be installed after the Full Retrieval Alternative module has been implemented. The modified RCRA Type C surface barrier minimizes groundwater migration through the buried waste zone. An integrated biotic barrier minimizes the risk of terrestrial exposure. At the completion of the RCRA cap installation, wells, lysimeters, vapor ports, and tensiometers will be installed and monitored at regular intervals to ensure that the waste is not

migrating through the environmental media, causing an unacceptable risk. The risk associated with this activity is not included in the STRA due to the long-term nature of this activity

A-5.1 Five-Year Construction Schedule

The activities associated with the RCRA Type C cap include:

- Demolish or relocate environmental monitoring equipment and utilities
- Install water storage tank
- Install new SDA perimeter gravel road
- Install new SDA perimeter fence and demolish old SDA perimeter fence
- Abandon or extend existing wells
- Extend existing OCVZ wells and temporarily relocate OCVZ treatment units
- Install grading fill
- Install 4-in. asphalt base and 6-in. asphalt layer
- Install 6-in. gravel layer and 6-in. gravel filter layer
- Install 6-in. sand layer
- Install 20-in. compacted topsoil layer
- Install 20-in. topsoil layer and plant vegetation
- OCVZ abovegrade piping to wells
- Install armor layers
- Install six sampling wells outside the SDA
- Recontour southern and eastern ends of SDA for drainage.

A-6. REMEDIAL ALTERNATIVE MODULE 6 – GAS EXTRACTION MANIFOLD FOR THE EVAPOTRANSPIRATION SURFACE BARRIER

Soil gas will be actively extracted from the evapotranspration surface barrier using a manifold buried within the gas transport layer. The extraction manifold will be coupled to the OCVZ treatment system. The extraction manifold will not penetrate the buried waste.

A-6.1 Six-Month Construction Schedule

The activities associated with the gas/vapor extraction manifold include:

- Install gas vent lines within gas collection layer of cap
- Connect vent pipes to OCVZ off-gas treatment units.

A-7. REMEDIAL ALTERNATIVE MODULE 7 – GAS EXTRACTION WELLS FOR THE MODIFIED RCRA TYPE C SURFACE BARRIER

This alternative module will remove soil gas from the modified RCRA Type C surface barrier. Soil gas will be actively extracted from the modified RCRA Type C surface barrier using wells completed in the basalt below the waste zone. Gas extraction wells will be coupled to the OCVZ vapor treatment system. Soil gas is removed from the modified RCRA Type C surface barrier using extraction wells that are completed to the basalt below the waste. Soil gas is conveyed to the OCVZ system for treatment before release to the atmosphere.

A-7.1 Six-Month Construction Schedule

The activities associated with the gas/vapor extraction wells for the RCRA barrier include:

- Install gas vent lines within gas collection layer of cap
- Connect vent pipes to OCVZ off-gas treatment units.

A-8. REMEDIAL ALTERNATIVE MODULE 8 – DYNAMIC COMPACTION OF PITS

The dynamic compaction of pits will reduce voids in burial pits in order to mitigate differential subsidence of the surface barrier. Trenches and soil vaults will not require treatment to reduce voids in the buried waste. Dynamic compaction will not expose buried waste. Dynamic compaction will not disrupt operations at collocated facilities. A specialized crane is used to repeatedly drop a multi-ton weight at predetermined locations within pits at the SDA. The resulting soil compression is expected to eliminate gross void spaces within the buried waste. Impact craters are immediately covered with clean fill.

A-8.1 1-1/2-Year Construction Schedule

The activities associated with the dynamic compaction include:

- Hauling 48 in. of fill
- Dynamic compaction of 18.7 acres
- Final “iron” compaction and roller compaction.

A-9. REMEDIAL ALTERNATIVE MODULE 9 – DYNAMIC COMPACTION OF PAD A

Dynamic compaction of Pad A will not be precluded because of concerns about potential reactivity of nitrate salts. Dynamic compaction will not expose waste emplaced on Pad A nor will it disrupt operations at collocated facilities, including the Advanced Mixed Waste Treatment Project. A specialized crane is used to repeatedly drop a multi-ton weight at predetermined locations upon Pad A. The resulting soil compression is expected to eliminate gross void spaces within Pad A. Impact craters are immediately covered with clean fill, which is integrated into the base grade for the final surface barrier.

A-9.1 One-Year Construction Schedule

The activities associated with the dynamic compaction include:

- Hauling 12 in. of fill
- Dynamic compaction of Pad A
- Final "iron" compaction and roller compaction.

A-10. REMEDIAL ALTERNATIVE MODULE 10 – FOUNDATION GROUTING

This module includes jet-grouting of 18.7 acres of pits to provide ground stability for future placement of a cap. Jet-grouted columns will be constructed at nominal 12-ft centers within the pits. Most of these columns will be constructed in pits containing transuranic wastes. The grouting process will utilize conventional large hydraulic tracked excavators. These excavators will be modified to deploy a roto-percussion drill rig to inject grout into the waste.

Grout will be supplied to the jet grouting systems by ready-mix trucks. Each grout injection system will feature a self-contained high-pressure pump, which will provide the pressure required for jet fluid grouting. Grout returns are managed by moving 1 ft of soil in a region of injection prior to foundation grouting, injecting foundation grout, and then backfilling the region of injection (covering returns with 1 ft of soil).

A-10.1 One-Year Construction Schedule

The activities associated with the foundation grouting include:

- Delivering grout to the SDA
- Foundation grouting of 18.7 acres
- Capping grout returns.

A-11. REMEDIAL ALTERNATIVE MODULE 11 – CONTAMINANT GROUTING

Contaminant grouting is used for in situ immobilization of contaminants of concern identified in the Remedial Investigation Baseline Risk Assessment (RIBRA) for OU 7-13/14. The grout will encapsulate the targeted region of the SDA by jetting grout columns on 20-in. centers. Contaminant grouting will focus on in situ treatment of buried wastes containing contaminants of concern in releasable form. The feasibility study will evaluate in situ grouting of documented disposals containing significant portions of releasable Tc-99 inventory. In situ treatment of wastes containing releasable Tc-99 will also retard migration of other contaminants of concern. Grout is injected into buried waste using conventional equipment. High-pressure jets mix the waste, interstitial soil, and cement.

A-11.1 1-1/2-Year Construction Schedule

The activities associated with the contaminant grouting include:

- Delivering grout to the SDA
- Containment grouting
- Capping grout returns.

A-12. REMEDIAL ALTERNATIVE MODULE 12 – PARTIAL RETRIEVAL OF TARGETED WASTE FROM TWO ACRES

This module partially retrieves targeted wastes from two acres total area using the T-RAD method. The alternative module will retrieve targeted wastes, highly contaminated with transuranic radionuclides, volatile organic compounds, and depleted uranium, from two acres total area within the SDA, and dispose of them at the Waste Isolation Pilot Project or at the Idaho CERCLA Disposal Facility. Contaminant inventory and waste volume has not been determined. Wastes targeted for retrieval will be Series 741 and 743 sludge, graphite, filters, and roaster oxide. Waste exhumations, with the exception of some in Pit 4, will be performed within mobile retrieval enclosures.

Determinations of whether retrieved waste is targeted or nontargeted will be made by operators within the retrieval enclosures. Nontargeted wastes will be returned to the exhumation area. Targeted wastes will be transported to a centrally located enclosure where the waste will be manually segregated on sorting tables within the retrieval enclosures. Targeted wastes will be conveyed to stations attached to the enclosures for visual examination, removal of prohibited items, and packaging. All targeted wastes, except roaster oxides, will be certified for disposal at the Waste Isolation Pilot Project. All targeted wastes, except roaster oxides, will meet requirements for transportation to and disposal at the Waste Isolation Pilot Project without additional treatment. Roaster oxides will be sent to the Idaho CERCLA Disposal Facility or a similar on-Site or off-Site facility for treatment and disposal. Nontargeted wastes will be returned to the exhumation area.

A-12.1 Five-Year Construction/Remediation Schedule

The remediation process consists of the following steps:

- Removing clean overburden from the Accelerated Retrieval Project 2 (ARP) area
- Constructing a retrieval enclosure over the ARP2 excavation area and connecting the structure end-to-end with the ARP1 retrieval enclosure
- Selectively excavating targeted waste material beneath the wall and beneath the ARP2 retrieval enclosure while leaving nontargeted wastes within the pit
- Removing clean overburden from selected retrieval tent areas
- Selectively excavating targeted waste material beneath the retrieval tents while leaving nontargeted wastes within the pit
- Transferring targeted wastes (within the attached cargo container) from the three smaller retrieval tents to the larger ARP1/2 retrieval enclosure
- Random sampling of the waste

- Visually examining and packaging targeted waste in containers (e.g., 55-gal drums) within the ARP1/2 retrieval enclosure
- Temporary storage of transuranic waste drums until they are processed for shipment to the Waste Isolation Pilot Project
- Temporary storage of non-transuranic waste drums until they are processed for shipment to the Idaho CERCLA Disposal Facility
- Shipping the non-transuranic waste streams to the Idaho CERCLA Disposal Facility for treatment and disposal
- Preparing transuranic waste for shipment to the Waste Isolation Pilot Project by:
  - Assaying waste drums
  - Performing headspace gas sampling on transuranic waste and loading managed drums
  - Performing gas generation testing on drums that exceed the allowable headspace gas sampling thermal wattage limit or drums that contain test category waste
  - Performing limited volatile organic compound treatment of drums that failed gas generator test
- Containerizing (i.e., TRUPAC) the transuranic material for shipment to the Waste Isolation Pilot Project
- Moving the retrieval tents to new target locations, and restarting the retrieval process over a new retrieval area
- Deactivation, decontamination, and decommissioning of the retrieval enclosure
- Deactivation, decontamination, and decommissioning of other retrieval equipment.

A-13. REMEDIAL ALTERNATIVE MODULE 13 – PARTIAL RETRIEVAL OF TARGETED WASTES FROM FOUR ACRES TOTAL AREA USING THE T-RAD METHOD

This alternative module involves retrieval of targeted wastes, highly contaminated with transuranic radionuclides, volatile organic compounds, and depleted uranium, from four acres total area within the SDA, and disposal at the Waste Isolation Pilot Project or Idaho CERCLA Disposal Facility. Targeted waste will be retrieved from four acres total area. Wastes targeted for retrieval will be Series 741 and 743 sludge, graphite, filters, and roaster oxide. Waste exhumations, with the exception of some in Pit 4, will be performed within mobile retrieval enclosures. Determinations of whether retrieved waste is targeted or nontargeted will be made by operators within the retrieval enclosures. Nontargeted wastes will be returned to the exhumation area. Targeted wastes will be manually segregated on sorting tables within the retrieval enclosures. Targeted wastes will be transported to a centrally located enclosure where the waste will be manually segregated on sorting tables within the retrieval enclosures. Targeted wastes will be conveyed to stations attached to the enclosures for visual examination, removal of prohibited items, and packaging. All targeted wastes, except roaster oxides, will be certified for disposal at the Waste Isolation Pilot Project. All targeted wastes, except roaster oxides, will meet requirements for transportation to and disposal at the Waste Isolation Pilot Project without additional treatment. Roaster oxides will be sent to the Idaho CERCLA Disposal Facility or a similar on-Site or off-Site facility for treatment and disposal.

A-13.1 Nine-Year Construction/Remediation and Storage Schedule

The remediation process consists of the following steps:

- Removing clean overburden from the ARP2 area
- Constructing a retrieval enclosure over the ARP2 excavation area, and connecting the structure end-to-end with the ARP1 retrieval enclosure
- Selectively excavating targeted waste material beneath the wall and beneath the ARP2 retrieval enclosure while leaving nontargeted wastes within the pit
- Removing clean overburden from selected retrieval tent areas
- Selectively excavating targeted waste material beneath the retrieval tents while leaving nontargeted wastes within the pit
- Transferring targeted wastes (within the attached cargo container) from the three smaller retrieval tents to the larger ARP1/2 retrieval enclosure
- Random sampling of the waste
- Visually examining and packaging targeted waste in containers (e.g., 55-gal drums) within the ARP1/2 retrieval enclosure
- Temporary storage of transuranic waste drums until they are processed for shipment to the Waste Isolation Pilot Project
- Temporary storage of non-transuranic waste drums until they are processed for shipment to the Idaho CERCLA Disposal Facility
- Shipping the non-transuranic waste streams to the Idaho CERCLA Disposal Facility for treatment and disposal
- Preparing transuranic waste for shipment to the Waste Isolation Pilot Project by:
  - Assaying waste drums
  - Performing headspace gas sampling on transuranic waste and loading managed drums
  - Performing gas generation testing on drums that exceed the allowable headspace gas sampling thermal wattage limit or drums that contain test category waste
  - Performing limited volatile organic compound treatment of drums that failed gas generator test
- Containerizing (i.e., TRUPAC) the transuranic material for shipment to the Waste Isolation Pilot Project
- Moving the retrieval tents to new target locations, and restarting the retrieval process over a new retrieval area
- Deactivation, decontamination, and decommissioning of the retrieval enclosure
- Deactivation, decontamination, and decommissioning of other retrieval equipment.

A-14. REMEDIAL ALTERNATIVE MODULE 14 – RETRIEVAL OF ALL WASTE FROM THE SUBSURFACE DISPOSAL AREA USING THE T-RAD METHOD

Retrieve all waste buried within the SDA using the T-RAD method and dispose of waste at the Waste Isolation Pilot Project or appropriate on-Site or off-Site treatment, storage, and/or disposal facilities.

All wastes will be retrieved from the SDA. Transuranic wastes will be sent to the Waste Isolation Pilot Project for disposal. Low activity non-transuranic wastes will be sent to appropriate on-Site or off-Site facilities for treatment and disposal. Approximately 25% of non-transuranic wastes will require treatment prior to disposal. High activity wastes will be placed in an on-Site interim storage facility until a national repository is available.

A-14.1 Twenty-Seven-Year Construction/Remediation and Storage Schedule

The remediation process consists of the following steps:

- Removing clean overburden from the ARP2 area
- Constructing a retrieval enclosure over the ARP 2 excavation area, and connecting the structure end-to-end with the ARP1 retrieval enclosure
- Selectively excavating targeted waste material beneath the wall and beneath the ARP2 retrieval enclosure while leaving nontargeted wastes within the pit
- Removing clean overburden from beneath retrieval tents
- Constructing retrieval tents over the excavation areas
- Excavating the waste zone material, and separating transuranic waste from non-transuranic waste
- Excavating high radiation field items
- Excavating large objects
- Random sampling of the excavated wastes
- Visual examination and packaging of waste in containers (e.g., 55-gal drums)
- Sizing and packaging of large item wastes
- Temporary storage of transuranic waste drums until they are processed for shipment to the Waste Isolation Pilot Project
- Temporary storage of non-transuranic waste drums until they are processed for shipment to either the Idaho CERCLA Disposal Facility or Envirocare (or equivalent)
- Storing remote-handled waste
- Shipping the non-transuranic waste streams to the Idaho CERCLA Disposal Facility for treatment and disposal
- Shipping the non-transuranic waste streams to Envirocare (or equivalent) for treatment and disposal
- Preparing transuranic waste for shipment to the Waste Isolation Pilot Project by:

- Assaying waste drums
- Performing headspace gas sampling on transuranic and load managed drums
- Performing gas generation testing on drums that exceed the allowable headspace gas sampling thermal wattage limit or drums that contain test category waste
- Performing limited volatile organic compound treatment of drums

- Containerizing (i.e., TRUPAC) the transuranic material for shipment to the Waste Isolation Pilot Project
- Moving the enclosure tent, and restarting the retrieval process
- Deactivation, decontamination, and decommissioning of the retrieval enclosure and disposal in a facility outside of the SDA
- Storing remote-handled waste for 20 years
- After 20 years, shipping the remote-handled waste to an acceptable federal facility.

A-15. REMEDIAL ALTERNATIVE MODULE 15 – REMOVE PAD A AND DISPOSE OF IN THE RWMC LOW-LEVEL WASTE REPOSITORY WITHOUT TREATMENT

Pad A waste removal will be performed in an ARP-like retrieval enclosure. Waste retrieval will be performed with a manned excavator. Most waste packaging will not be structurally intact. No attempt will be made to segregate waste forms. Pad A waste, in composite, will be less than 10 nCi/g transuranic isotopes, consistent with the Pad A Record of Decisions (ROD). Waste removed from Pad A and relocated to the RWMC low-level waste pit will meet waste acceptance criteria without additional characterization. Thirty percent of the contoured sideburden and overburden will be disposed of as contaminated media. Structurally intact drums will be loaded into wooden boxes. Loose waste, debris, and contaminated soil will be packaged in sided lift liners. Waste boxes and lift liners will be transferred to the active low-level waste pit for disposal.

A-15.1 Two-Year Construction/Remediation and Storage Schedule

The associated activities include:

- Remove noncontaminated soil
- Transfer noncontaminated soil to staging area
- Radiological survey of retrieval area
- Retrieve Pad A waste
- Package Pad A waste
- Transfer Pad A Waste
- Demobilize equipment
- D&D retrieval enclosure
- Backfill to grade.

A-16. REMEDIAL ALTERNATIVE MODULE 16 – REMOVE PAD A, THEN TREAT AND DISPOSE OF AT THE IDAHO CERCLA DISPOSAL FACILITY

Pad A waste removal will be performed in an ARP-like retrieval enclosure. Waste retrieval will be performed with a manned excavator. Most waste packaging will not be structurally intact, and no attempt will be made to segregate waste forms. Pad A waste, in composite, will be less than 10 nCi/g transuranic isotopes consistent with the Pad A ROD, and will meet the Idaho CERCLA Disposal Facility waste acceptance criteria for radioactive and hazardous constituents.

Prohibited items will be excluded by visual examination. Disposal path for prohibited items is to be determined. Thirty percent of the contoured sideburden and overburden will be disposed of as contaminated media. Waste and contaminated media less than 6 in. in diameter will be sent to the Idaho CERCLA Disposal Facility for treatment as fines. Contaminated media with diameter greater than 6 in. will be sent to the Idaho CERCLA Disposal Facility for treatment as debris. Fines will be packaged in reusable metal boxes. Debris will be packaged in wooden boxes. Fines will be stabilized in the Idaho CERCLA Disposal Facility's paddle mixer using an appropriate grout. The grout-stabilized fines will be disposed of in the Idaho CERCLA Disposal Facility landfill without additional containment. Debris will be stabilized by filling the waste boxes with a flowable grout. Stabilized debris waste boxes will be disposed of in the ICDF landfill.

A-16.1 2-1/2-Year Construction/Remediation and Storage Schedule

The associated activities include:

- Remove noncontaminated soil
- Transfer noncontaminated soil to staging area
- Radiological survey of retrieval area
- Retrieve Pad A waste
- Visual examination and packaging
- Characterize waste
- Transfer Pad A waste to storage
- Transfer waste to the Idaho CERCLA Disposal Facility
- Demobilize equipment
- Deactivate and decontaminate retrieval enclosure
- Backfill to grade.

A-17. REMEDIAL ALTERNATIVE MODULE 17 – REMOVE PAD A, THEN TREAT AND DISPOSE OF AT ENVIROCARE

This module removes Pad A waste from the SDA and disposes of it at an off-Site treatment, storage and/or disposal facility. Pad A waste removal will be performed in an ARP-like retrieval enclosure. Waste retrieval will be performed with a manned excavator. Most waste packaging will not be structurally intact. No attempt will be made to segregate waste forms. Pad A waste, in composite, will be less than 10 nCi/g transuranic isotopes, consistent with the Pad A ROD. Thirty percent of the contoured

sideburden and overburden will be disposed of as contaminated media. Retrieved waste and contaminated media will be excavated and placed directly into sea-land containers. Waste shipped to Envirocare will not be examined for prohibited items. Sea-land containers will be transported by truck to the CFA for loadout to rail cars. Sea-land containers will be transported by rail to the Envirocare site for waste treatment and disposal.

A-17.1 21/2-Year Construction/Remediation and Storage Schedule

The associated activities include:

- Remove noncontaminated soil
- Transfer noncontaminated soil to staging area
- Radiological survey of retrieval area
- Retrieve Pad A waste
- Package waste
- Characterize waste
- Transfer Pad A waste to CFA rail spur, and load onto railcars
- Transfer waste to Envirocare
- Demobilize equipment
- Deactivate and Decontaminate retrieval enclosure
- Backfill to grade.

A-18. REMEDIAL ALTERNATIVE MODULE 18 – REMOVE PAD A, TREAT AT SUBSURFACE DISPOSAL AREA, AND DISPOSE OF IN THE RWMC LOW-LEVEL WASTE REPOSITORY

Pad A waste removal will be performed in an ARP-like retrieval enclosure. Waste retrieval will be performed with a manned excavator. Most waste packaging will not be structurally intact. No attempt will be made to segregate waste forms. Pad A waste, in composite, will be less than 10 nCi/g transuranic isotopes, consistent with the Pad A ROD. Waste removed from Pad A and relocated to the RWMC low-level waste pit will meet waste acceptance criteria for radioactive and hazardous constituents (pending determination). Thirty percent of the contoured sideburden and overburden will be disposed of as contaminated media. Retrieved waste and contaminated media will be sorted into fines and debris. Prohibited items will be excluded by visual examination. Disposal path for prohibited items will be determined at a later date. Fines and debris will be packaged in wooden boxes and transferred to an attached enclosure for stabilization. Fines will be stabilized using an appropriate grout and returned to the original wooden box. Debris will be stabilized by filling the waste boxes with a flowable grout. Stabilized waste boxes will be transported to the RWMC low-level waste landfill for disposal.

A-18.1 Three-Year Construction/Remediation Schedule

The associated activities include:

- Remove noncontaminated soil
- Transfer noncontaminated soil to staging area
- Radiological survey of retrieval area

- Retrieve Pad A waste
- Ex situ stabilization of Pad A waste
- Package waste
- Characterize waste
- Transfer treated Pad A waste to storage
- Transfer waste to low-level waste repository
- Demobilize equipment
- D&D retrieval enclosure
- Backfill to grade.

A-19. REMEDIAL ALTERNATIVE MODULE 19 – MONITORING MODULE

The monitoring option is a stand-alone option that will not require any additional retrieval or work to be done at the SDA. Wells, lysimeters, vapor ports, and tensiometers will be monitored at regular intervals to ensure that the waste is not migrating through the environmental media causing an unacceptable risk. There will not be any chemical or radiological risks because the waste will not be contacted in this module; risk will only be present from worker injuries and transportation of materials to the site.

A-20. REMEDIAL ALTERNATIVE MODULE 20 – ORGANIC CONTAMINATION IN THE VADOSE ZONE OPERATIONS AND MAINTENANCE

This module consists of operating and maintaining the OCVZ and can be used in conjunction with several of the other modules. There will not be any chemical or radiological risks because the waste will not be contacted in this module; risk will only be present from worker injuries and transportation of materials to the site.

Appendix B

Summary of Nonradioactive Releases and Chronic and Acute Risks from Modules 12, 13, and 14

Appendix B

Summary of Nonradioactive Releases and Chronic and Acute Risks from Modules 12, 13, and 14

Table B-1. Mass release calculations for the full retrieval option.

Pit #	CCl_4[a] (g)	CCl_4 Releasable Mass[b] (g)	C_2Cl_4[c] (g)	C_2Cl_4 Releasable Mass[b] (g)	C_2HCl_3[c] (g)	C_2HCl_3 Releasable Mass[b] (g)	CH_2Cl_2[c] (g)	CH_2Cl_2 Releasable Mass[b] (g)	$CHCl_3$[d] (g)	$CHCl_3$ Releasable Mass[b] (g)
4 Total[a]	3.48E+08		4.37E+07		4.37E+07		6.24E+06		6.24E+06	
4 A1+ 4A2[e]	5.95E+07		7.47E+06		7.47E+06		1.07E+06		1.07E+06	
4 without A1 and A2	2.88E+08	1.44E+08	3.62E+07	1.81E+07	3.62E+07	1.81E+07	5.18E+06	2.59E+06	5.18E+06	2.59E+06
5	3.45E+06	1.73E+06	4.33E+05	2.17E+05	4.33E+05	2.17E+05	6.19E+04	3.09E+04	6.19E+04	3.09E+04
6	2.36E+08	1.18E+08	2.96E+07	1.48E+07	2.96E+07	1.48E+07	4.23E+06	2.12E+06	4.23E+06	2.12E+06
9	1.03E+08	5.15E+07	1.29E+07	6.47E+06	1.29E+07	6.47E+06	1.85E+06	9.24E+05	1.85E+06	9.24E+05
10	9.57E+07	4.79E+07	1.20E+07	6.01E+06	1.20E+07	6.01E+06	1.72E+06	8.58E+05	1.72E+06	8.58E+05
Total mass of each compound in full retrieval area[f]	7.86E+08		9.87E+07		9.87E+07		1.41E+07		1.41E+07	7.86E+08
743 waste volume[g] in full retrieval is 63,756 ft^3	1.23E+04		1.55E+03		1.55E+03		2.21E+02		2.21E+02	1.23E+04
Grams of organic compound/ft^3 743 Waste	1.23E+04		1.55E+03		1.55E+03		2.21E+02		2.21E+02	1.23E+04
Total inventory without A1 and A2(g)[f]	7.27E+08		9.12E+07		9.12E+07		1.30E+07		1.30E+07	

Table B-1. (continued).

Pit #	CCl_4[a] (g)	CCl_4 Releasable Mass[b] (g)	C_2Cl_4[c] (g)	C_2Cl_4 Releasable Mass[b] (g)	C_2HCl_3[c] (g)	C_2HCl_3 Releasable Mass[b] (g)	CH_2Cl_2[c] (g)	CH_2Cl_2 Releasable Mass[b] (g)	$CHCl_3$[d] (g)	$CHCl_3$ Releasable Mass[b] (g)
Total releasable inventory (g)[b]		3.63E+08		4.56E+07		4.56E+07		6.52E+06		6.52E+06

NOTE: Highlighted values were used for full retrieval option release calculations and in Table 3-8 of the STRA report.

a. Carbon tetrachloride values for individual pits from RIBRA (Holdren et al. 2006) Table 4-84.
b. Assumes 50% of original volatile organic compounds from the 743 waste are still present in the SDA (Sondrup 2005).
c. C_2Cl_4 mass for each pit was determined by dividing the total mass of C_2Cl_4 in the full retrieval area by the total mass of CCl_4 in the full retrieval area and then multiplying by the mass of CCl_4 in each of the respective pits. This method was also used for C_2HCl_3 and $C_2H_2Cl_2$.
d. CH_2Cl_2 to $CHCl_3$ ratio was assumed to be equal (EDF-2322).
e. The mass of the organic compounds in the 4A1 and 4A2 subarea is calculated as follows: Total organic mass in Pit 4 (3.48E+08) × (((1-((Total SDA Volume of 743 waste (63,756 ft^3) – Volume of 743 waste in 4A1&4A2 (4,828 ft^3))/(Total SDA Volume of 743 waste (63,756 ft^3))). Volume of 743 waste in 4A1 and 4A2 is from EDF-5978.
f. Mass totals of each compound from RIBRA (Holdren et al. 2006), Section 4.19 for C_2Cl_4 and 4.20 for $C_2H_2Cl_2$.
g. From WILD database.

Table B-2. Mass release calculations for the two-acre retrieval option.

Organic Compound	Mass of Organic Compound/ft^3 of 743 Waste from Table B-1 (g/ft^3)	Releasable Inventory Beneath ARP 2 Structure (subareas 4B1, 4B2, and 4C)[a,b] (g)	Releasable Inventory Beneath Mobile Tents (Pits 5, 6, 9, 10)[b,c] (g)	Total two-acre Releasable Inventory (g)	743 Waste Volume Beneath ARP 2 Structure (subareas 4B1, 4B2, and 4C)[a,b] 2.55+04	743 Waste Volume Beneath Mobile Tents Pits 5, 6, 9, 10 Inventory[b,c] 4.51E+03
CCl_4	1.23E+04	1.57E+08	2.78E+07	1.85E+08		
C_2Cl_4	1.55E+03	1.97E+07	3.49E+06	2.32E+07		
C_2HCl_3	1.55E+03	1.97E+07	3.49E+06	2.32E+07		
CH_2Cl_3	2.21E+02	2.82E+06	4.98E+05	3.32E+06		
$CHCl_3$	2.21E+02	2.82E+06	4.98E+05	3.32E+06		

NOTE: Highlighted values were used for full retrieval option release calculations and in Table 3-8 of the STRA report.

a. From WILD database total waste volume for Pit 4 subareas 4B1, 4B2 and 4C for two-acre option is 25,487 ft^3.
b. From WILD database total waste volume for mobile tents (Pits 5, 6, 9, 10) for the two-acre option is 4,506 ft^3.
c. Mass calculated based on grams/ft^3 values from Table B-1 and is equal to the mass of each compound per ft^3 of waste times the total volume of waste in the two-acre retrieval option, excluding Pit 4.

Table B-3. Mass release calculations for the four-acre retrieval option.

Organic Compound	Mass of Organic Compound/ft^3 of 743 Waste from Table B-1 (g/ft^3)	Releasable ARP Structure Inventory[a,b] from Grids 4014, 4015, 4016, 6005, 6006, 6020 (g)	Releasable Inventory Beneath Mobile Tents (Pits 5,6,9,10) [b,c] (g)	Total 4 Acre Releasable Inventory (g)	743 Waste Volume Beneath ARP 2 Structure Grids 4014, 4015, 4016, 6005, 6006, 6020 (ft^3)[a] 2.73E+04	743 Waste Volume Beneath Mobile Tents Pits 5,6,9,10 Inventory[b,c] 6.54E+03
CCl_4	1.23E+04	1.68E+08	4.03E+07	2.09E+08		
C_2Cl_4	1.55E+03	2.12E+07	5.06E+06	2.62E+07		
C_2HCl_3	1.55E+03	2.12E+07	5.06E+06	2.62E+07		
CH_2Cl_2	2.21E+02	3.02E+06	7.24E+05	3.75E+06		
$CHCl_3$	2.21E+02	3.02E+06	7.24E+05	3.75E+06		

NOTE: Highlighted values in yellow were used for 2- and four-acre retrieval option release calculations and in Table 3-8 of the STRA report.

a. From WILD database; total waste volume for Pit 4 Grids 4014, 4015, 4016, 6005, 6006, 6020 for the four-acre option is 27,332 ft^3.
b. Mass calculated based on grams/ft^3 values from Table B-1 and is equal to the mass of each compound per ft^3 of 743 waste times the total volume of waste in the four-acre retrieval option excluding Pit 4.
c. From WILD database; total waste volume for the mobile tents (Pits 5, 6, 9, 10) for the four-acre option is 6,543 ft^3.

Table B-4. Two-acre release calculations summary mass of contaminants of concern per subarea.

Pit	Pit 4 without 4A1 and 4A2	Pit 5, 6, 9, 10	Total Mass
	Total Releasable Inventory (g)[a]		
Carbon tetrachloride	1.57E+08	2.78E+07	1.85E+08
Tetrachloroethylene	1.97E+07	3.49E+06	2.32E+07
Trichloroethylene	1.97E+07	3.49E+06	2.32E+07
Chloroform	2.82E+06	4.98E+05	3.32E+06
Methylene chloride	2.82E+06	4.98E+05	3.32E+06
Retrieval time, months[b]	18.00	36	5.400E+01
Normal ventilation flow rate (acfm)[c]	20,000	10,000	
	Average Air Concentration in Enclosures (g/ft^3)		
Carbon tetrachloride	1.0E-02	1.8E-03	
Tetrachloroethylene	1.3E-03	2.2E-04	
Trichloroethylene	1.3E-03	2.2E-04	
Chloroform	1.8E-04	3.2E-05	
Methylene chloride	1.8E-04	3.2E-05	
	Stack Release Concentration (g/sec)		
Carbon tetrachloride	3.4E+00	3.0E-01	
Tetrachloroethylene	4.2E-01	3.7E-02	
Trichloroethylene	4.2E-01	3.7E-02	
Chloroform	6.0E-02	5.3E-03	
Methylene chloride	6.0E-02	5.3E-03	

a. Releasable inventory from Table B-1.
b. Retrieval durations from scheduling sequence in Feasibility Study Modules dated 12/16/05.
c. Ventilation flow rates from EDF-4856 for ARP II and Brian Preussner for movable tents.

Table B-5. Two-acre release concentrations per subarea.

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Carbon tetrachloride 1-hour releases using Screen 3	758 m[a]	458.0	758 m[a]	77.1
	2,900 m[b]	277.2	2,900 m[b]	30.2
	5,600 m[c]	140.8	5,600 m[c]	14.0
Tetrachloroethylene 1-hour releases using Screen 3	758 m[a]	57.5	758 m[a]	9.7
	2,900 m[b]	34.8	2,900 m[b]	3.8
	5,600 m[c]	17.7	5,600 m[c]	1.8
Trichloroethylene 1-hour releases using Screen 3	758 m[a]	57.5	758 ma[a]	9.7
	2,900 m[b]	34.8	2,900 m[b]	3.8
	5,600 m[c]	17.716.7	5,600 m[c]	1.8
Chloroform 1-hour releases using Screen 3	758 m[a]	8.2	758 m[a]	1.4
	2,900 m[b]	5.0	2,900 m[b]	0.5
	5,600 m[c]	2.5	5,600 m[c]	0.3
Methylene chloride 1-hour releases using Screen 3	758 m[a]	8.2	758 m[a]	1.4
	2,900 m[b]	5.0	2,900 m[b]	0.5
	5,600 m[c]	2.5	5,600 m[c]	0.3
Carbon tetrachloride 8 hour[d]	758 m[a]	320.6	758 m[a]	54.0
	2,900 m[b]	194.0	2,900 m[b]	21.2
	5,600 m[c]	98.5	5,600 m[c]	9.8
Tetrachloroethylene 8 hour[d]	758 m[a]	40.3	758 m[a]	6.8
	2,900 m[b]	24.4	2,900 m[b]	2.7
	5,600 m[c]	12.4	5,600 m[c]	1.2
Trichloroethylene 8 hour[d]	758 m[a]	40.3	758 m[a]	6.8
	2,900 m[b]	24.4	2,900 m[b]	2.7
	5,600 m[c]	12.4	5,600 m[c]	1.2
Chloroform 8 hour[d]	758 m[a]	5.8	758 m[a]	1.0
	2,900 m[b]	3.5	2,900 m[b]	0.4
	5,600 m[c]	1.8	5,600 m[c]	0.2
Methylene chloride 8 hour[d]	758 m[a]	5.8	758 m[a]	1.0
	2,900 m[b]	3.5	2,900 m[b]	0.4
	5,600 m[c]	1.8	5,600 m[c]	0.2
Carbon tetrachloride 24 hour[e]	758 m[a]	183.2	758 m[a]	30.8
	2,900 m[b]	110.9	2,900 m[b]	12.1
	5,600 m[c]	56.3	5,600 m[c]	5.6

Table B-5. (continued).

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Tetrachloroethylene 24 hour[e]	758 m[a]	23.0	758 m[a]	3.9
	2,900 m[b]	13.9	2,900 m[b]	1.5
	5,600 m[c]	7.1	5,600 m[c]	0.7
Trichloroethylene 24 hour[e]	758 m[a]	23.0	758 m[a]	3.9
	2,900 m[b]	13.9	2,900 m[b]	1.5
	5,600 m[c]	7.1	5,600 m[c]	0.7
Chloroform 24 hour[e]	758 m[a]	3.3	758 m[a]	0.6
	2,900 m[b]	2.0	2,900 m[b]	0.2
	5,600 m[c]	1.0	5,600 m[c]	0.1
Methylene chloride 24 hour[e]	758 m[a]	3.3	758 m[a]	0.6
	2,900 m[b]	2.0	2,900 m[b]	0.2
	5,600 m[c]	1.0	5,600 m[c]	0.1
Carbon tetrachloride annual[f]	758 m[a]	55.0	758 m[a]	9.3
	2,900 m[b]	33.3	2,900 m[b]	3.6
	5,600 m[c]	16.9	5,600 m[c]	1.7
Tetrachloroethylene annual[f]	758 m[a]	6.9	758 m[a]	1.2
	2,900 m[b]	4.2	2,900 m[b]	0.5
	5,600 m[c]	2.1	5,600 m[c]	0.2
Trichloroethylene annual[f]	758 m[a]	6.9	758 m[a]	1.2
	2,900 m[b]	4.2	2,900 m[b]	0.5
	5,600 m[c]	2.1	5,600 m[c]	0.2
Chloroform annual[f]	758 m[a]	1.0	758 m[a]	0.2
	2,900 m[b]	0.6	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.0
Methylene chloride annual[f]	758 m[a]	1.0	758 m[a]	0.2
	2,900 m[b]	0.6	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.0

a. Distance to max. exposed collocated worker.
b. Distance to public receptor (EBR-1).
c. Distance to public receptor (Rest Area).
d. 8-hour average = 0.7 × 1-hour average for workers.
e. 24-hour average = 0.4 × 1-hour average.
f. Annual average = 0.12 × 1-hour average.

Table B-6. Chronic dose calculations for two-acre collocated worker.

Volatile chemical inhalation dose calculation equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs

	Annual Average Air Concentration	Units
Carbon tetrachloride	3.15E+01[b]	µg/m^3
Chloroform	5.65E–01[b]	µg/m^3
Methylene chloride	5.65E–01[b]	µg/m^3
Tetrachloroethylene	3.95E+00[b]	µg/m^3
Trichloroethylene	3.95E+00[b]	µg/m^3
Exposure time (ET)	10[b]	hr/day
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	200[b]	d/year
Exposure duration (ED)	3.50[b]	yr
Body weight (BW)	70[a]	kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,550[a]	d

Outputs

	Noncancer Dose (ug/kg-dy)	Cancer Dose (ug/kg-dy)
Carbon tetrachloride	2.40E-01	1.03E-01
Chloroform	4.30E-03	1.84E-03
Methylene chloride	4.30E-03	1.84E-03
Tetrachloroethylene	3.01E-02	1.29E-02
Trichloroethylene	3.01E-02	1.29E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RfDi)
Risk = Inhalation Slope Factor (Sfi) × Dose.

Table B-6. (continued).

Inputs and Outputs						
	Noncarcinogenic			Carcinogenic		
Parameter	Dose (µg/kg-dy)	RfDi (µg/kg-dy)	HQ (unitless)	Dose (µg/kg-dy)	Sfi (kg-dy/µg)	Risk (unitless)
Carbon tetrachloride	2.40E-01	7.00E–01	3.42E-01	1.03E-01	5.25E–05[e]	5.39E-06
Chloroform	4.30E-03	9.00E+00	4.78E-04	1.84E-03	8.05E–05[e]	1.48E-07
Methylene chloride	4.30E-03	8.57E+02[c]	5.02E-06	1.84E-03	1.65E–06[e]	3.03E-09
Tetrachloroethylene	3.01E-02	1.70E+02[d]	1.77E-04	1.29E-02	2.07E–05[f]	2.67E-07
Trichloroethylene	3.01E-02	1.14E+01[g]	2.64E-03	1.29E-02	4.00E–04[g]	5.16E-06
Total			**3.5E-01**			**1.1E-05**

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
d. Provisional value that should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
e. EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).
g. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). USEPA EPA/600/P-01/002A. 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC.

Table B-7. Acute dose calculation for two-acre collocated worker.

Acute Hazards Assessment for the Collocated Worker					
Contaminant of Potential Concern	Peak 1-Hour Exposure Concentration (µg/m^3)[a]	Acute Criteria (µg/m^3)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	5.35E+02	1.90E+03	7	REL	2.8E-01
Chloroform	9.60E+00	1.50E+02	7	REL	6.4E-02
Methylene chloride	9.60E+00	1.40E+04	1	REL	6.9E-04
Tetrachloroethylene	6.72E+01	2.37E+05	1	AEGL-1	2.8E-04
Trichloroethylene	6.72E+01	7.10E+05	1	AEGL-1	9.5E-05
			Total hazard index		**0.35**

a. Highest 1-hour modeled concentration for worst-case receptor includes consideration of upset conditions and multiple retrieval operation.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-8. Chronic dose calculation for two-acre off-Site public.

Volatile Chemical Inhalation Dose Calculation Equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs		
	Annual Average Air Concentration	Units
Carbon tetrachloride	8.68E+00[b]	µg/m^3
Chloroform	1.56E-01[b]	µg/m^3
Methylene chloride	1.56E-01[b]	µg/m^3
Tetrachloroethylene	1.09E+00[b]	µg/m^3
Trichloroethylene	1.09E+00[b]	µg/m^3
Exposure time (ET)	24[b]	hr/event
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	350[b]	events/yr
Exposure duration (ED)	3.50[b]	yr
Body weight (BW)	70[a]	Kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,550[a]	d

Outputs		
	Noncancer Dose (ug/kg-dy)	Cancer Dose (ug/kg-dy)
Carbon tetrachloride	2.77E-01	1.19E-01
Chloroform	4.97E-03	2.13E-03
Methylene chloride	4.97E-03	2.13E-03
Tetrachloroethylene	3.48E-02	1.49E-02
Trichloroethylene	3.48E-02	1.49E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RFDi)
Risk = Inhalation Slope Factor (Sfi) × Dose

Table B-8. (continued).

Inputs and Outputs						
	Noncarcinogenic			Carcinogenic		
Parameter	Dose (µg/kg-dy)	RfDi (µg/kg-dy)	HQ (unitless)	Dose (µg/kg-dy)	Sfi (kg-dy/µg)	Risk (unitless)
Carbon tetrachloride	2.77E-01	7.00E-01	3.96E-01	1.19E-01	5.25E-05[c]	6.24E-06
Chloroform	4.97E-03	9.00E+00	5.53E-04	2.13E-03	8.05E-05[c]	1.72E-07
Methylene chloride	4.97E-03	8.57E+02[d]	5.80E-06	2.13E-03	1.65E-06[c]	3.51E-09
Tetrachloroethylene	3.48E-02	1.70E+02[e]	2.05E-04	1.49E-02	2.07E-05[f]	3.09E-07
Trichloroethylene	3.48E-02	1.14E+01[g]	3.05E-03	1.49E-02	4.00E-04[g]	5.97E-06
Total			**4.0E-01**			**1.3E-05**

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c. EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
d. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
e. Provisional value that should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).
g. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). USEPA EPA/600/P-01/002A. 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC.

Table B-9. Acute dose calculation for two-acre off-Site public.

Acute Hazards Assessment for the General Public					
Contaminant of Potential Concern	Peak 1-hour Exposure Concentration. (µg/m^3)[a]	Acute Criteria (µg/m^3)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	3.07E+02	1.90E+03	7	REL	1.6E-01
Chloroform	5.52E+00	1.50E+02	7	REL	3.7E-02
Methylene chloride	5.52E+00	1.40E+04	1	REL	3.9E-04
Tetrachloroethylene	3.86E+01	2.37E+05	1	AEGL-1	1.6E-04
Trichloroethylene	3.86E+01	7.10E+05	1	AEGL-1	5.4E-05
				Total hazard index	**0.20**

a. Highest 1-hour modeled concentration for worst-case receptor includes consideration of upset conditions.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-10. Four-acre release calculations summary mass of contaminants of potential concern per subarea.

Pit	Pit 4 without 4A1 and 4A2	Pit 5, 6, 9, 10	Total Mass
	Total Releasable Inventory (g)[a]		
Carbon tetrachloride	1.68E+08	4.03E+07	2.09E+08
Tetrachloroethylene	2.12E+07	5.06E+06	2.62E+07
Trichloroethylene	2.12E+07	5.06E+06	2.62E+07
Chloroform	3.02E+06	7.24E+05	3.75E+06
Methylene chloride	3.02E+06	7.24E+05	3.75E+06
Retrieval time months[b]	18.00	66	
Normal ventilation flow rate (acfm)[c]	20,000	10,000	
	Average Air Concentration In Enclosures (g/ft^3)		
Carbon tetrachloride	1.1E-02	1.4E-03	
Tetrachloroethylene	1.4E-03	1.8E-04	
Trichloroethylene	1.4E-03	1.8E-04	
Chloroform	1.9E-04	2.5E-05	
Methylene chloride	1.9E-04	2.5E-05	
	Stack Release Concentration (g/sec)		
Carbon tetrachloride	3.6E+00	2.4E-01	
Tetrachloroethylene	4.5E-01	3.0E-02	
Trichloroethylene	4.5E-01	3.0E-02	
Chloroform	6.5E-02	4.2E-03	
Methylene chloride	6.5E-02	4.2E-03	

a. Releasable inventory from Table B-1.
b. Retrevial durations from scheduling sequence in FS Modules Dated 12/16/05.
c. Ventilation flow rates from EDF-4856 for ARP II and Brian Preussner for movable tents.

Table B-11. Four-acre release concentrations per subarea.

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Carbon tetrachloride 1-hour releases using Screen 3	758 m[a]	491.1	833 m[a]	61.1
	2,900 m[b]	297.3	2,900 m[b]	24.0
	5,600 m[c]	150.9	5,600 m[c]	11.1
Tetrachloroethylene 1-hour releases using Screen 3	758 m[a]	61.7	833 m[a]	7.7
	2,900 m[b]	37.3	2,900 m[b]	3.0
	5,600 m[c]	19.0	5,600 m[c]	1.4
Trichloroethylene 1-hour releases using Screen 3	758 m[a]	61.7	833 m[a]	7.7
	2,900 m[b]	37.3	2,900 m[b]	3.0
	5,600 m[c]	19.0	5,600 m[c]	1.4
Chloroform 1-hour releases using Screen 3	758 m[a]	8.8	833 m[a]	1.1
	2,900 m[b]	5.3	2,900 m[b]	0.4
	5,600 m[c]	2.76	5,600 m[c]	0.2
Methylene chloride 1-hour releases using Screen 3	758 m[a]	8.8	833 m[a]	1.1
	2,900 m[b]	5.3	2,900 m[b]	0.4
	5,600 m[c]	2.7	5,600 m[c]	0.2
Carbon tetrachloride 8-hour[d]	758 m[a]	343.8	833 m[a]	42.7
	2,900 m[b]	208.1	2,900 m[b]	16.8
	5,600 m[c]	10.57	5,600 m[c]	7.7
Tetrachloroethylene 8-hour[d]	758 m[a]	43.2	833 m[a]	5.4
	2,900 m[b]	26.1	2,900 m[b]	2.1
	5,600 m[c]	13.3	5,600 m[c]	1.0
Trichloroethylene 8-hour[d]	758 m[a]	43.2	833 m[a]	5.4
	2,900 m[b]	26.1	2,900 m[b]	2.1
	5,600 m[c]	13.3	5,600 m[c]	1.0
Chloroform 8-hour[d]	758 m[a]	6.2	833 m[a]	0.8
	2,900 m[b]	3.7	2,900 m[b]	0.3
	5,600 m[c]	1.9	5,600 m[c]	0.1
Methylene chloride 8-hour[d]	758 m[a]	6.2	833 m[a]	0.8
	2,900 m[b]	3.7	2,900 m[b]	0.3
	5,600 m[c]	1.98	5,600 m[c]	0.1
Carbon tetrachloride 24-hour[e]	758 m[a]	196.4	833 m[a]	24.4
	2,900 m[b]	118.9	2,900 m[b]	9.6
	5,600 m[c]	60.4	5,600 m[c]	4.4

Table B-11. (continued).

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Tetrachloroethylene 24 hour[e]	758 m[a]	24.7	833 m[a]	3.1
	2,900 m[b]	14.9	2,900 m[b]	1.2
	5,600 m[c]	7.6	5,600 m[c]	0.6
Trichloroethylene 24 hour[e]	758 m[a]	24.7	833 m[a]	3.1
	2,900 m[b]	14.9	2,900 m[b]	1.2
	5,600 m[c]	7.6	5,600 m[c]	0.6
Chloroform 24 hour[e]	758 m[a]	3.5	833 ma	0.4
	2,900 m[b]	2.1	2,900 m[b]	0.2
	5,600 m[c]	1.1	5,600 m[c]	0.1
Methylene chloride 24 hour[e]	758 m[a]	3.5	833 m[a]	0.4
	2,900 m[b]	2.1	2,900 m[b]	0.2
	5,600 m[c]	1.1	5,600 m[c]	0.1
Carbon tetrachloride annual[f]	758 m[a]	58.9	833 m[a]	7.3
	2,900 m[b]	35.7	2,900 m[b]	2.9
	5,600 m[c]	18.1	5,600 m[c]	1.3
Tetrachloroethylene annual[f]	758 m[a]	7.4	833 m[a]	0.9
	2,900 m[b]	4.5	2,900 m[b]	0.4
	5,600 m[c]	2.3	5,600 m[c]	0.2
Trichloroethylene annual[f]	758 m[a]	7.4	833 m[a]	0.9
	2,900 m[b]	4.5	2,900 m[b]	0.4
	5,600 m[c]	2.3	5,600 m[c]	0.2
Chloroform annual[f]	758 m[a]	1.1	833 m[a]	0.1
	2,900 m[b]	0.6	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.02
Methylene chloride annual[f]	758 m[a]	1.1	833 m[a]	0.1
	2,900 m[b]	0.6	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.02

a. Distance to max. exposed collocated worker.
b. Distance to public receptor (EBR-1).
c. Distance to public receptor (Rest Area).
d. 8-hour average = 0.7 × 1-hour average for workers.
e. 24 hour average = 0.4 × 1-hour average.
f. Annual average = 0.12 × 1-hour average.

Table B-12. Acute dose calculation for four-acre collocated worker.

Volatile Chemical Inhalation Dose Calculation Equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs

	Annual Average Air Concentration	Units
Carbon tetrachloride	2.14E+01[b]	µg/m^3
Chloroform	3.85E-01[b]	µg/m^3
Methylene chloride	3.85E-01[b]	µg/m^3
Tetrachloroethylene	2.69E+00[b]	µg/m^3
Trichloroethylene	2.69E+00[b]	µg/m^3
Exposure time (ET)	10[b]	hr/d
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	200[b]	d/yr
Exposure duration (ED)	6.00[b]	yr
Body weight (BW)	70[1]	kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,550[a]	d

Outputs

	Noncancer Dose (ug/kg-dy)	Cancer Dose (ug/kg-dy)
Carbon tetrachloride	2.80E-01	1.20E-01
Chloroform	5.02E-03	2.15E-03
Methylene chloride	5.02E-03	2.15E-03
Tetrachloroethylene	3.51E-02	1.51E-02
Trichloroethylene	3.51E-02	1.51E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RfDi)
Risk = Inhalation Slope Factor (Sfi) × Dose.

Inputs and Outputs

	Noncarcinogenic			Carcinogenic		
Parameter	Dose (µg/kg-dy)	RfDi (µg/kg-dy)	HQ (unitless)	Dose (µg/kg-dy)	Sfi (kg-dy/µg)	Risk (unitless)
Carbon Tetrachloride	2.80E-01	7.00E-01	4.00E-01	1.20E-01	5.25E-05[c]	6.30E-06
Chloroform	5.02E-03	9.00E+00	5.58E-04	2.15E-03	8.05E-05[c]	1.73E-07
Methylene Chloride	5.02E-03	8.57E+02[d]	5.86E-06	2.15E-03	1.65E-06[c]	3.54E-09
Tetrachloroethylene	3.51E-02	1.70E+02[e]	2.07E-04	1.51E-02	2.07E-05[f]	3.12E-07
Trichloroethylene	3.51E-02	1.14E+01[g]	3.08E-03	1.51E-02	4.00E-04[g]	6.02E-06
Totals			**4.0E-01**			**1.3E-05**

Table B-12. (continued).

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c. EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
d. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
e. Provisional value which should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).
g. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). USEPA EPA/600/P-01/002A. 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC.

Table B-13. Acute dose calculation for four-acre collocated worker.

Acute Hazards Assessment for the Collocated Worker

Contaminant of Potential Concern	Peak 1-hour Exposure Concentration ($\mu g/m^3$)[a]	Acute Criteria ($\mu g/m^3$)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	5.52E+02	1.90E+03	7	REL	2.9E-01
Chloroform	9.91E+00	1.50E+02	7	REL	6.6E-02
Methylene chloride	9.91E+00	1.40E+04	1	REL	7.1E-04
Tetrachloroethylene	6.93E+01	2.37E+05	1	AEGL-1	2.9E-04
Trichloroethylene	6.93E+01	7.10E+05	1	AEGL-1	9.8E-05
			Total hazard index		**0.37**

a. Highest 1-hour modeled concentration for worst-case receptor includes consideration of upset conditions.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-14. Chronic dose calculation for four-acre off-Site public.

Volatile Chemical Inhalation Dose Calculation Equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs		
	Annual Average Air Concentration (SA)	Units
Carbon tetrachloride	5.75E+00[b]	µg/m^3
Chloroform	1.03E–01[b]	µg/m^3
Methylene chloride	1.03E–01[b]	µg/m^3
Tetrachloroethylene	7.21E-01[b]	µg/m^3
Trichloroethylene	7.21E-01[b]	µg/m^3
Exposure time (ET)	24[b]	hr/event
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	350[b]	events/yr
Exposure duration (ED)	6.00[b]	yr
Body weight (BW)	70[a]	kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,55a	d
Outputs		
	Noncancer	Cancer
Carbon tetrachloride	3.15E-01	1.35E-01
Chloroform	5.65E-03	2.42E-03
Methylene chloride	5.65E-03	2.42E-03
Tetrachloroethylene	3.95E-02	1.69E-02
Tetrachloroethylene	3.95E-02	1.69E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RfDi)
Risk = Inhalation Slope Factor (Sfi) × Dose.

Table B-14. (continued).

Inputs and Outputs						
	Noncarcinogenic			Carcinogenic		
Parameter	Dose µg/kg-dy	RfDi µg/kg-dy	HQ unitless	Dose µg/kg-dy	Sfi kg-dy/µg	Risk unitless
Carbon tetrachloride	3.15E-01	7.00E–01	4.50E-01	1.35E-01	5.25E–05[c]	7.08E-06
Chloroform	5.65E-03	9.00E+00	6.28E-04	2.42E-03	8.05E–05[c]	1.95E-07
Methylene chloride	5.65E-03	8.57E+02[d]	6.59E-06	2.42E-03	1.65E–06[c]	3.98E-09
Tetrachloroethylene	3.95E-02	1.70E+02[e]	2.33E-04	1.69E-02	2.07E–05[f]	3.51E-07
Trichloroethylene	3.95E-02	1.14E+01[g]	3.47E-03	1.69E-02	4.00E–04[g]	6.78E-06
Totals			**4.5E-01**			**1.4E-05**

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
d. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
e. Provisional value which should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).
g. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). USEPA EPA/600/P-01/002A. 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC.

Table B-15. Acute dose calculation for four-acre off-Site public.

Acute Hazards Assessment for the General Public					
Contaminant of Potential Concern	Peak one-hour Exposure Concentration (µg/m^3)[a]	Acute Criteria (µg/m^3)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	3.21E+02	1.90E+03	7	REL	1.7E-01
Chloroform	5.76E+00	1.50E+02	7	REL	3.8E-02
Methylene chloride	5.76E+00	1.40E+04	1	REL	4.1E-04
Tetrachloroethylene	4.03E+01	2.37E+05	1	AEGL-1	1.7E-04
Trichloroethylene	4.03E+01	7.10E+05	1	AEGL-1	5.7E-05
			Total hazard index		**0.21**

a. Highest 1-hour modeled concentration for worst case receptor includes consideration of upset conditions.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-16. Full retrieval release calculations summary mass of organic compounds by pit.

Pit	Pit 4 without 4A1 and 4A2	Pit 5, 6, 9, 10	Total Mass
	Total Releasable Inventory (g)[a]		
Carbon tetrachloride	1.44E+08	2.19E+08	3.63E+08
Tetrachloroethylene	1.81E+07	2.75E+07	4.54E+07
Trichloroethylene	1.81E+07	2.75E+07	4.54E+07
Chloroform	2.59E+06	3.93E+06	6.48E+06
Methylene chloride	2.59E+06	3.93E+06	6.48E+06
Retrieval time months[b]	18.00	294	
Normal ventilation flow rate (acfm)[c]	20,000	10,000	
	Average Air Concentration In Enclosures (g/ft^3)		
Carbon tetrachloride	9.3E-03	1.7E-03	
Tetrachloroethylene	1.2E-03	2.2E-04	
Trichloroethylene	1.2E-03	2.2E-04	
Chloroform	1.7E-04	3.1E-05	
Methylene chloride	1.7E-04	3.1E-05	
	Stack Release Concentration (g/sec)		
Carbon tetrachloride	3.1E+00	2.9E-01	
Tetrachloroethylene	3.9E-01	3.6E-02	
Trichloroethylene	3.9E-01	3.6E-02	
Chloroform	5.5E-02	5.2E-03	
Methylene chloride	5.5E-02	5.2E-03	

a. Releasable inventory from Table B-1.
b. Retrieval durations from scheduling sequence in FS Modules Dated 12/16/05.
c. Ventilation flow rates from EDF-4856 for ARP II and Brian Preussner for movable tents.

Table B-17. Full retrieval dispersion model release concentrations

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Carbon tetrachloride 1-hour releases using Screen 3	758 m[a]	420.5	833 m[a]	74.5
	2,900 m[b]	254.5	2,900 m[b]	29.2
	5,600 m[c]	129.2	5,600 m[c]	14.4
Tetrachloroethylene 1-hour releases using Screen 3	758 m[a]	52.8	833 m[a]	9.3
	2,900 m[b]	32.0	2,900 m[b]	3.7
	5,600 m[c]	16.2	5,600 m[c]	1.8
Trichloroethylene 1-hour releases using Screen 3	758 m[a]	52.8	833 m[a]	9.3
	2,900 m[b]	32.0	2,900 m[b]	3.7
	5,600 m[c]	16.2	5,600 m[c]	1.8
Chloroform 1-hour releases using Screen 3	758 m[a]	7.5	833 m[a]	1.3
	2,900 m[b]	4.6	2,900 m[b]	0.5
	5,600 m[c]	2.3	5,600 m[c]	0.3
Methylene chloride 1-hour releases using Screen 3	758 m[a]	7.5	833 m[a]	1.3
	2,900 m[b]	4.6	2,900 m[b]	0.5
	5,600 m[c]	2.3	5,600 m[c]	0.3
Carbon tetrachloride 8-hour[d]	758 m[a]	294.3	833 m[a]	52.1
	2,900 m[b]	178.1	2,900 m[b]	20.4
	5,600 m[c]	90.5	5,600 m[c]	10.0
Tetrachloroethylene 8-hour[d]	758 m[a]	37.0	833 m[a]	6.5
	2,900 m[b]	22.4	2,900 m[b]	2.6
	5,600 m[c]	11.4	5,600 m[c]	1.3
Trichloroethylene 8-hour[d]	758 m[a]	37.0	833 m[a]	6.5
	2,900 m[b]	22.4	2,900 m[b]	2.6
	5,600 m[c]	11.4	5,600 m[c]	1.3
Chloroform 8-hour[d]	758 m[a]	5.3	833 m[a]	0.9
	2,900 m[b]	3.2	2,900 m[b]	0.4
	5,600 m[c]	1.6	5,600 m[c]	0.2
Methylene chloride 8-hour[d]	758 m[a]	5.3	833 m[a]	0.9
	2,900 m[b]	3.2	2,900 m[b]	0.4
	5,600 m[c]	1.6	5,600 m[c]	0.2
Carbon tetrachloride 24-hour[e]	758 m[a]	168.2	833 m[a]	29.8
	2,900 m[b]	101.8	2,900 m[b]	11.7
	5,600 m[c]	51.7	5,600 m[c]	5.7

Table B-17. (continued).

	Distance (m)	Pit 4 without 4A1 and 4A2 (μg/m^3)	Distance (m)	Pit 5, 6, 9, 10 (μg/m^3)
Tetrachloroethylene 24 hour[e]	758 m[a]	21.1	833 m[a]	3.7
	2,900 m[b]	12.8	2,900 m[b]	1.5
	5,600 m[c]	6.5	5,600 m[c]	0.7
Trichloroethylene 24 hour[e]	758 m[a]	21.1	833 m[a]	3.7
	2,900 m[b]	12.8	2,900 m[b]	1.5
	5,600 m[c]	6.5	5,600 m[c]	0.7
Chloroform 24 hour[e]	758 m[a]	3.0	833 m[a]	0.5
	2,900 m[b]	1.8	2,900 m[b]	0.2
	5,600 m[c]	0.9	5,600 m[c]	0.1
Methylene chloride 24 hour[e]	758 m[a]	3.0	833 m[a]	0.5
	2,900 m[b]	1.8	2,900 m[b]	0.2
	5,600 m[c]	0.9	5,600 m[c]	0.1
Carbon tetrachloride annual[f]	758 m[a]	50.5	833 m[a]	8.9
	2,900 m[b]	30.5	2,900 m[b]	3.5
	5,600 m[c]	15.5	5,600 m[c]	1.7
Tetrachloroethylene annual[f]	758 m[a]	6.3	833 m[a]	1.1
	2,900 m[b]	3.8	2,900 m[b]	0.4
	5,600 m[c]	1.9	5,600 m[c]	0.2
Trichloroethylene annual[f]	758 m[a]	6.3	833 m[a]	1.1
	2,900 m[b]	3.8	2,900 m[b]	0.4
	5,600 m[c]	1.9	5,600 m[c]	0.2
Chloroform annual[f]	758 m[a]	0.9	833 m[a]	0.2
	2,900 m[b]	0.5	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.0
Methylene chloride annual[f]	758 m[a]	0.9	833 m[a]	0.2
	2,900 m[b]	0.5	2,900 m[b]	0.1
	5,600 m[c]	0.3	5,600 m[c]	0.0

a. Distance to max. exposed collocated worker.
b. Distance to public receptor (EBR-1).
c. Distance to public receptor (Rest Area).
d. 8-hour average = 0.7 × 1-hour average for workers.
e. 24-hour average = 0.4 × 1-hour average.
f. Annual average = 0.12 × 1-hour average.

Table B-18. Chronic dose calculation for full retrieval collocated worker.

Volatile Chemical Inhalation Dose Calculation Equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs		
	Annual Average Air Concentration	Units
Carbon tetrachloride	1.18E+01[b]	µg/m^3
Chloroform	2.11E−01[b]	µg/m^3
Methylene chloride	2.11E−01[b]	µg/m^3
Tetrachloroethylene	1.48E+00[b]	µg/m^3
Trichloroethylene	1.48E+00[b]	µg/m^3
Exposure time (ET)	10[b]	hr/d
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	200[b]	d/yr
Exposure duration (ED)	25[b]	yr
Body weight (BW)	70[a]	kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,550[a]	d

Outputs		
	Noncancer Dose (ug/kg-dy)	Cancer Dose (ug/kg-dy)
Carbon tetrachloride	6.41E-01	2.75E-01
Chloroform	1.15E-02	4.92E-03
Methylene chloride	1.15E-02	4.92E-03
Tetrachloroethylene	8.04E-02	3.45E-02
Trichloroethylene	8.04E-02	3.45E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RfDi)
Risk = Inhalation Slope Factor (Sfi) × Dose.

Table B-18. (continued).

Inputs and Outputs						
	Noncarcinogenic			Carcinogenic		
Parameter	Dose (µg/kg-dy)	RfDi (µg/kg-dy)	HQ (unitless)	Dose (µg/kg-dy)	Sfi (kg-dy/µg)	Risk (unitless)
Carbon tetrachloride	6.41E-01	7.00E–01	9.15E-01	2.75E-01	5.25E–05[c]	1.44E-05
Chloroform	1.15E-02	9.00E+00	1.28E-03	4.92E-03	8.05E–05[c]	3.96E-07
Methylene chloride	1.15E-02	8.57E+02[d]	1.34E-05	4.92E-03	1.65E–06[c]	8.10E-09
Tetrachloroethylene	8.04E-02	1.70E+02[e]	4.73E-04	3.45E-02	2.07E–05[f]	7.14E-07
Trichloroethylene	8.04E-02	1.14E+01[g]	7.06E-03	3.45E-02	4.00E–04[g]	1.38E-05
Totals			**9.2E-01**			**2.9E-05**

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c. EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
d. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
e. Provisional value which should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).
g. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). USEPA EPA/600/P-01/002A. 01 August 2001. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC.

Table B-19. Acute dose calculation for full retrieval collocated worker.

Acute Hazards Assessment for the Collocated Worker					
Contaminant of Potential Concern	Peak 1-hour Exposure Concentration (µg/m^3)[a]	Acute Criteria (µg/m^3)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	4.95E+02	1.90E+03	7	REL	2.6E-01
Chloroform	8.88E+00	1.50E+02	7	REL	5.9E-02
Methylene chloride	8.88E+00	1.40E+04	1	REL	6.3E-04
Tetrachloroethylene	6.21E+01	2.37E+05	1	AEGL-1	2.6E-04
Trichloroethylene	6.21E+01	7.10E+05	1	AEGL-1	8.8E-05
			Total Hazard Index		**0.32**

a. Highest one-hour modeled concentration for worst-case receptor includes consideration of upset conditions.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-20. Chronic dose calculation for full retrieval off-Site public.

Volatile Chemical Inhalation Dose Calculation Equation: Dose (µg chem./kg bw-dy) = $\frac{(CA \times ET \times IR \times EF \times ED)}{BW \times AT^{a}}$

Inputs		
	Annual Average Air Concentration	Units
Carbon tetrachloride	2.62E+00[b]	µg/m^3
Chloroform	4.70E–02[b]	µg/m^3
Methylene chloride	4.70E–02[b]	µg/m^3
Tetrachloroethylene	3.29E-01[b]	µg/m^3
Trichloroethylene	3.29E-01[b]	µg/m^3
Exposure time (ET)	24[b]	hr/event
Inhalation rate (IR)	0.83[a]	m^3/hr
Exposure frequency (EF)	350[b]	events/yr
Exposure duration (ED)	25[b]	yr
Body weight (BW)	70[a]	kg
Averaging time (AT)		
Noncarcinogenic	10,950[a]	d
Carcinogenic	25,550[a]	d

Outputs		
	Noncancer Dose (ug/kg-dy)	Cancer Dose (ug/kg-dy)
Carbon tetrachloride	5.98E-01	2.56E-01
Chloroform	1.07E-02	4.60E-03
Methylene chloride	1.07E-02	4.60E-03
Tetrachloroethylene	7.51E-02	3.22E-02
Trichloroethylene	7.51E-02	3.22E-02

Volatile Chemical Noncancer Hazard Quotient and Cancer Risk Calculation Equation:
Hazard Quotient (HQ) = Dose/Inhalation Reference Dose (RfDi)
Risk = Inhalation Slope Factor (Sfi) × Dose.

Table B-20. (continued).

Inputs and Outputs						
	Noncarcinogenic			Carcinogenic		
Parameter	Dose (µg/kg-dy)	RfDi (µg/kg-dy)	HQ (unitless)	Dose (µg/kg-dy)	Sfi (kg-dy/µg)	Risk (unitless)
Carbon tetrachloride	5.98E-01	7.00E–01	8.54E-01	2.56E-01	5.25E–05[c]	1.35E-05
Chloroform	1.07E-02	9.00E+00	1.19E-03	4.60E-03	8.05E–05[c]	3.7E-07
Methylene chloride	1.07E-02	8.57E+02[d]	1.25E-05	4.60E-03	1.65E–06[c]	7.56E-09
Tetrachloroethylene	7.51E-02	1.70E+02[e]	4.4.2E-04	3.22E-02	2.07E–05[f]	6.66E-07
Trichloroethylene	7.51E-02	1.14E+01[f]	6.59E-03	3.22E-02	4.00E–04[g]	1.28E-05
Totals			**8.6E-01**			**2.7E-05**

a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Vol. 1, Part A, U.S. EPA, 1989.
b. Site-specific estimated value.
c. EPA Integrated Risk Information System (IRIS). The inhalation slope factor was calculated from inhalation unit risk per EPA Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment, Interim Guidance, November 1995 (i.e., 70 kg adult and 20 m^3/day).
d. EPA Health Effects Assessment Summary Table (HEAST) values obtained from DOE Risk Assessment Program.
e. Provisional value which should be used for DOE–ORR projects, established by the DOE Risk Assessment Program.
f. Provisional slope factor per California EPA and EPA Region 9 as published by the DOE Risk Information System EPA Integrated Risk Information System (http://www.epa.gov/iris/index.html) DOE Risk Information System (http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad).

Table B-21. Acute dose for full retrieval off-Site public.

Acute Hazards Assessment for the General Public					
Contaminant of Potential Concern	Peak 1-hour Exposure Concentration (µg/m^3)[a]	Acute Criteria (µg/m^3)	Averaging Time (hrs)[b]	Source[c]	Hazard Quotient
Carbon tetrachloride	2.84E+02	1.90E+03	7	REL	1.5E-01
Chloroform	5.09E+00	1.50E+02	7	REL	3.4E-02
Methylene chloride	5.09E+00	1.40E+04	1	REL	3.6E-04
Tetrachloroethylene	3.56E+01	2.37E+05	1	AEGL-1	1.5E-04
Trichloroethylene	3.56E+01	7.10E+05	1	AEGL-1	5.0E-05
			Total hazard index		**0.18**

a. Highest 1-hour modeled concentration for worst case receptor includes consideration of upset conditions and multiple retrieval operation.
b. The time duration applicable to the standard. As averaging time increases, criteria concentrations increase.
c. In order of preference selected: REL—Air Toxics Hot Spots Program Risk Assessment Guidelines, Part 1, The Determination of Acute Reference Exposure Levels for Airborne Toxicants, California EPA, 1999. AEGL-1—Level 1 Acute Exposure Guidelines, National Advisory Committee, 1997. ERPG-1—Level 1 Emergency Response Planning Guidelines Levels, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. TEEL-1—Level 1 Temporary Emergency Exposure Limits, Subcommittee on Consequence Assessment and Protective Guidelines, 1997. OSHA – Time Weight Average Permissible Exposure Level, 29 CRF 1910.1000.

Table B-22. Screen3 output for Subarea 4.

```
                    *** SCREEN3 MODEL RUN ***
                    *** VERSION DATED 96043 ***
ARP Building

SIMPLE TERRAIN INPUTS:
 SOURCE TYPE      =    POINT
 EMISSION RATE (G/S)  =   1.00000
 STACK HEIGHT (M)    =    8.8400
 STK INSIDE DIAM (M)  =    .8230
 STK EXIT VELOCITY (M/S)=   17.7433
 STK GAS EXIT TEMP (K) =   293.0000
 AMBIENT AIR TEMP (K)  =   293.0000
 RECEPTOR HEIGHT (M)  =    1.0000
 URBAN/RURAL OPTION   =    RURAL
 BUILDING HEIGHT (M)  =    .0000
 MIN HORIZ BLDG DIM (M) =    .0000
 MAX HORIZ BLDG DIM (M) =    .0000

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

 STACK EXIT VELOCITY WAS CALCULATED FROM
 VOLUME FLOW RATE =  20000.000   (ACFM)

BUOY. FLUX =   .000 M**4/S**3; MOM. FLUX =  53.310 M**4/S**2.

                    *** FULL METEOROLOGY ***

                  **********************************
                  *** SCREEN AUTOMATED DISTANCES ***
                  **********************************
 *** TERRAIN HEIGHT OF  0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES
***
```

Table B-22. (continued).

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
100.	82.12	2	5.0	5.0	1600.0	17.60	19.43	10.90	NO
200.	90.23	3	4.0	4.0	1280.0	19.79	23.83	14.37	NO
300.	82.34	4	5.0	5.0	1600.0	17.60	22.75	12.35	NO
400.	82.34	5	1.0	1.0	10000.0	27.93	22.68	12.11	NO
500.	111.6	5	1.0	1.0	10000.0	27.93	27.56	13.91	NO
600.	128.8	5	1.0	1.0	10000.0	27.93	32.39	15.67	NO
700.	136.0	5	1.0	1.0	10000.0	27.93	37.17	17.39	NO
800.	136.5	5	1.0	1.0	10000.0	27.93	41.90	19.06	NO
900.	133.0	5	1.0	1.0	10000.0	27.93	46.59	20.70	NO
1000.	131.5	6	1.0	1.0	10000.0	26.23	34.25	14.81	NO
1100.	134.1	6	1.0	1.0	10000.0	26.23	37.30	15.63	NO
1200.	134.7	6	1.0	1.0	10000.0	26.23	40.32	16.43	NO
1300.	133.9	6	1.0	1.0	10000.0	26.23	43.33	17.20	NO
1400.	132.0	6	1.0	1.0	10000.0	26.23	46.31	17.96	NO
1500.	129.4	6	1.0	1.0	10000.0	26.23	49.28	18.70	NO
1600.	126.2	6	1.0	1.0	10000.0	26.23	52.23	19.43	NO
1700.	122.8	6	1.0	1.0	10000.0	26.23	55.16	20.14	NO
1800.	119.2	6	1.0	1.0	10000.0	26.23	58.08	20.83	NO
1900.	115.5	6	1.0	1.0	10000.0	26.23	60.98	21.52	NO
2000.	111.7	6	1.0	1.0	10000.0	26.23	63.87	22.19	NO
2100.	107.9	6	1.0	1.0	10000.0	26.23	66.74	22.76	NO
2200.	104.2	6	1.0	1.0	10000.0	26.23	69.60	23.32	NO
2300.	100.7	6	1.0	1.0	10000.0	26.23	72.45	23.86	NO
2400.	97.26	6	1.0	1.0	10000.0	26.23	75.28	24.40	NO
2500.	94.00	6	1.0	1.0	10000.0	26.23	78.11	24.92	NO
2600.	90.89	6	1.0	1.0	10000.0	26.23	80.92	25.44	NO
2700.	87.92	6	1.0	1.0	10000.0	26.23	83.72	25.95	NO
2800.	85.08	6	1.0	1.0	10000.0	26.23	86.51	26.45	NO
2900.	82.38	6	1.0	1.0	10000.0	26.23	89.29	26.94	NO
3000.	79.80	6	1.0	1.0	10000.0	26.23	92.06	27.43	NO
3500.	68.75	6	1.0	1.0	10000.0	26.23	105.77	29.40	NO

Table B-22. (continued).

```
 4000.  60.05    6   1.0  1.0 10000.0  26.23 119.27  31.23  NO
 4500.  53.07    6   1.0  1.0 10000.0  26.23 132.59  32.95  NO
 5000.  47.37    6   1.0  1.0 10000.0  26.23 145.76  34.57  NO
 5500.  42.65    6   1.0  1.0 10000.0  26.23 158.77  36.10  NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND  100. M:
 758.  136.9    5   1.0  1.0 10000.0  27.93  39.97  18.38  NO

DWASH=  MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB
                              ********************************
                            *** SCREEN DISCRETE DISTANCES ***
                              ********************************
 *** TERRAIN HEIGHT OF  0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES
***

 DIST   CONC       U10M  USTK MIX HT  PLUME  SIGMA  SIGMA
 (M)  (UG/M**3)  STAB (M/S) (M/S)  (M)  HT (M)  Y (M)  Z (M) DWASH
------- ---------- ---- ----- ----- ------ ------ ------ ------ -----
 100.  82.12    2   5.0  5.0 1600.0  17.60  19.43  10.90  NO
 2900.  82.38    6   1.0  1.0 10000.0  26.23  89.29  26.94  NO
 5600.  41.80    6   1.0  1.0 10000.0  26.23 161.36  36.40  NO

DWASH=  MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB
                          ************************************
                        *** SUMMARY OF SCREEN MODEL RESULTS ***
                          ************************************
CALCULATION    MAX CONC  DIST TO  TERRAIN
```

Table B-22. (continued).

```
 PROCEDURE    (UG/M**3)  MAX (M)  HT (M)
--------------  -----------  -------  -------
SIMPLE TERRAIN   136.9     758.    0.
                    ************************************************
            ** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
                    ************************************************
```

Table B-23. Screen3 Output for portable tents.

```
                    01/26/06
                    09:53:34
                              *** SCREEN3 MODEL RUN ***
                              *** VERSION DATED 96043 ***
ARP tent

SIMPLE TERRAIN INPUTS:
 SOURCE TYPE      =    POINT
 EMISSION RATE (G/S)  =   1.00000
 STACK HEIGHT (M)    =    8.8400
 STK INSIDE DIAM (M)  =    .8230
 STK EXIT VELOCITY (M/S)=    8.8716
 STK GAS EXIT TEMP (K) =   293.0000
 AMBIENT AIR TEMP (K)  =   293.0000
 RECEPTOR HEIGHT (M)  =    1.0000
 URBAN/RURAL OPTION   =    RURAL
 BUILDING HEIGHT (M)  =    .0000
 MIN HORIZ BLDG DIM (M) =    .0000
 MAX HORIZ BLDG DIM (M) =    .0000

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

 STACK EXIT VELOCITY WAS CALCULATED FROM
 VOLUME FLOW RATE =  10000.000   (ACFM)

BUOY. FLUX =   .000 M**4/S**3; MOM. FLUX =  13.327 M**4/S**2.

                              *** FULL METEOROLOGY ***

                          **********************************
                         *** SCREEN AUTOMATED DISTANCES ***
```

Table B-23. (continued).

```
                                  **********************************

 *** TERRAIN HEIGHT OF  0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES
***


 DIST   CONC       U10M  USTK MIX HT  PLUME  SIGMA  SIGMA
 (M)  (UG/M**3)  STAB (M/S) (M/S)  (M)  HT (M)  Y (M)  Z (M) DWASH
-------- ---------- ---- ----- ----- ------ ------ ------ ------ -----
 100.  167.0    2   3.0  3.0  960.0  16.14  19.38  10.81  NO
 200.  180.5    3   2.0  2.0  640.0  19.79  23.83  14.37  NO
 300.  167.6    5   1.0  1.0 10000.0  20.86  17.24  9.35  NO
 400.  234.3    5   1.0  1.0 10000.0  20.86  22.28  11.35  NO
 500.  256.5    5   1.0  1.0 10000.0  20.86  27.23  13.25  NO
 600.  253.1    5   1.0  1.0 10000.0  20.86  32.12  15.09  NO
 700.  251.4    6   1.0  1.0 10000.0  19.79  24.66  11.37  NO
 800.  258.8    6   1.0  1.0 10000.0  19.79  27.81  12.38  NO
 900.  257.7    6   1.0  1.0 10000.0  19.79  30.93  13.35  NO
 1000.  251.5    6   1.0  1.0 10000.0  19.79  34.03  14.30  NO
 1100.  241.6    6   1.0  1.0 10000.0  19.79  37.10  15.15  NO
 1200.  230.6    6   1.0  1.0 10000.0  19.79  40.14  15.97  NO
 1300.  219.3    6   1.0  1.0 10000.0  19.79  43.16  16.77  NO
 1400.  208.1    6   1.0  1.0 10000.0  19.79  46.15  17.54  NO
 1500.  197.3    6   1.0  1.0 10000.0  19.79  49.13  18.30  NO
 1600.  187.0    6   1.0  1.0 10000.0  19.79  52.09  19.04  NO
 1700.  177.3    6   1.0  1.0 10000.0  19.79  55.03  19.76  NO
 1800.  168.1    6   1.0  1.0 10000.0  19.79  57.95  20.47  NO
 1900.  159.6    6   1.0  1.0 10000.0  19.79  60.86  21.17  NO
 2000.  151.6    6   1.0  1.0 10000.0  19.79  63.75  21.85  NO
 2100.  144.3    6   1.0  1.0 10000.0  19.79  66.63  22.43  NO
 2200.  137.5    6   1.0  1.0 10000.0  19.79  69.49  22.99  NO
 2300.  131.2    6   1.0  1.0 10000.0  19.79  72.35  23.55  NO
 2400.  125.4    6   1.0  1.0 10000.0  19.79  75.18  24.09  NO
 2500.  119.9    6   1.0  1.0 10000.0  19.79  78.01  24.62  NO
 2600.  114.9    6   1.0  1.0 10000.0  19.79  80.83  25.15  NO
 2700.  110.1    6   1.0  1.0 10000.0  19.79  83.63  25.66  NO
 2800.  105.7    6   1.0  1.0 10000.0  19.79  86.42  26.17  NO
```

Table B-23. (continued).

```
 2900.  101.6    6   1.0  1.0 10000.0  19.79  89.20  26.67  NO
 3000.  97.68    6   1.0  1.0 10000.0  19.79  91.98  27.16  NO
 3500.  82.02    6   1.0  1.0 10000.0  19.79 105.70  29.15  NO
 4000.  70.24    6   1.0  1.0 10000.0  19.79 119.21  30.99  NO
 4500.  61.11    6   1.0  1.0 10000.0  19.79 132.54  32.72  NO
 5000.  53.85    6   1.0  1.0 10000.0  19.79 145.70  34.35  NO
 5500.  47.98    6   1.0  1.0 10000.0  19.79 158.72  35.89  NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND  100. M:
 833.  259.2    6   1.0  1.0 10000.0  19.79  28.88  12.71  NO

DWASH=  MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB
                              ********************************
                            *** SCREEN DISCRETE DISTANCES ***
                              ********************************
*** TERRAIN HEIGHT OF  0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES
***

 DIST   CONC       U10M  USTK MIX HT  PLUME  SIGMA  SIGMA
 (M)  (UG/M**3)  STAB (M/S) (M/S)  (M)  HT (M)  Y (M)  Z (M) DWASH
------- ---------- ---- ----- ----- ------ ------ ------ ------ -----
 100.  167.0    2   3.0  3.0  960.0  16.14  19.38  10.81  NO
 2900.  101.6    6   1.0  1.0 10000.0  19.79  89.20  26.67  NO
 5600.  46.94    6   1.0  1.0 10000.0  19.79 161.31 36.19  NO

DWASH=  MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB
                          ************************************
```

Table B-23. (continued).

```
                    *** SUMMARY OF SCREEN MODEL RESULTS ***
                    ***************************************
CALCULATION    MAX CONC  DIST TO  TERRAIN
 PROCEDURE    (UG/M**3)  MAX (M)  HT (M)
--------------  -----------  -------  -------
SIMPLE TERRAIN   259.2     833.    0.
                    ***************************************************
            ** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
                    ***************************************************
```

Appendix C

Details of the Industrial and Transportation Risk Calculations

Appendix C

Details of the Industrial and Transportation Risk Calculations

This appendix contains two tables that show how the industrial and transportation risks for each module were calculated. The risks determined for each module were then used to calculate projected risks for each of the alternatives, as shown in Section 6.

Table C-1 shows the calculation of projected industrial injuries and fatalities. Table C-2 shows the calculation of projected transportation injuries and fatalities.

Projections of injuries are based on incidence rates specific to the various labor types and the numbers of hours of each labor type that are worked. The numerical labor types in the tables are as follows:

1. Support (i.e., construction subcontractors)
2. Service subcontractors, projects, and production
3. Research
4. Services
5. Architect/engineers
6. Security.

When more than one labor type is associated with a number of labor hours, the incidence rate is an average of the rates for the labor types indicated.

Injuries presented in this appendix are classified as recordable cases. Recordable cases include all work related illnesses and injuries which result in a loss of consciousness, days away from work, restricted work activity or job transfer, or medical treatment beyond first aid.

Table C-1. Industrial risks for each module.

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
1	Slurry Cut-Off Wall	Security	2,279	6	8.06E-06	1.84E-02	3.40E-09	7.75E-06
		Bentonite delivery, slurry pond formation, excavate-mix-and backfill, QA lab testing	5,334	1, 1a	1.07E-05	5.71E-02	3.40E-09	1.81E-05
			Module 1	**Totals**		**7.54E-02**		**2.59E-05**
2	Preloading Compaction	Security	2,279	6	8.06E-06	1.84E-02	3.40E-09	7.75E-06
		Haul in soil for compaction	2,624	1, 1a	1.07E-05	2.81E-02	3.40E-09	8.92E-06
		Proof Roll SDA for Stability	1,835	1, 1a	1.07E-05	1.96E-02	3.40E-09	6.24E-06
			Module 2	**Totals**		**6.61E–02**		**2.29E-05**
3	ET Cap	Security	58,824	6	8.06E-06	4.74E-01	3.40E-09	2.00E-04
		Demolish or relocate environmental monitoring equipment and utilities	7,165	1, 1a	1.07E-05	7.67E-02	3.40E-09	2.44E-05
		Install water storage tank	1,059	1, 1a	1.07E-05	1.13E-02	3.40E-09	3.60E-06
		Install new SDA perimeter gravel road	2,256	1, 1a	1.07E-05	2.41E-02	3.40E-09	7.67E-06
		Install new SDA perimeter fence and demolish old SDA perimeter fence	13,132	1, 1a	1.07E-05	1.41E-01	3.40E-09	4.46E-05
		Abandon or extend existing wells and probes	6,176	1, 1a	1.07E-05	6.61E-02	3.40E-09	2.10E-05
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	5,286	1, 1a	1.07E-05	5.66E-02	3.40E-09	1.80E-05
		Extend existing tensiometers and install new tensiometers	3,126	1, 1a	1.07E-05	3.34E-02	3.40E-09	1.06E-05
		Install grading fill	33,213	1, 1a	1.07E-05	3.55E-01	3.40E-09	1.13E-04
		Install 24-in. cobble layer	33,975	1, 1a	1.07E-05	3.64E-01	3.40E-09	1.16E-04
		Install 12-in. gravel layer and 12-in. sand layer	22,954	1, 1a	1.07E-05	2.46E-01	3.40E-09	7.80E-05
		Install 48-in. fine soil layer	50,657	1, 1a	1.07E-05	5.42E-01	3.40E-09	1.72E-04
		Install 12-in. topsoil layer and vegetate	14,315	1, 1a	1.07E-05	1.53E-01	3.40E-09	4.87E-05
		OCVZ abovegrade piping to probes	29,443	1, 1a	1.07E-05	3.15E-01	3.40E-09	1.00E-04
		Install side slope and armor layers	14,585	1, 1a	1.07E-05	1.56E-01	3.40E-09	4.96E-05
		Install 6 sampling wells outside the SDA	16,469	1, 1a	1.07E-05	1.76E-01	3.40E-09	5.60E-05
		Recontour south and east ends of SDA for drainage	6,842	1, 1a	1.07E-05	7.32E-02	3.40E-09	2.33E-05
			Module 3	**Totals**		**3.26E+00**		**1.09E-03**
4	ET Cap without Gas Vent Layer	Security	29,412	6	8.06E-06	2.37E-01	3.40E-09	1.00E-04
		Demolish or relocate environmental monitoring equipment and utilities	7,165	1, 1a	1.07E-05	7.67E-02	3.40E-09	2.44E-05
		Install water storage tank	1,059	1, 1a	1.07E-05	1.13E-02	3.40E-09	3.60E-06

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
		Install new SDA perimeter gravel road	2,256	1, 1a	1.07E-05	2.41E-02	3.40E-09	7.67E-06
		Install new SDA perimeter fence and demolish old SDA perimeter fence	13,132	1, 1a	1.07E-05	1.41E-01	3.40E-09	4.46E-05
		Abandon or extend existing wells and probes	6,176	1, 1a	1.07E-05	6.61E-02	3.40E-09	2.10E-05
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	5,286	1, 1a	1.07E-05	5.66E-02	3.40E-09	1.80E-05
		Extend existing tensiometers and install new tensiometers	3,126	1, 1a	1.07E-05	3.34E-02	3.40E-09	1.06E-05
		Install grading fill	33,213	1, 1a	1.07E-05	3.55E-01	3.40E-09	1.13E-04
		Install 12-in. topsoil layer and vegetate	14,315	1, 1a	1.07E-05	1.53E-01	3.40E-09	4.87E-05
		OCVZ abovegrade piping to probes	16,357	1, 1a	1.07E-05	1.75E-01	3.40E-09	5.56E-05
		Install 6 sampling wells outside the SDA	16,469	1, 1a	1.07E-05	1.76E-01	3.40E-09	5.60E-05
		Recontour south and east ends of SDA for drainage	6,842	1, 1a	1.07E-05	7.32E-02	3.40E-09	2.33E-05
			Module 4	**Totals**		**1.58E+00**		**5.26E-04**
5	RCRA Type C Cap	Security	52,941	6	8.06E-06	4.27E-01	3.40E-09	1.80E-04
		Demolish or relocate environmental monitoring equipment and utilities	7,165	1,1a	1.07E-05	7.67E-02	3.40E-09	2.44E-05
		Install water storage tank	1,059	1,1a	1.07E-05	1.13E-02	3.40E-09	3.60E-06
		Install new SDA perimeter gravel road	2,256	1,1a	1.07E-05	2.41E-02	3.40E-09	7.67E-06
		Install new SDA perimeter fence and demolish old SDA perimeter fence	13,132	1,1a	1.07E-05	1.41E-01	3.40E-09	4.46E-05
		Abandon or extend existing wells and probes	6,176	1,1a	1.07E-05	6.61E-02	3.40E-09	2.10E-05
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	5,286	1,1a	1.07E-05	5.66E-02	3.40E-09	1.80E-05
		Extend existing tensiometers and install new tensiometers	3,126	1,1a	1.07E-05	3.34E-02	3.40E-09	1.06E-05
		Install grading fill	33,213	1,1a	1.07E-05	3.55E-01	3.40E-09	1.13E-04
		Install 4-in. asphalt base and 6-in. asphalt layer	144,283	1,1a	1.07E-05	1.54E+00	3.40E-09	4.91E-04
		Install 6-in. gravel layer and 6-in. gravel filter layer	15,264	1,1a	1.07E-05	1.63E-01	3.40E-09	5.19E-05
		Install 6-in. sand layer	3,967	1,1a	1.07E-05	4.24E-02	3.40E-09	1.35E-05
		Install 20-in. compacted topsoil layer	21,183	1,1a	1.07E-05	2.27E-01	3.40E-09	7.20E-05
		Install 20-in. topsoil layer and vegetate	22,619	1,1a	1.07E-05	2.42E-01	3.40E-09	7.69E-05
		OCVZ abovegrade piping to probes	16,357	1,1a	1.07E-05	1.75E-01	3.40E-09	5.56E-05

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
		Install side slope and armor layers	12,162	1,1a	1.07E-05	1.30E-01	3.40E-09	4.14E-05
		Install 6 sampling wells outside the SDA	16,469	1,1a	1.07E-05	1.76E-01	3.40E-09	5.60E-05
		Recontour south and east ends of SDA for drainage	6,805	1,1a	1.07E-05	7.28E-02	3.40E-09	2.31E-05
			Module 5	**Totals**		**3.96E+00**		**1.30E-03**
6	Gas Vent Layer Extraction Pipe	Install gas vent lines within gas collection layer of cap	6,368	4	1.19E-05	7.58E-02	3.40E-09	2.17E-05
		Manifold and connect 6 vent pipes to OCVZ offgas treatment units	8,445	4	1.19E-05	1.00E-01	3.40E-09	2.87E-05
			Module 6	**Totals**		**1.76E-01**		**5.04E-05**
7	Shallow Extraction Pipe	Security	308	6	8.06E-06	2.48E-03	3.40E–09	1.05E–06
		Surveying	159	5	1.50E-06	2.38E-04	3.40E–09	5.40E–07
		Drilling and installing shallow extraction wells	1,631	1,1a	1.07E-05	1.75E-02	3.40E–09	5.55E–06
		Connect wells to OCVZ offgas treatment units	10,355	1,1a	1.07E-05	1.11E-01	3.40E–09	3.52E-05
			Module 7	**Totals**		**1.31E-01**		**4.23E-05**
8	Dynamic Compaction: Pits	Security	4,559	6	8.06E-06	3.67E-02	3.40E-09	1.55E-05
		Surveying	118	5	1.50E-06	1.77E-04	3.40E-09	4.00E-07
		12-in. fill prior to compaction	2,078	1,1a	1.07E-05	2.22E-02	3.40E-09	7.07E-06
		18.7-acre dynamic compaction	11,340	1,1a	1.07E-05	1.21E-01	3.40E-09	3.86E-05
			Module 8	**Totals**		**1.81E-01**		**6.15E-05**
9	Dynamic Compaction: Pad A	Security	456	6	8.06E-06	3.67E-03	3.40E-09	1.55E-06
		Surveying	118	5	1.50E-06	1.77E-04	3.40E-09	4.00E-07
		12-in. fill prior to compaction	89	1,1a	1.07E-05	9.51E-04	3.40E-09	3.02E-07
		Pad A dynamic compaction	479	1,1a	1.07E-05	5.13E-03	3.40E-09	1.63E-06
			Module 9	**Totals**		**9.93E-03**		**3.88E-06**
10	Foundation Grouting	Security	9,118	6	8.06E-06	7.35E-02	3.40E-09	3.10E-05
		Surveying	115	5	1.50E-06	1.72E-04	3.40E-09	3.91E-07
		Modify trackhoe	42,422	1,1a	1.07E-05	4.54E-01	3.40E-09	1.44E-04
		18.7-acre foundation grouting	25,917	1,1a	1.07E-05	2.77E-01	3.40E-09	8.81E-05
		Capping grout returns	553	1,1a	1.07E-05	5.92E-03	3.40E-09	1.88E-06
			Module 10	**Totals**		**8.11E-01**		**2.66E-04**

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
11	Contaminant Grouting	Security	4,559	6	8.06E-06	3.67E-02	3.40E-09	1.55E-05
		Surveying	942	5	1.50E-05	1.41E-02	3.40E-09	3.20E-06
		Modify trackhoe	63,851	1,1a	1.07E-05	6.83E-01	3.40E-09	2.17E-04
		0.7-acre foundation grouting	64,571	1,1a	1.07E-05	6.91E-01	3.40E-09	2.20E-04
		Capping grout returns	640	1,1a	1.07E-05	6.85E-03	3.40E-09	2.18E-06
			Module 11	**Totals**		**1.43E+00**		**4.58E-04**
12	two-acre Excavation	Security	76,471	6	8.06E-06	6.16E-01	3.40E-09	2.60E-04
		Procurement and construction of 1 retrieval enclosure (RE2), 3 tents, and 43 tent moves	281,268	1,1a	1.07E-05	3.01E+00	3.40E-09	9.56E-04
		Waste excavation within the RE and 46 tents (packaging, retrieval, sampling, tent moves)	1,041,634	1,1a	1.07E-05	1.11E+01	3.40E-09	3.54E-03
		Deactivation, decontamination, and decommissioning of tents and RE	114,635	1,1a	1.07E-05	1.23E+00	3.40E-09	3.90E-04
		Assay waste drums	133,627	1,1a	1.07E-05	1.43E+00	3.40E-09	4.54E-04
		Storage, characterization, and shipment of transuranic waste to the Waste Isolation Pilot Project	1,069,097	1,1a	1.07E-05	1.14E+01	3.40E-09	3.63E-03
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	1,997	1,1a	1.07E-05	2.14E-02	3.40E-09	6.79E-06
			Module 12	**Totals**		**2.89E+01**		**9.24E-03**
13	four-acre Excavation	Security	105,882	6	8.06E-06	8.53E-01	3.40E-09	3.60E-04
		Procurement and construction of one retrieval enclosure (RE2), three tents, and 80 tent moves	381,973	1,1a	1.07E-05	4.09E+00	3.40E-09	1.30E-03
		Waste excavation within the RE and 83 tents (packaging, retrieval, sampling, tent moves)	1,826,631	1,1a	1.07E-05	1.95E+01	3.40E-09	6.21E-03
		Deactivation, decontamination, and decommissioning of tents and RE	158,818	1,1a	1.07E-05	1.70E+00	3.40E-09	5.40E-04
		Assay waste drums	307,342	1,1a	1.07E-05	3.29E+00	3.40E-09	1.04E-03
		Storage, characterization, and shipment of transuranic waste to the Waste Isolation Pilot Project	1,367,850	1,1a	1.07E-05	1.46E+01	3.40E-09	4.65E-03
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	2,790	1,1a	1.07E-05	2.99E-02	3.40E-09	9.49E-06
			Module 13	**Totals**		**4.41E+01**		**1.41E-02**

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
14	Full Excavation	Security	329,412	6	8.06E-06	2.66E+00	3.40E-09	1.12E-03
		Procurement and construction of one retrieval enclosure (RE2), three tents, and 80 tent moves	3,528,294	1,1a	1.07E-05	3.78E+01	3.40E-09	1.20E-02
		Waste excavation within the RE and 83 tents (packaging, retrieval, sampling, tent moves)	36,800,839	1,1a	1.07E-05	3.94E+02	3.40E-09	1.25E-01
		Deactivation, decontamination, and decommissioning of tents and RE	1,121,813	1,1a	1.07E-05	1.20E+01	3.40E-09	3.81E-03
		Assay waste drums	2,458,734	1,1a	1.07E-05	2.63E+01	3.40E-09	8.36E-03
		Storage, characterization, and shipment of transuranic waste to the Waste Isolation Pilot Project	9,295,329	1,1a	1.07E-05	9.95E+01	3.40E-09	3.16E-02
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	1,778,686	1,1a	1.07E-05	1.90E+01	3.40E-09	6.05E-03
		Storage and shipment of non-transuranic waste to off-Site facility	923,036	1,1a	1.07E-05	9.88E+00	3.40E-09	3.14E-03
		Storage and shipment of remote-handled waste	902,495	1,1a	1.07E-05	9.66E+00	3.40E-09	3.07E-03
			Module 14	**Totals**		**6.11E+02**		**1.94E-01**
15	Pad A Removed without Treatment + Ship to LLW Pit	Security	41,176	6	8.06E-06	3.32E-01	3.40E-09	1.40E-04
		Construction of utilities, access road, one retrieval enclosure (RE), and one storage building	108,475	1,1a	1.07E-05	1.16E+00	3.40E-09	3.69E-04
		Noncontaminated sideburden removal	232	1,1a	1.07E-05	2.48E-03	3.40E-09	7.89E-07
		Surveying	353	1,1a	1.07E-05	3.78E-03	3.40E-09	1.20E-06
		Waste excavation	108,800	1,1a	1.07E-05	1.16E+00	3.40E-09	3.70E-04
		Deactivation, decontamination, and decommissioning of new RE	58,676	1,1a	1.07E-05	6.28E-01	3.40E-09	2.00E-04
		Storage and shipment of waste to LLW pit	480	1,1a	1.07E-05	5.14E-03	3.40E-09	1.63E-06
			Module15	**Totals**		**3.30E+00**		**1.08E-03**

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
16	Pad A Removed without Treatment + Ship to the Idaho CERCLA Disposal Facility Pit	Security	47,059	6	8.06E-06	3.79E-01	3.40E-09	1.60E-04
		Construction of utilities, access road, one retrieval enclosure (RE), and one storage building	108,474	1,1a	1.07E-05	1.16E+00	3.40E-09	3.69E-04
		Noncontaminated sideburden removal	232	1,1a	1.07E-05	2.48E-03	3.40E-09	7.89E-07
		Surveying	315	1,1a	1.07E-05	3.37E-03	3.40E-09	1.07E-06
		Waste excavation	508,856	1,1a	1.07E-05	5.44E+00	3.40E-09	1.73E-03
		Deactivation, decontamination, and decommissioning of new RE	65,265	1,1a	1.07E-05	6.98E-01	3.40E-09	2.22E-04
		Storage and shipment of waste to the Idaho CERCLA Disposal Facility pit	86,468	1,1a	1.07E-05	9.25E-01	3.40E-09	2.94E-04
			Module 16	**Totals**		**8.61E+00**		**2.78E-03**
17	Pad A Removed without Treatment + Ship to Off-Site Pit	Security	52,941	6	8.06E-06	4.27E-01	3.40E-09	1.80E-04
		Construction of utilities, access road, one retrieval enclosure (RE), and rail spur	109,681	1,1a	1.07E-05	1.17E+00	3.40E-09	3.73E-04
		Noncontaminated sideburden removal	232	1,1a	1.07E-05	2.48E-03	3.40E-09	7.89E-07
		Surveying	315	1,1a	1.07E-05	3.37E-03	3.40E-09	1.07E-06
		Waste excavation	102,421	1,1a	1.07E-05	1.10E+00	3.40E-09	3.48E-04
		Deactivation, decontamination, and decommissioning of new RE	54,571	1,1a	1.07E-05	5.84E-01	3.40E-09	1.86E-04
		Storage and shipment of waste to off-Site facility	15,018	1,1a	1.07E-05	1.61E-01	3.40E-09	5.11E-05
			Module 17	**Totals**		**3.45E+00**		**1.14E-03**
18	Pad A Ex Situ Grout Treatment	Security	47,059	6	8.06E-06	3.79E-01	3.40E-09	1.60E-04
		Construction of utilities, access road, one retrieval enclosure (RE), and one storage building	107,710	1,1a	1.07E-05	1.15E+00	3.40E-09	3.66E-04
		Noncontaminated sideburden removal	232	1,1a	1.07E-05	2.48E-03	3.40E-09	7.89E-07
		Surveying	315	1,1a	1.07E-05	3.37E-03	3.40E-09	1.07E-06
		Waste excavation and treatment	403,204	1,1a	1.07E-05	4.31E+00	3.40E-09	1.37E-03
		Deactivation, decontamination, and decommissioning of new RE	67,999	1,1a	1.07E-05	7.28E-01	3.40E-09	2.31E-04
		Storage and shipment of waste to LLW pit	9,342	1,1a	1.07E-05	1.00E-01	3.40E-09	3.18E-05
			Module 18	**Totals**		**6.68E+00**		**2.16E-03**
19	Monitoring (O&M)	Groundwater monitoring	209,907	3,4,5	5.36E-06	1.13E+00	3.40E-09	7.14E-04
		Vadose zone monitoring	743,923	3,4,5	5.36E-06	3.99E+00	3.40E-09	2.53E-03

Table C-1. (continued).

Module Number	Alternative Modules	Module Task	Labor Hours	Labor Type[a]	Injury/Hr	Injuries	Fatalities/Hr	Fatalities
		Technical support	158,972	3,4,5	5.36E-06	8.52E-01	3.40E-09	5.41E-04
			Module 19	**Totals**		**5.96E+00**		**3.78E-03**
20a	OCVZ 5-year operation and maintenance	OCVZ sampling and analysis	15,338	3,4,5	5.36E-06	8.22E-02	3.40E-09	5.21E-05
		OCVZ reporting	20,310	3	2.67E-06	5.42E-02	3.40E-09	6.91E-05
		OCVZ waste management	735	4	1.19E-05	8.74E-03	3.40E-09	2.50E-06
		OCVZ routine maintenance	7,665	4	1.19E-05	9.12E-02	3.40E-09	2.61E-05
		OCVZ modifications (example: catalyst replacement)	8,169	4	1.19E-05	9.72E-02	3.40E-09	2.78E-05
			Module 20a	**Totals**		**3.34E–01**		**1.78E-04**
20b	OCVZ 20-year replacement	Security	1,000	6	8.06E-06	8.06E-03	3.40E-09	3.40E-06
		Replacement of old OCVZ treatment unit	1,545	1	4.71E-06	7.27E-03	3.40E-09	5.25E-06
		Demolition and removal of old treatment unit	2,534	1	4.71E-06	1.19E-02	3.40E-09	8.62E-06
			Module 20b	**Totals**		**2.73E–02**		**1.73E-05**
20c	OCVZ shutdown monitoring	OCVZ closure monitoring	8,859	3,4,5	5.36E-06	4.75E-02	3.40E-09	2.92E-05
			Module 20c	**Totals**		**4.75E–02**		**2.92E-05**

a. The numerical labor types are as follows:

1. Support (i.e., construction subcontractors)
2. Service subcontractors, projects, and production
3. Research
4. Services
5. Architect/engineers
6. Security.

When more than one labor type is associated with a number of labor hours, the incidence rate is an average of the rates for the labor types indicated.

Table C-2. Transportation risks for each module.

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
1	Slurry Cut-Off Wall	Security	0				0.00E+00		0.00E+00
		Bentonite delivery, slurry pond formation, excavate-mix-and backfill, QA lab testing	70,000	Hwy/55	**Public**	1.01E-06	7.07E-02	2.26E-08	1.58E-03
2	Preloading Compaction	Security	0				0.00E+00		0.00E+00
		Haul in soil for compaction	4,600	Paved/35	**Workers**	1.01E-06	4.65E-03	3.45E-08	1.59E-04
		Proof roll SDA for stability	0				0.00E+00		0.00E+00
3	ET Cap	Security	0				0.00E+00		0.00E+00
		Demolish or relocate environmental monitoring equipment and utilities	0				0.00E+00		0.00E+00
		Install water storage tank	0				0.00E+00		0.00E+00
		Install new SDA perimeter gravel road	0				0.00E+00		0.00E+00
		Install new SDA perimeter fence and demolish old SDA perimeter fence	0				0.00E+00		0.00E+00
		Abandon or extend existing wells and probes	0				0.00E+00		0.00E+00
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	0				0.00E+00		0.00E+00
		Extend existing tensiometers and install new tensiometers	0				0.00E+00		0.00E+00
		Install grading fill	66,000	Paved/35	Workers	1.01E-06	6.67E-02	3.45E-08	2.28E-03
		Install 24-in. cobble layer	600,000	Hwy/55	Public	1.01E-06	6.06E-01	2.26E-08	1.36E-02
		Install 12-in. gravel layer and 12-in. sand layer	39,000	Paved/35	Workers	1.01E-06	3.94E-02	3.45E-08	1.35E-03
		Install 48-in. fine soil layer	270,000	Hwy/Paved 55/35	Public	1.01E-06	2.73E-01	2.86E-08	7.72E-03
		Install 12-in. topsoil layer and vegetate	67,000	Hwy/Paved 55/35	Public	1.01E-06	6.77E-02	2.86E-08	1.92E-03
		OCVZ abovegrade piping to probes	0				0.00E+00		0.00E+00
		Install side slope and armor layers	48,000	Hwy/55	Public	1.01E-06	4.85E-02	2.26E-08	1.08E-03

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
		Install 6 sampling wells outside the SDA	0				0.00E+00		0.00E+00
		Recontour south and east ends of SDA for drainage	0				0.00E+00		0.00E+00
	ET Cap (O&M)	Groundwater monitoring	0				0.00E+00		0.00E+00
		Vadose zone monitoring	0				0.00E+00		0.00E+00
		Cap repair	0				0.00E+00		0.00E+00
		Cap surveillance	0				0.00E+00		0.00E+00
		Technical support	0				0.00E+00		0.00E+00
Sums for Module 3				**Workers**			**1.11E-01**		**3.62E-03**
				Public			**1.07E+00**		**2.43E-02**
4	ET Cap without Gas Vent Layer	Security	0				0.00E+00		0.00E+00
		Demolish or relocate environmental monitoring equipment and utilities	0				0.00E+00		0.00E+00
		Install water storage tank	0				0.00E+00		0.00E+00
		Install new SDA perimeter gravel road	0				0.00E+00		0.00E+00
		Install new SDA perimeter fence and demolish old SDA perimeter fence	0				0.00E+00		0.00E+00
		Abandon or extend existing wells and probes	0				0.00E+00		0.00E+00
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	0				0.00E+00		0.00E+00
		Extend existing tensiometers and install new tensiometers	0				0.00E+00		0.00E+00
		Install grading fill	66,000	Paved/35	**Workers**	1.01E-06	6.67E-02	3.45E-08	2.28E-03
		Install 12-in. topsoil layer and vegetate	140,000	Hwy/Paved 55/35	**Public**	1.01E-06	1.41E-01	2.86E-08	4.00E-03
		OCVZ abovegrade piping to probes	0				0.00E+00		0.00E+00
		Install 6 sampling wells outside the SDA	0				0.00E+00		0.00E+00
		Recontour south and east ends of SDA for	0				0.00E+00		0.00E+00

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
		drainage							
	ET Cap without Gas Vent Layer (O&M)	Groundwater monitoring	0				0.00E+00		0.00E+00
		Vadose zone monitoring	0				0.00E+00		0.00E+00
		Cap repair	0				0.00E+00		0.00E+00
		Cap surveillance	0				0.00E+00		0.00E+00
		Technical support	0				0.00E+00		0.00E+00
5	RCRA Type C Cap	Security	0				0.00E+00		0.00E+00
		Demolish or relocate environmental monitoring equipment and utilities	0				0.00E+00		0.00E+00
		Install water storage tank	0				0.00E+00		0.00E+00
		Install new SDA perimeter gravel road	0				0.00E+00		0.00E+00
		Install new SDA perimeter fence and demolish old SDA perimeter fence	0				0.00E+00		0.00E+00
		Abandon or extend existing wells and probes	0				0.00E+00		0.00E+00
		Extend existing OCVZ probes and temporarily relocate OCVZ treatment units	0				0.00E+00		0.00E+00
		Extend existing tensiometers and install new tensiometers	0				0.00E+00		0.00E+00
		Install grading fill	66,000	Paved/35	Workers	1.01E-06	6.67E-02	3.45E-08	2.28E-03
		Install 4-in. asphalt base and 6-in. asphalt layer	420,000	Hwy/55	Public	1.01E-06	4.24E-01	2.26E-08	9.49E-03
		Install 6-in. gravel layer and 6-in. gravel filter layer	20,000	Paved 35	Workers	1.01E-06	2.02E-02	3.45E-08	6.90E-04
		Install 6-in. sand layer	10,000	Paved 35	Workers	1.01E-06	1.01E-02	3.45E-08	3.45E-04
		Install 20-in. compacted topsoil layer	110,000	Hwy/Paved 55/35	Public	1.01E-06	1.11E-01	2.86E-08	3.15E-03
		Install 20-in. topsoil layer and vegetate	110,000	Hwy/Paved 55/35	Public	1.01E-06	1.11E-01	2.86E-08	3.15E-03
		OCVZ abovegrade piping to probes	0				0.00E+00		0.00E+00

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
		Install side slope and armor layers	34,000	Hwy/55	Public	1.01E-06	3.43E-02	2.26E-08	7.68E-04
		Install 6 sampling wells outside the SDA	0				0.00E+00		0.00E+00
		Recontour south and east ends of SDA for drainage	0				0.00E+00		0.00E+00
	RCRA Type C Cap (O&M)	Groundwater monitoring	0				0.00E+00		0.00E+00
		Vadose zone monitoring	0				0.00E+00		0.00E+00
		Cap repair	0				0.00E+00		0.00E+00
		Cap surveillance	0				0.00E+00		0.00E+00
		Technical support	0				0.00E+00		0.00E+00
Sums for Module 5					**Workers**		**9.70E-02**		**3.31E-03**
					Public		**6.81E-01**		**1.66E-02**
10	Foundation Grouting	Security	0				0.00E+00		0.00E+00
		Surveying	0				0.00E+00		0.00E+00
		Modify trackhoe	0				0.00E+00		0.00E+00
		18.7-acre foundation grouting (Option 1—Grout from onsite batch plant)	1,300	Paved/25	**Workers**	1.01E-06	1.31E-03	3.45E-08	4.49E-05
		18.7-acre foundation grouting (Option 2—Grout from IF)	80,000	Hwy/55	**Public**	1.01E-06	8.08E-02	2.26E-08	1.81E-03
		Capping grout returns	0				0.00E+00		0.00E+00
11	Contaminant Grouting	Security	0				0.00E+00		0.00E+00
		Surveying	0				0.00E+00		0.00E+00
		Modify trackhoe	0				0.00E+00		0.00E+00
		0.7-acre foundation grouting (Option 1—Grout from onsite batch plant)	2,800	Paved/25	**Workers**	1.01E-06	2.83E-03	3.45E-08	9.66E-05
		0.7-acre foundation grouting (Option 2—Grout from IF)	170,000	Hwy/55	**Public**	1.01E-06	1.72E-01	2.26E-08	3.84E-03
		Capping grout returns	0				0.00E+00		0.00E+00
12	2 Acre	Security	0				0.00E+00		0.00E+00

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
	Excavation	Construction of one retrieval enclosure (RE2), three tents, and 43 tent moves	0				0.00E+00		0.00E+00
		Waste excavation within the retrieval enclosure and 46 tents (packaging, retrieval, sampling, tent moves)	0				0.00E+00		0.00E+00
		Deactivation, decontamination, and decommissioning of tents and retrieval enclosure	0				0.00E+00		0.00E+00
		Assay waste drums	0				0.00E+00		0.00E+00
		Storage and shipment of transuranic waste to the Waste Isolation Pilot Project	2,444,000	Hwy/55	**Public**	1.01E-06	2.47E+00	1.19E-08	2.91E-02
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	380	Paved/25	**Workers**	1.01E-06	3.84E-04	3.45E-08	1.31E-05
13	4 Acre Excavation	Security	0				0.00E+00		0.00E+00
		Construction of one Retrieval Enclosure (RE2), three tents, and 80 tent moves	0				0.00E+00		0.00E+00
		Waste excavation within the retrieval enclosure and 83 tents (packaging, retrieval, sampling, tent moves)	0				0.00E+00		0.00E+00
		Deactivation, decontamination, and decommissioning of tents and retrieval enclosure	0				0.00E+00		0.00E+00
		Assay waste drums	0				0.00E+00		0.00E+00
		Storage and shipment of transuranic waste to the Waste Isolation Pilot Project	3,127,000	Hwy/55	**Public**	1.01E-06	3.16E+00	1.19E-08	3.72E-02
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	540	Paved/25	**Workers**	1.01E-06	5.45E-04	3.45E-08	1.86E-05
14	Full Excavation	Security	0				0.00E+00		0.00E+00
		Construction of one retrieval enclosure (RE2), three tents, and 80 tent moves	0				0.00E+00		0.00E+00
		Waste excavation within the retrieval	0				0.00E+00		0.00E+00

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
		enclosure and 83 tents (packaging, retrieval, sampling, tent moves)							
		Deactivation, decontamination, and decommissioning of tents and retrieval enclosure	0				0.00E+00		0.00E+00
		Assay waste drums	0				0.00E+00		0.00E+00
		Storage and shipment of transuranic waste to the Waste Isolation Pilot Project	3,127,000	Hwy/55	Public	1.01E-06	3.16E+00	1.19E-08	3.72E-02
		Storage and shipment of non-transuranic waste to the Idaho CERCLA Disposal Facility	540	Paved/25	Workers	1.01E-06	5.45E-04	3.45E-08	1.86E-05
		Storage and shipment of non-transuranic waste to off-Site facility	27,000,000	Hwy/55	Public	1.01E-06	2.73E+01	1.19E-08	3.21E-01
		Storage and shipment of remote handled waste	0				0.00E+00		0.00E+00
		Sums for Module 14			**Workers**		**5.45E-04**		**1.86E-05**
					Public		**3.04E+01**		**3,59E-01**
16	Pad A Removed without Treatment + Ship to the Idaho CERCLA Disposal Facility Pit	Security	0				0.00E+00		0.00E+00
		Construction of utilities, access road, one retrieval enclosure, and one storage building	0				0.00E+00		0.00E+00
		Noncontaminated sideburden removal	0				0.00E+00		0.00E+00
		Surveying	0				0.00E+00		0.00E+00
		Waste excavation	0				0.00E+00		0.00E+00
		Deactivation, decontamination, and decommissioning of new retrieval enclosure	0				0.00E+00		0.00E+00
		Storage and shipment of waste to the Idaho CERCLA Disposal Facility pit	39,000	Paved/25	**Workers**	1.01E-06	3.94E-02	3.45E-08	1.35E-03
17	Pad A Removed without Treatment + Ship to	Security	0				0.00E+00		0.00E+00
		Construction of utilities, access road, one retrieval enclosure, and rail spur	0				0.00E+00		0.00E+00
		Noncontaminated sideburden removal	0				0.00E+00		0.00E+00

Table C-2. (continued).

Module Number	Alternative Modules	Module Task	Total Miles (round trip)	Road Type/Speed (mph)	Persons at Risk[a]	Injury Incidence Rate	Projected Injuries	Fatality Incidence Rate	Projected Fatalities
	Off-Site Pit	Surveying	0				0.00E+00		0.00E+00
		Waste excavation	0				0.00E+00		0.00E+00
		Deactivation, decontamination, and decommissioning of new retrieval enclosure	0				0.00E+00		0.00E+00
		Storage and shipment of waste to off-Site facility	160,000	Paved/25	**Workers**	1.01E-06	1.62E-01	3.45E-08	5.52E-03

a. All workers are collocated workers.

Appendix D

Radionuclide Data and Calculations

Appendix D

Radionuclide Data and Calculations

D-1. RWMC Area Dosimetry Data

Table D-1. Area TLD exposure rates measured outside retrieval enclosures during the ARP project.

Site	Area	Location	TLD #	Begin	End	Days	Hours	Reading		Exposure Rate	
INEEL-2,5,8,11	RWMC	O-20 ARP RA	2308	1-Aug-05	31-Oct-05	91	2184	84.4	mR	3.86E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-20 ARP RA	3536	1-Feb-05	30-Apr-05	88	2112	82.8	mR	3.92E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-20 ARP RA	4184	1-May-05	31-Jul-05	91	2184	77.8	mR	3.56E–02	mR/hr
INEEL-	RWMC	O-21 ARP RA	2309	1-Aug-05	31-Oct-05	91	2184	61.2	mR	2.80E–02	mR/hr

Site	Area	Location	TLD #	Begin	End	Days	Hours	Reading		Exposure Rate	
2,5,8,11											
INEEL-2,5,8,11	RWMC	O-21 ARP RA	3537	1-Feb-05	30-Apr-05	88	2112	59.7	mR	2.83E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-21 ARP RA	4183	1-May-05	31-Jul-05	91	2184	58.7	mR	2.69E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-22 ARA RA	2310	1-Aug-05	31-Oct-05	91	2184	101.1	mR	4.63E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-22 ARA RA	3538	1-Feb-05	30-Apr-05	88	2112	122	mR	5.78E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-22 ARA RA	4182	1-May-05	31-Jul-05	91	2184	102.3	mR	4.68E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-23 ARA RA	2311	1-Aug-05	31-Oct-05	91	2184	70.8	mR	3.24E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-23 ARA RA	3539	1-Feb-05	30-Apr-05	88	2112	77.6	mR	3.67E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-23 ARA RA	4180	1-May-05	31-Jul-05	91	2184	84.4	mR	3.86E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-24 ARA RA	2312	1-Aug-05	31-Oct-05	91	2184	78.1	mR	3.58E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-24 ARA RA	3540	1-Feb-05	30-Apr-05	88	2112	81.7	mR	3.87E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-24 ARA RA	4178	1-May-05	31-Jul-05	91	2184	95	mR	4.35E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-25 ARA RA	2313	1-Aug-05	31-Oct-05	91	2184	84.3	mR	3.86E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-25 ARA RA	3541	1-Feb-05	30-Apr-05	88	2112	90.6	mR	4.29E–02	mR/hr
INEEL-	RWMC	O-25 ARA RA	4177	1-May-05	31-Jul-05	91	2184	98.3	mR	4.50E–02	mR/hr

Site	Area	Location	TLD #	Begin	End	Days	Hours	Reading		Exposure Rate	
2,5,8,11											
INEEL-2,5,8,11	RWMC	O-26 ARA RA	2315	1-Aug-05	31-Oct-05	91	2184	79.6	mR	3.64E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-26 ARA RA	3542	1-Feb-05	30-Apr-05	88	2112	88.7	mR	4.20E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-26 ARA RA	4176	1-May-05	31-Jul-05	91	2184	100.4	mR	4.60E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-27 ARA RA	2316	1-Aug-05	31-Oct-05	91	2184	77.9	mR	3.57E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-27 ARA RA	3543	1-Feb-05	30-Apr-05	88	2112	73.7	mR	3.49E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-27 ARA RA	4175	1-May-05	31-Jul-05	91	2184	82.8	mR	3.79E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-28 ARA RA	2317	1-Aug-05	31-Oct-05	91	2184	209.8	mR	9.61E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-28 ARA RA	3544	1-Feb-05	30-Apr-05	88	2112	118.2	mR	5.60E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-28 ARA RA	4174	1-May-05	31-Jul-05	91	2184	133.8	mR	6.13E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-29 ARA RA	2318	1-Aug-05	31-Oct-05	91	2184	59.2	mR	2.71E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-29 ARA RA	3545	1-Feb-05	30-Apr-05	88	2112	81.6	mR	3.86E–02	mR/hr
INEEL-2,5,8,11	RWMC	O-29 ARA RA	4172	1-May-05	31-Jul-05	91	2184	81	mR	3.71E–02	mR/hr
									Average	0.04	mR/hr
									Net	0.03	mR/hr

Site	Area	Location	TLD #	Begin	End	Days	Hours	Reading		Exposure Rate	
INEEL-2,5,8,11	RWMC	Control RDR	3530	1-Feb-05	30-Apr-05	88	2112	28.4	mR	1.34E–02	mR/hr
INEEL-2,5,8,11	RWMC	Control RDR	4190	1-May-05	31-Jul-05	91	2184	25.9	mR	1.19E–02	mR/hr
INEEL-2,5,8,11	RWMC	Control RDR	4385	1-Aug-05	31-Oct-05	91	2184	28	mR	1.28E–02	mR/hr
									Average	0.01	mR/hr

D-2. RADIONUCLIDE INVENTORY

D-2.1 Two-Acre Retrieval Radionuclide Inventory (Alternative Module 12)

The radionuclide inventory for the two-acre retrieval options (Alternative Modules 12) was based on the information provided in EDF-4591 "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4." EDF-4591 provides normalized radionuclide inventories per drum for each waste category included in Alternative Module 12. The waste categories to be retrieved include Series 741 sludge, Series 742 sludge, Series 743 sludge, filter waste, graphite waste, and roaster oxide waste.

EDF-4591 relied on information obtained from EDF-3374, "Radioassay Data Collected During 3,100 Cubic Meter Project," and Clements (1982). EDF-3374 documents the data obtained from the assay of thousands of waste drums of various waste types for the 3,100 Cubic Meter Project from 1997 through 2002. The data from EDF-3374 include the mass per drum for each radonuclide after 20 years of decay. EDF-3374 often listed an average mass per drum for a specific radionuclide based on a fraction of the total number of drums assayed in that waste category. Therefore, the data were normalized to the total number of drums assayed for that particular waste category. For example, the Series 741 sludge waste category included 6,407 waste drums during the assay and U-238 was detected in 4,441 drums at a mean mass per drum of 1.65E+03 grams. The normalization method assumed that the mean mass per drum of U-238 was distributed as an average over the 6,407 drums at an average drum content of 1.14E+03 grams.

The data chosen to represent the radioactive waste for the two-acre retrieval (Alternative Module 12) from EDF-4591 were all decayed from a start date of January 1966 to the approximate midpoint of retrieval operations, assumed to be 2010. Because the waste data from EDF-3374 were already decayed 20 years from time of assay to 1986, these data were decayed to the midpoint of retrieval in 2010.

The anticipated volume of waste to be excavated is provided in Table D-1. The radionuclide inventories, by each waste category, are provided in Tables D-2 through D-7 for the two-acre retrieval Alternative Module 12. The inventories, decayed to 2010, were screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993), provided in Table D-8. The 2010 radionuclide inventories for those nuclides that comprise the majority of the screening dose are provided in Table D-9. The release rate calculations from the retrieval enclosure are provided in Table D-10.

Table D-1. Two-acre retrieval waste types and volumes.

Waste Type	Waste Volume (ft^3)	Packaged Drum Equivalents
Series 741 sludge	30,739	8,077
Series 742 sludge	14,593	3,835
Series 743 sludge	29,991	7,881
Filter waste	23,336	6,132
Graphite waste	7,036	1,849
RO waste	1,829	481
Total	**107,524**	**28,254**

Table D-2. Two-acre retrieval (Alternative Module 12) Series 741 sludge (30,739 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	2.4107E+04	2.3293E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	4.4089E+01	3.6475E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	1.4264E+03	1.4254E+03
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	3.1670E+02	3.1590E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	4.3193E+03	1.3605E+03
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	4.1150E-02	4.1148E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	1.2629E-02	1.2637E-02
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	2.2380E-01	2.2663E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	4.2696E-02	4.2730E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	1.6267E+00	1.6267E+00

Table D-3. Two-acre retrieval (Alternative Module 12) Series 742 sludge (14,539 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	1.1445E+04	1.1059E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	2.0931E+01	1.7316E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	6.7719E+02	6.7672E+02
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	1.5035E+02	1.4997E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	2.0505E+03	6.4587E+02
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	1.9535E-02	1.9534E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	5.9956E-03	5.9995E-03
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	1.0624E-01	1.0758E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	2.0269E-02	2.0285E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	7.7226E-01	7.7226E-01

Table D-4. Two-acre retrieval (Alternative Module 12) Series 743 sludge (29,991 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	5.3670E-03	3.5000E+00	1.8785E-02	2.5549E-03	7.6623E+01	9.5657E+01
Pu-238	1.7760E-04	1.7300E+01	3.0725E-03	4.1789E-04	1.2533E+01	1.0369E+01
Pu-239	1.3610E+00	6.3000E-02	8.5743E-02	1.1662E-02	3.4975E+02	3.4951E+02
Pu-240	8.3670E-02	2.3000E-01	1.9244E-02	2.6174E-03	7.8498E+01	7.8299E+01
Pu-241	2.3170E-03	1.0400E+02	2.4097E-01	3.2774E-02	9.8292E+02	3.0960E+02
Pu-242	5.2020E-04	4.0000E-03	2.0808E-06	2.8301E-07	8.4877E-03	8.4873E-03
U-233	2.2566E-04	9.7600E-03	2.2024E-06	2.9955E-07	8.9838E-03	8.9829E-03
U-234	8.1632E-05	6.3200E-03	5.1591E-07	7.0169E-08	2.1044E-03	2.8819E-03
U-235	5.8228E-02	2.1900E-06	1.2752E-07	1.7344E-08	5.2015E-04	5.2841E-04
U-238	9.7084E+00	3.4000E-07	3.3008E-06	4.4894E-07	1.3464E-02	1.3464E-02

Table D-5. Two-acre retrieval (Alternative Module 12) filter waste (23,336 ft^3) inventory.

Nuclide	Nuclide Mass per Typical Box (g)	Specific Activity (Ci/g)	Nuclide Activity per Box in 1966 (Ci)	Nuclide Activity per Box Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.0000E-01	3.5000E+00	3.5000E-01	3.1250E-03	7.2925E+01	9.37E+01
Pu-238	1.5000E-03	1.7300E+01	2.5950E-02	2.3170E-04	5.4069E+00	3.82E+00
Pu-239	1.1728E+01	6.3000E-02	7.3888E-01	6.5971E-03	1.5395E+02	1.54E+02
Pu-240	7.2750E-01	2.3000E-01	1.6733E-01	1.4940E-03	3.4863E+01	3.47E+01
Pu-241	4.2500E-02	1.0400E+02	4.4200E+00	3.9464E-02	9.2094E+02	1.11E+02
Pu-242	3.0000E-03	4.0000E-03	1.2000E-05	1.0714E-07	2.5003E-03	2.50E-03

Table D-6. Two-acre retrieval (Alternative Module 12) graphite waste (7,036 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	6.7020E-02	3.5000E+00	2.3457E-01	3.1904E-02	2.2447E+02	2.99E+02
Pu-238	3.9063E-03	1.7300E+01	6.7579E-02	9.1914E-03	6.4671E+01	5.35E+01
Pu-239	2.4830E+01	6.3000E-02	1.5643E+00	2.1276E-01	1.4970E+03	1.50E+03
Pu-240	1.5500E+00	2.3000E-01	3.5650E-01	4.8487E-02	3.4116E+02	3.40E+02
Pu-241	3.7340E-02	1.0400E+02	3.8834E+00	5.2817E-01	3.7162E+03	1.17E+03
Pu-242	6.8018E-03	4.0000E-03	2.7207E-05	3.7004E-06	2.6036E-02	2.60E-02
U-233	1.1799E-03	9.7600E-03	1.1516E-05	1.5662E-06	1.1020E-02	1.10E-02
U-234	1.8829E-05	6.3200E-03	1.1900E-07	1.6185E-08	1.1388E-04	4.12E-03
U-235	1.7583E-02	2.1900E-06	3.8506E-08	5.2372E-09	3.6849E-05	7.22E-05
U-238	1.6647E-03	3.4000E-07	5.6599E-10	7.6980E-11	5.4163E-07	5.42E-07

Table D-7. Two-acre retrieval (Alternative Module 12) roaster oxide (1,829 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1966 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1966 (Ci)	Nuclide Activity per Drum Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
U-234	2.3900E+00	6.3200E-03	1.5105E-02	2.0544E-03	3.7575E+00	3.76E+00
U-235	5.1440E+02	2.1900E-06	1.1265E-03	1.5322E-04	2.8024E-01	2.80E-01
U-236	1.4360E+01	6.5400E-05	9.3914E-04	1.2773E-04	2.3362E-01	2.34E-01
U-238	2.3874E+05	3.4000E-07	8.1172E-02	1.1040E-02	2.0192E+01	2.02E+01

Table D-8. Dose conversion factors used to screen 2010 radionuclide inventories.

Nuclide	Internal – Inhalation (rem/Ci)	Internal – Ingestion (rem/Ci)	External (rem per Ci s g^{-1})
Ac-225	1.08E+07	1.11E+05	1.79E+07
Ac-227	6.70E+09	1.41E+07	1.44E+05
Ac-228	3.08E+05	2.16E+03	1.12E+09
Am-24	4.44E+08	3.64E+06	2.15E+07
At-217	0.00E+00	0.00E+00	3.64E+05
Bi-210	1.96E+05	6.40E+03	1.03E+06
Bi-211	0.00E+00	0.00E+00	5.53E+07
Bi-212	2.16E+04	1.06E+03	2.15E+08
Bi-213	1.71E+04	7.22E+02	1.59E+08
Bi-214	6.59E+03	2.83E+02	1.71E+09
Fr-221	0.00E+00	0.00E+00	3.60E+07
Fr-223	6.21E+03	8.62E+03	5.79E+07
Np-237	5.40E+08	4.44E+06	2.58E+07
Pa-231	1.28E+09	1.06E+07	4.30E+07
Pa-233	9.55E+03	3.63E+03	2.32E+08
Pa-234	8.14E+02	2.16E+03	2.20E+09
Pa-234m	0.00E+00	0.00E+00	1.78E+07
Pb-209	9.47E+01	2.13E+02	2.62E+05
Pb-210	1.36E+07	5.37E+06	1.54E+06
Pb-211	8.69E+03	5.25E+02	6.07E+07
Pb-212	1.69E+05	4.55E+04	1.70E+08
Pb-214	7.81E+03	6.25E+02	2.93E+08
Po-210	9.40E+06	1.90E+06	9.94E+03
Po-211	0.00E+00	0.00E+00	9.13E+06
Po-212	0.00E+00	0.00E+00	0.00E+00
Po-213	0.00E+00	0.00E+00	0.00E+00
Po-214	0.00E+00	0.00E+00	9.75E+04
Po-215	0.00E+00	0.00E+00	2.11E+05
Po-216	0.00E+00	0.00E+00	1.98E+04
Po-218	0.00E+00	0.00E+00	1.06E+04
Pu-238	3.92E+08	3.20E+06	1.18E+05
Pu-239	4.29E+08	3.54E+06	1.05E+05

Table D-8. (continued).

Nuclide	Internal – Inhalation (rem/Ci)	Internal – Ingestion (rem/Ci)	External (rem per Ci s g^{-1})
Pu-240	4.29E+08	3.54E+06	1.16E+05
Pu-241	8.25E+06	6.85E+04	1.79E+03
Pu-242	4.11E+08	3.36E+06	9.77E+04
Ra-223	7.84E+06	6.59E+05	1.51E+08
Ra-224	3.16E+06	3.66E+05	1.16E+07
Ra-225	7.77E+06	3.85E+05	7.92E+06
Ra-226	8.58E+06	1.32E+06	7.75E+06
Ra-228	4.77E+06	1.44E+06	0.00E+00
Rn-219	0.00E+00	0.00E+00	6.65E+07
Rn-220	0.00E+00	0.00E+00	4.58E+05
Rn-222	0.00E+00	0.00E+00	4.74E+05
Th-227	1.62E+07	3.81E+04	1.21E+08
Th-228	3.42E+08	3.96E+05	2.28E+06
Th-229	2.15E+09	3.53E+06	9.51E+07
Th-230	3.26E+08	5.48E+05	4.35E+05
Th-231	8.77E+02	1.35E+03	1.32E+07
Th-232	1.64E+09	2.73E+06	2.17E+05
Th-234	3.50E+04	1.37E+04	8.52E+06
Tl-207	0.00E+00	0.00E+00	4.22E+06
Tl-208	0.00E+00	0.00E+00	3.66E+09
Tl-209	0.00E+00	0.00E+00	2.30E+09
U-233	1.35E+08	2.89E+05	4.03E+05
U-234	1.32E+08	2.83E+05	1.89E+05
U-235	1.23E+08	2.66E+05	1.77E+08
U-236	1.25E+08	2.69E+05	1.22E+05
U-237	3.53E+03	3.17E+03	1.49E+08
U-238	1.18E+08	2.55E+05	8.26E+04
C-14	2.09E+03	2.09E+03	8.03E+03
Ce-144	2.16E+07	2.10E+04	2.15E+07
Co-58	1.09E+04	3.58E+03	1.14E+09
Co-60	2.19E+05	2.69E+04	2.84E+09
Cr-51	3.34E+02	1.47E+02	3.75E+07
Cs-137	3.19E+04	5.00E+04	2.50E+05

Table D-8. (continued).

Nuclide	Internal – Inhalation (rem/Ci)	Internal – Ingestion (rem/Ci)	External (rem per Ci s g^{-1})
Ba-137m	0.00E+00	0.00E+00	7.02E+08
Fe-55	2.69E+03	6.07E+02	0.00E+00
H-3	6.40E+01	6.40E+01	0.00E+00
I-129	1.74E+05	2.76E+05	1.11E+07
Mn-54	6.70E+03	2.77E+03	9.73E+08
Ni-59	2.70E+03	2.10E+02	0.00E+00
Ni-63	3.10E+03	5.77E+02	0.00E+00
Sr-90	1.30E+06	1.42E+05	2.45E+05
Y-90	8.44E+03	1.08E+04	5.79E+06
Tc-99	8.33E+03	1.46E+03	5.45E+04

Table D-9. Two-acre screening results for the 2010 radionuclide inventory.

Nuclide	Inventory 2010 (Ci)	Inhalation (rem)	Ingestion (rem)	External (rem)	Total Dose (rem)	Dose Fraction	Total Dose Percent
Co-60	5.85E+03	1.28E+09	1.58E+08	1.66E+13	1.66E+13	4.70E-01	4.70E+01
Am-241	3.48E+04	1.55E+13	1.27E+11	7.48E+11	1.63E+13	4.62E-01	9.32E+01
Pu-239	4.10E+03	1.76E+12	1.45E+10	4.30E+08	1.78E+12	5.02E-02	9.83E+01
Pu-240	9.19E+02	3.95E+11	3.25E+09	1.06E+08	3.98E+11	1.13E-02	9.94E+01
Ba-137m	1.77E+02	0.00E+00	0.00E+00	1.24E+11	1.24E+11	3.52E-03	9.97E+01
Pu-238	1.21E+02	4.76E+10	3.89E+08	1.44E+07	4.80E+10	1.36E-03	9.99E+01
Pu-241	3.60E+03	2.97E+10	2.46E+08	6.45E+06	2.99E+10	8.47E-04	1.00E+02

Table D-10. Two-acre retrieval enclosure radionuclide release rates.

Nuclide	two-acre (Ci)	two-acre[a] (Ci/ft^3)	Enclosure[b] (Ci/yr)	HEPA[c] (Ci/yr)	0.5% Loss[d] (Ci/yr)	Total[e] (Ci/yr)
Am-241	3.48E+04	2.75E-01	9.95E+00	2.97E-03	4.98E-02	5.27E-02
Ce-144	3.147E+01	2.48E-04	8.99E-03	2.68E-06	4.50E-05	4.76E-05
Co-58	2.36E+00	1.86E-05	6.75E-04	2.01E-07	3.37E-06	3.57E-06
Co-60	5.85E+03	4.61E-02	1.67E+00	4.99E-04	8.35E-03	8.85E-03
Cs-137	1.770E+02	1.39E-03	5.06E-02	1.51E-05	2.53E-04	2.68E-04
Ba-137m	1.770E+02	1.39E-03	5.06E-02	1.51E-05	2.53E-04	2.68E-04
Mn-54	5.99E+00	4.72E-05	1.71E-03	5.11E-07	8.56E-06	9.07E-06
Np-237	2.76E-01	2.17E-06	7.88E-05	2.35E-08	3.94E-07	4.18E-07

Table D-10. (continued).

Nuclide	two-acre (Ci)	two-acre[a] (Ci/ft^3)	Enclosure[b] (Ci/yr)	HEPA[c] (Ci/yr)	0.5% Loss[d] (Ci/yr)	Total[e] (Ci/yr)
Pa-234m	2.26E+01	1.78E-04	6.46E-03	1.93E-06	3.23E-05	3.42E-05
Pu-238	1.21E+02	9.57E-04	3.47E-02	1.04E-05	1.74E-04	1.84E-04
Pu-239	4.10E+03	3.23E-02	1.17E+00	3.50E-04	5.86E-03	6.21E-03
Pu-240	9.19E+02	7.24E-03	2.63E-01	7.84E-05	1.31E-03	1.39E-03
Pu-241	3.60E+03	2.84E-02	1.03E+00	3.07E-04	5.14E-03	5.45E-03
Sr-90	1.089E+02	8.59E-04	3.11E-02	9.29E-06	1.56E-04	1.65E-04
Y-90	1.089E+02	8.59E-04	3.11E-02	9.29E-06	1.56E-04	1.65E-04

a. 107,524 ft^3 + 19,354 ft^3 (18% LLW) = 126,878 ft^3.
b. (Ci/ft^3 × 36,251 ft^3/yr) × 1E-3, where: 36,251 ft^3/yr is 126,878 ft^3 over 3.5 years and 1E-3 is the airborne fraction for particulate matter based on 40 CFR 61, App. D.
c. Enclosure Ci/yr × 0.995 × 3E-4, where 0.995 assumes 99.5% goes through HEPAs and 3E-4 is the HEPA efficiency (i.e., 99.97%).
d. Enclosure Ci/yr × 0.005, where 0.005 is 0.55% of loss from enclosures due to wind, HEPA loss, etc.
e. Total release rate per year = release through the HEPA plus loss from enclosures due to wind, HEPA loss, etc.

D-2.2 Four-Acre Retrieval (Alternative Module 13)

The radionuclide inventory for the four-acre retrieval option (Alternative Modules 13) was also based on the information provided in EDF-4591, "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4." The same methodology described previously for the two-acre retrieval option (Alternative Module 12) was used for the four-acre retrieval option.

The anticipated volume of waste to be excavated is provided in Table D-11. The radionuclide inventories, by each waste category, are provided in Tables D-12 through D-17 for the four-acre retrieval Alternative Module 13. The inventories, decayed to 2010, were screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993), provided in Table D-8. The 2010 radionuclide inventories for those nuclides that comprise the majority of the screening doses are provided in Table D-18. The release rate calculations from the retrieval enclosure are provided in Table D-19.

Table D-11. Four-acre retrieval waste types and volumes.

Waste Type	Waste Volume (ft^3)	Packaged Drum Equivalents
Series 741 sludge	35,201	9,250
Series 742 sludge	20,486	5,383
Series 743 sludge	33,875	8,901
Filter waste	34,581	9,087
Graphite waste	11,086	2,913
RO waste	2,559	672
Total	**137,789**	**36,207**

Table D-12. Four-acre retrieval (Alternative Module 13) Series 741 sludge (35,201 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	2.7606E+04	2.68E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	5.0489E+01	4.24E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	1.6335E+03	1.63E+03
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	3.6267E+02	3.62E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	4.9463E+03	1.72E+03
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	4.7123E-02	4.71E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	1.4462E-02	1.45E-02
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	2.5628E-01	2.59E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	4.8893E-02	4.89E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	1.8628E+00	1.86E+00

Table D-13. Four-acre retrieval (Alternative Module 13) Series 742 sludge (40,973 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	3.2133E+04	3.10E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	5.8768E+01	4.86E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	1.9014E+03	1.90E+03
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	4.2214E+02	4.21E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	5.7573E+03	1.81E+03
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	5.4850E-02	5.48E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	1.6834E-02	1.68E-02
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	2.9830E-01	3.02E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	5.6910E-02	5.70E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	2.1683E+00	2.17E+00

Table D-14. Four-acre retrieval (Alternative Module 13) Series 743 sludge (33,875 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	5.3670E-03	3.5000E+00	1.8785E-02	2.5549E-03	8.6546E+01	1.08E+02
Pu-238	1.7760E-04	1.7300E+01	3.0725E-03	4.1789E-04	1.4156E+01	1.17E+01
Pu-239	1.3610E+00	6.3000E-02	8.5743E-02	1.1662E-02	3.9504E+02	3.95E+02
Pu-240	8.3670E-02	2.3000E-01	1.9244E-02	2.6174E-03	8.8663E+01	8.84E+01
Pu-241	2.3170E-03	1.0400E+02	2.4097E-01	3.2774E-02	1.1102E+03	3.50E+02
Pu-242	5.2020E-04	4.0000E-03	2.0808E-06	2.8301E-07	9.5869E-03	9.59E-03
U-233	2.2566E-04	9.7600E-03	2.2024E-06	2.9955E-07	1.0147E-02	1.01E-02
U-234	8.1632E-05	6.3200E-03	5.1591E-07	7.0169E-08	2.3770E-03	3.26E-03
U-235	5.8228E-02	2.1900E-06	1.2752E-07	1.7344E-08	5.8752E-04	5.97E-04
U-238	9.7084E+00	3.4000E-07	3.3008E-06	4.4894E-07	1.5208E-02	1.52E-02

Table D-15. Four-acre retrieval (Alternative Module 13) filter waste (34,581 ft^3) inventory.

Nuclide	Nuclide Mass per Typical Box (g)	Specific Activity (Ci/g)	Nuclide Activity per Box in 1966 (Ci)	Nuclide Activity per Box Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.0000E-01	3.5000E+00	3.5000E-01	3.1250E-03	1.0807E+02	1.39E+02
Pu-238	1.5000E-03	1.7300E+01	2.5950E-02	2.3170E-04	8.0123E+00	5.66E+00
Pu-239	1.1728E+01	6.3000E-02	7.3888E-01	6.5971E-03	2.2814E+02	2.28E+02
Pu-240	7.2750E-01	2.3000E-01	1.6733E-01	1.4940E-03	5.1663E+01	5.14E+01
Pu-241	4.2500E-02	1.0400E+02	4.4200E+00	3.9464E-02	1.3647E+03	1.64E+02
Pu-242	3.0000E-03	4.0000E-03	1.2000E-05	1.0714E-07	3.7051E-03	3.70E-03

Table D-16. Four-acre retrieval (Alternative Module 13) graphite waste (11,086 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	6.7020E-02	3.5000E+00	2.3457E-01	3.1904E-02	3.5368E+02	4.71E+02
Pu-238	3.9063E-03	1.7300E+01	6.7579E-02	9.1914E-03	1.0190E+02	8.43E+01
Pu-239	2.4830E+01	6.3000E-02	1.5643E+00	2.1276E-01	2.3586E+03	2.36E+03
Pu-240	1.5500E+00	2.3000E-01	3.5650E-01	4.8487E-02	5.3753E+02	5.36E+02
Pu-241	3.7340E-02	1.0400E+02	3.8834E+00	5.2817E-01	5.8553E+03	1.84E+03
Pu-242	6.8018E-03	4.0000E-03	2.7207E-05	3.7004E-06	4.1023E-02	4.10E-02
U-233	1.1799E-03	9.7600E-03	1.1516E-05	1.5662E-06	1.7363E-02	1.74E-02
U-234	1.8829E-05	6.3200E-03	1.1900E-07	1.6185E-08	1.7942E-04	6.49E-03
U-235	1.7583E-02	2.1900E-06	3.8506E-08	5.2372E-09	5.8059E-05	1.14E-04
U-238	1.6647E-03	3.4000E-07	5.6599E-10	7.6980E-11	8.5340E-07	8.54E-07

Table D-17. Four-acre retrieval (Alternative Module 13) roaster oxide (2,559 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1966 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1966 (Ci)	Nuclide Activity per Drum Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
U-234	2.3900E+00	6.3200E-03	1.5105E-02	2.0544E-03	5.2572E+00	5.26E+00
U-235	5.1440E+02	2.1900E-06	1.1265E-03	1.5322E-04	3.9209E-01	3.92E-01
U-236	1.4360E+01	6.5400E-05	9.3914E-04	1.2773E-04	3.2687E-01	3.27E-01
U-238	2.3874E+05	3.4000E-07	8.1172E-02	1.1040E-02	2.8252E+01	2.83E+01

Table D-18. Four-acre screening results for the 2010 radionuclide inventory.

Nuclide	Inventory 2010 (Ci)	Inhalation (rem)	Ingestion (rem)	External (rem)	Total Dose (rem)	Dose Fraction	Total Dose Percent
Am-241	5.85E+04	2.60E+13	2.13E+11	1.26E+12	2.75E+13	4.93E-01	4.93E+01
Co-60	8.61E+03	1.88E+09	2.32E+08	2.44E+13	2.44E+13	4.39E-01	9.32E+01
Pu-239	6.51E+03	2.80E+12	2.30E+10	6.82E+08	2.82E+12	5.06E-02	9.83E+01
Pu-240	1.46E+03	6.26E+11	5.16E+09	1.69E+08	6.32E+11	1.13E-02	9.94E+01
Ba-137m	2.60E+02	0.00E+00	0.00E+00	1.83E+11	1.83E+11	3.29E-03	9.97E+01
Pu-238	1.93E+02	7.56E+10	6.17E+08	2.28E+07	7.62E+10	1.37E-03	9.99E+01
Pu-241	5.89E+03	4.86E+10	4.03E+08	1.06E+07	4.90E+10	8.80E-04	1.00E+02

Table D-19. Four-acre retrieval enclosure radionuclide release rates.

Nuclide	four-acre (Ci)	four-acre[a] (Ci/ft^3)	Enclosure[b] (Ci/yr)	HEPA[c] (Ci/yr)	0.5% Loss[d] (Ci/yr)	Total[e] (Ci/yr)
Am-241	5.85E+04	3.13E-01	9.75E+00	2.91E-03	4.88E-02	5.17E-02
Ce-144	4.63E+01	2.48E-04	7.72E-03	2.30E-06	3.86E-05	4.09E-05
Co-58	3.48E+00	1.86E-05	5.79E-04	1.73E-07	2.90E-06	3.07E-06
Co-60	8.61E+03	4.61E-02	1.43E+00	4.28E-04	7.17E-03	7.60E-03
Cs-137	2.60E+02	1.39E-03	4.34E-02	1.30E-05	2.17E-04	2.30E-04
Ba-137m	2.60E+02	1.39E-03	4.34E-02	1.30E-05	2.17E-04	2.30E-04
Mn-54	8.82E+00	4.72E-05	1.47E-03	4.39E-07	7.35E-06	7.79E-06
Np-237	4.45E-01	2.38E-06	7.42E-05	2.22E-08	3.71E-07	3.93E-07
Pa-234m	3.23E+01	1.73E-04	5.38E-03	1.61E-06	2.69E-05	2.85E-05
Pu-238	1.93E+02	1.03E-03	3.21E-02	9.59E-06	1.61E-04	1.70E-04
Pu-239	6.51E+03	3.49E-02	1.09E+00	3.24E-04	5.43E-03	5.75E-03
Pu-240	1.46E+03	7.81E-03	2.43E-01	7.26E-05	1.22E-03	1.29E-03
Pu-241	5.89E+03	3.15E-02	9.81E-01	2.93E-04	4.91E-03	5.20E-03
Sr-90	1.60E+02	8.59E-04	2.67E-02	7.98E-06	1.34E-04	1.42E-04
Y-90	1.60E+02	8.59E-04	2.67E-02	7.98E-06	1.34E-04	1.42E-04

a. 158,275 ft^3 + 28,489 ft^3 (18% LLW) = 186,764 ft^3.
b. (Ci/ft^3 × 31,127 ft^3/yr) × 1E-3, where: 31,127 ft^3/yr is 186,764 ft^3 over 3.5 years and 1E–3 is the airborne fraction for particulate matter based on 40 CFR 61, App. D.
c. Enclosure Ci/yr × 0.995 × 3E-4, where 0.995 assumes 99.5% goes through HEPAs and 3E–4 is the HEPA efficiency (i.e., 99.97%).
d. Enclosure Ci/yr × 0.005, where 0.005 is 0.5% of loss from enclosures due to wind, HEPA loss, etc.
e. Total release rate per year = release through the HEPA plus 0.5% loss from enclosures due to wind, HEPA loss, etc.

D-2.3 Full Retrieval (Alternative Module 14)

The radionuclide inventory for the full retrieval options (Alternative Module 14) was also based on the information provided in EDF-4591, "Waste Categories and Characteristics for the Accelerated Retrieval Project for a Described Area within Pit 4" as described in the previous sections.

EDF-4591 does not provide information for waste categories designated as (1) Other transuranic Waste, (2) Other Non-transuranic Waste, and (3) Remote-Handled Waste. The inventory for these waste categories was obtained from SDA databases.[b] The inventories for these waste categories were based on disposal records and previously decayed to 2010.

The anticipated volume of waste to be excavated is provided in Table D-20. The radionuclide inventories, by each waste category, are provided in Tables D-21 through D-29 for the full RTD retrieval Alternative Module 14. The inventories, decayed to 2010, were screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained

b. Personal communication David Thorne, Portage Environmental Inc., with Brian Preussner, CWI, January 13, 2006.

from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993), provided in Table D-8. The 2010 radionuclide inventories for those nuclides that comprise the majority of the screening dose are provided in Table D-30. The release rate calculations from the retrieval enclosure are provided in Table D-31.

Table D-20. Full retrieval, treatment, and disposal waste types and volumes.

Waste Type	Source Date (ft^3)	Packaged Drum Equivalents (#55-gal drum)
Series 741 sludge	64,141	14,412
Series 742 sludge	55,302	12,426
Series 743 sludge	63,756	14,325
Filter waste	79,764	17,922
Graphite waste	34,612	7,777
Roaster oxide waste	166,041	37,307
Other transuranic waste	777,139	174,613
Other non-transuranic waste	6,963,571	1,564,624
Remote-handled waste	92,750	20,840
Total	**8,297,076**	**1,864,245**

Table D-21. Full retrieval (Alternative Module 14) Series 741 sludge (64,141 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	5.0302E+04	4.86E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	9.1998E+01	7.61E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	2.9765E+03	2.97E+03
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	6.6083E+02	6.59E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	9.0128E+03	2.84E+03
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	8.5864E-02	8.59E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	2.6352E-02	2.64E-02
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	4.6698E-01	4.73E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	8.9090E-02	8.92E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	3.3943E+00	3.39E+00

Table D-22. Full retrieval (Alternative Module 14) Series 742 sludge (55,302 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.6475E+00	3.5000E+00	5.7661E+00	7.8425E-01	4.3370E+04	4.19E+04
Pu-238	6.0958E-04	1.7300E+01	1.0546E-02	1.4343E-03	7.9320E+01	6.56E+01
Pu-239	5.4157E+00	6.3000E-02	3.4119E-01	4.6405E-02	2.5663E+03	2.56E+03
Pu-240	3.2935E-01	2.3000E-01	7.5751E-02	1.0303E-02	5.6977E+02	5.68E+02
Pu-241	9.9339E-03	1.0400E+02	1.0331E+00	1.4051E-01	7.7707E+03	2.45E+03
Pu-242	2.4606E-03	4.0000E-03	9.8426E-06	1.3387E-06	7.4032E-02	7.40E-02
U-233	3.0951E-04	9.7600E-03	3.0208E-06	4.1085E-07	2.2721E-02	2.27E-02
U-234	8.4699E-03	6.3200E-03	5.3530E-05	7.2805E-06	4.0263E-01	4.08E-01
U-235	4.6632E+00	2.1900E-06	1.0212E-05	1.3890E-06	7.6813E-02	7.69E-02
U-238	1.1444E+03	3.4000E-07	3.8909E-04	5.2920E-05	2.9266E+00	2.93E+00

Table D-23. Full retrieval (Alternative Module 14) Series 743 sludge (63,756 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	5.3670E-03	3.5000E+00	1.8785E-02	2.5549E-03	1.6289E+02	4.19E+04
Pu-238	1.7760E-04	1.7300E+01	3.0725E-03	4.1789E-04	2.6643E+01	6.56E+01
Pu-239	1.3610E+00	6.3000E-02	8.5743E-02	1.1662E-02	7.4351E+02	2.56E+03
Pu-240	8.3670E-02	2.3000E-01	1.9244E-02	2.6174E-03	1.6687E+02	5.68E+02
Pu-241	2.3170E-03	1.0400E+02	2.4097E-01	3.2774E-02	2.0895E+03	2.45E+03
Pu-242	5.2020E-04	4.0000E-03	2.0808E-06	2.8301E-07	1.8043E-02	7.40E-02
U-233	2.2566E-04	9.7600E-03	2.2024E-06	2.9955E-07	1.9098E-02	2.27E-02
U-234	8.1632E-05	6.3200E-03	5.1591E-07	7.0169E-08	4.4737E-03	4.08E-01
U-235	5.8228E-02	2.1900E-06	1.2752E-07	1.7344E-08	1.1058E-03	7.69E-02
U-238	9.7084E+00	3.4000E-07	3.3008E-06	4.4894E-07	2.8623E-02	2.93E+00

Table D-24. Full retrieval (Alternative Module 14) filter waste (79,764 ft^3) inventory.

Nuclide	Nuclide Mass per Typical Box (g)	Specific Activity (Ci/g)	Nuclide Activity per Box in 1966 (Ci)	Nuclide Activity per Box Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
Am-241	1.0000E-01	3.5000E+00	3.5000E-01	3.1250E-03	2.4926E+02	4.19E+04
Pu-238	1.5000E-03	1.7300E+01	2.5950E-02	2.3170E-04	1.8481E+01	6.56E+01
Pu-239	1.1728E+01	6.3000E-02	7.3888E-01	6.5971E-03	5.2621E+02	2.56E+03
Pu-240	7.2750E-01	2.3000E-01	1.6733E-01	1.4940E-03	1.1917E+02	5.68E+02
Pu-241	4.2500E-02	1.0400E+02	4.4200E+00	3.9464E-02	3.1478E+03	2.45E+03
Pu-242	3.0000E-03	4.0000E-03	1.2000E-05	1.0714E-07	8.5461E-03	7.40E-02

Table D-25. Full retrieval (Alternative Module 14) graphite waste (34,612 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1986 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1986 (Ci)	Nuclide Activity per Drum Cubic Foot in 1986 (Ci/ft^3)	Total Activity in 1986 (Ci)	Total Activity in 2010 (Ci)
Am-241	6.7020E-02	3.5000E+00	2.3457E-01	3.1904E-02	1.1042E+03	4.19E+04
Pu-238	3.9063E-03	1.7300E+01	6.7579E-02	9.1914E-03	3.1813E+02	6.56E+01
Pu-239	2.4830E+01	6.3000E-02	1.5643E+00	2.1276E-01	7.3640E+03	2.56E+03
Pu-240	1.5500E+00	2.3000E-01	3.5650E-01	4.8487E-02	1.6782E+03	5.68E+02
Pu-241	3.7340E-02	1.0400E+02	3.8834E+00	5.2817E-01	1.8281E+04	2.45E+03
Pu-242	6.8018E-03	4.0000E-03	2.7207E-05	3.7004E-06	1.2808E-01	7.40E-02
U-233	1.1799E-03	9.7600E-03	1.1516E-05	1.5662E-06	5.4210E-02	2.27E-02
U-234	1.8829E-05	6.3200E-03	1.1900E-07	1.6185E-08	5.6019E-04	4.08E-01
U-235	1.7583E-02	2.1900E-06	3.8506E-08	5.2372E-09	1.8127E-04	7.69E-02
U-238	1.6647E-03	3.4000E-07	5.6599E-10	7.6980E-11	2.6644E-06	2.93E+00

Table D-26. Full retrieval (Alternative Module 14) roaster oxide (16,604,1 ft^3) inventory.

Nuclide	Nuclide Mass per Drum in 1966 (g)	Specific Activity (Ci/g)	Nuclide Activity per Drum in 1966 (Ci)	Nuclide Activity per Drum Cubic Foot in 1966 (Ci/ft^3)	Total Activity in 1966 (Ci)	Total Activity in 2010 (Ci)
U-234	2.3900E+00	6.3200E-03	1.5105E-02	2.0544E-03	3.4111E+02	3.41E+02
U-235	5.1440E+02	2.1900E-06	1.1265E-03	1.5322E-04	2.5441E+01	2.54E+01
U-23	1.4360E+01	6.5400E-05	9.3914E-04	1.2773E-04	2.1209E+01	2.12E+01
U-238	2.3874E+05	3.4000E-07	8.1172E-02	1.1040E-02	1.8331E+03	1.83E+03

Table D-27. Full retrieval (Alternative Module 14) other transuranic waste (777,139 ft^3).

Nuclide	744-Sludge (Ci)	Glass/Ceramic (Ci)	LGW (Ci)	Fire Waste (Ci)	Total Activity (Ci)
Am-241	0.000E+00	4.278E+02	8.187E+01	6.132E+03	6.641E+03
Pu-238	5.610E+00	6.031E+00	2.915E+02	1.115E+02	4.146E+02
Pu-239	1.827E+02	3.131E+03	9.486E+03	4.520E+03	1.732E+04
Pu-240	4.092E+01	7.017E+02	2.127E+03	1.021E+03	3.890E+03
Pu-241	1.094E+03	1.865E+04	5.684E+04	3.067E+04	1.073E+05
Pu-242	1.994E-03	7.986E-02	1.028E-02	1.608E-01	2.529E-01

Table D-28. Full retrieval (Alternative Module 14) other nontransuranic waste (6,963,571 ft^3).

Nuclide	Nuclide Activity per Cubic Foot (Ci/ft^3)	Nuclide Activity (Ci)
C-14	6.271E-05	4.367E+02
Ce-144	1.626E-03	1.132E+04
Co-58	1.220E-04	8.494E+02
Co-60	3.021E-01	2.104E+06
Cr-51	1.608E-04	1.120E+03
Cs-137	9.143E-03	6.367E+04
Ba-137m	9.143E-03	6.367E+04
Fe-55	3.244E-03	2.259E+04
H-3	5.523E-02	3.846E+05
I-129	1.579E-08	1.099E-01
Mn-54	3.097E-04	2.157E+03
Ni-59	3.640E-04	2.535E+03
Ni-63	8.746E-02	6.090E+05
Sr-90	5.629E-03	3.920E+04
Y-90	5.629E-03	3.920E+04
Tc-99	1.547E-06	1.077E+01
Am-241	4.557E-03	3.173E+04
Np-237	8.321E-09	5.794E-02
Pu-238	1.251E-04	8.709E+02
Pu-239	3.791E-03	2.640E+04
Pu-240	8.893E-04	6.193E+03
Pu-241	2.239E-02	1.559E+05
U-233	2.477E-07	1.725E+00
U-234	6.479E-06	4.512E+01
U-235	4.648E-07	3.237E+00
U-238	2.035E-06	1.417E+01

Table D-29. Full retrieval (Alternative Module 14) remote-handled waste (92,750 ft^3).

Nuclide	Nuclide Activity per Cubic Foot (Ci/ft^3)	Nuclide Activity (Ci)
C-14	3.476E-03	3.224E+02
Ce-144	4.804E-01	4.455E+04
Co-58	1.589E-02	1.474E+03
Co-60	2.947E+01	2.733E+06
Cr-51	1.168E-02	1.084E+03
Cs-137	1.160E+00	1.076E+05
Ba-137m	1.160E+00	1.076E+05
Fe-55	7.084E-02	6.570E+03
H-3	2.772E+01	2.571E+06
I-129	6.767E-07	6.276E-02
Mn-54	2.576E-03	2.389E+02
Ni-59	2.756E-02	2.557E+03
Ni-63	2.988E+00	2.771E+05
Sr-90	1.008E+00	9.345E+04
Y-90	1.008E+00	9.35E+04
Tc-99	3.254E-04	3.018E+01
Am-241	1.716E-04	1.592E+01
Np-237	6.900E-07	6.400E-02
Pu-238	1.379E-03	1.279E+02
Pu-239	3.732E-03	3.462E+02
Pu-240	4.953E-04	4.594E+01
Pu-241	3.652E-02	3.387E+03
U-233	2.250E-07	2.087E-02
U-234	1.437E-04	1.333E+01
U-235	6.255E-06	5.802E-01
U-238	1.139E-05	1.056E+00

Table D-30. Full retrieval, treatment, and disposal screening results for the 2010 radionuclide inventory.

Nuclide	Inventory 2010 (Ci)	Inhalation (rem)	Ingestion (rem)	External (rem)	Total Dose (rem)	Dose Fraction	Total Dose Percent
Co-60	4.84E+06	1.06E+12	1.30E+11	1.37E+16	1.37E+16	9.799E-01	9.80E+01
Ba-137m	1.71E+05	0.00E+00	0.00E+00	1.20E+14	1.20E+14	8.582E-03	9.88E+01
Am-241	2.55E+05	1.13E+14	9.27E+11	5.47E+12	1.19E+14	8.522E-03	9.97E+01
Pu-239	5.73E+04	2.46E+13	2.03E+11	6.00E+09	2.48E+13	1.769E-03	9.99E+01
Pu-240	1.31E+04	5.61E+12	4.62E+10	1.51E+09	5.65E+12	4.033E-04	9.99E+01
Co-58	2.32E+03	2.53E+07	8.32E+06	2.65E+12	2.65E+12	1.889E-04	9.99E+01
Ce-144	5.59E+04	1.21E+12	1.17E+09	1.20E+12	2.41E+12	1.719E-04	1.00E+02

Table D-31. Full retrieval, treatment, and disposal retrieval enclosure radionuclide release rates.

Nuclide	Full RTD (Ci)	Full RTD[a] (Ci/ft^3)	Enclosure[b] (Ci/yr)	HEPA[c] (Ci/yr)	0.5% Loss[d] (Ci/yr)	Total[e] (Ci/yr)
Am-241	2.55E+05	3.07E-02	1.02E+01	3.04E-03	5.09E-02	5.40E-02
Ce-144	5.59E+04	6.73E-03	2.24E+00	6.67E-04	1.12E-02	1.18E-02
Co-58	2.32E+03	2.80E-04	9.29E-02	2.77E-05	4.65E-04	4.92E-04
Co-60	4.84E+06	5.83E-01	1.93E+02	5.78E-02	9.67E-01	1.03E+00
Cs-137	1.71E+05	2.06E-02	6.85E+00	2.04E-03	3.43E-02	3.63E-02
Ba-137m	1.71E+05	2.06E-02	6.85E+00	2.04E-03	3.43E-02	3.63E-02
Ni-63	8.86E+05	1.07E-01	3.54E+01	1.06E-02	1.77E-01	1.88E-01
Mn-54	2.40E+03	2.89E-04	9.58E-02	2.86E-05	4.79E-04	5.08E-04
Pu-238	1.75E+03	2.11E-04	7.01E-02	2.09E-05	3.50E-04	3.71E-04
Pu-239	5.73E+04	6.91E-03	2.29E+00	6.84E-04	1.15E-02	1.21E-02
Pu-240	1.31E+04	1.57E-03	5.22E-01	1.56E-04	2.61E-03	2.77E-03
Pu-241	2.79E+05	3.36E-02	1.12E+01	3.33E-03	5.58E-02	5.92E-02
Sr-90	1.33E+05	1.60E-02	5.31E+00	1.58E-03	2.65E-02	2.81E-02
Y-90	1.33E+05	1.60E-02	5.31E+00	1.58E-03	2.65E-02	2.81E-02
U-238	1.86E+03	2.25E-04	7.45E-02	2.22E-05	3.73E-04	3.95E-04

a. 8,297,076 ft^3.
b. (Ci/ft^3 × 331,883 ft^3/yr) × 1E-3, where: 331,883 ft^3/yr is 8,297,076 ft^3 over 25 years and 1E-3 is the airborne fraction for particulate matter based on 40 CFR 61, App. D.
c. Enclosure Ci/yr × 0.995 × 3E-4, where 0.995 assumes 99.5% goes through HEPAs and 3E–4 is the HEPA efficiency (i.e., 99.97%).
d. Enclosure Ci/yr × 0.005, where 0.005 is 0.5% of loss from enclosures due to wind, HEPA loss, etc.
e. Total release rate per year is release through the HEPA plus 0.5% loss from enclosures due to wind, HEPA loss, etc.

D-2.4 PAD A Retrieval (Alternative Modules 15, 16, 17, and 18)

The inventory for Pad A was obtained from the SDA databases.[c] The inventories for these waste categories were based on disposal records and previously decayed to 2010.

The radionuclide inventory is provided in Table D-32 for the PAD A retrieval Alternative Modules 15, 16, 17, and 18. The inventory was screened according to the total activity of each radionuclide and dose conversion factors for inhalation, ingestion, and external exposure obtained from Federal Guidance Reports 11 and 12 (EPA 1998 and 1993) provided in Table D-8. The total radionuclide inventories for those nuclides that comprise the majority of the screening dose are provided in Table D-33. The release rate calculations from the retrieval enclosure are provided in Table D-34.

Table D-32. Pad A radionuclide inventory.

Nuclide	Ci
Ac-227	1.346E-15
Am-241	1.155E+01
Am-243	6.942E-11
C-14	1.415E-06
Ce-144	2.242E-08
Cl-36	1.745E-09
Cm-243	2.555E-11
Cm-244	1.131E-09
Cm-245	2.535E-14
Cm-246	8.990E-16
Co-60	8.112E-03
Cs-134	3.449E-09
Cs-137	4.227E-01
Ba-137m	4.227E-01
Eu-152	2.150E-05
Eu-154	2.240E-03
H-3	2.076E-03
I-129	1.065E-07
Nb-94	2.375E-07
Ni-59	4.297E-06
Ni-63	1.666E-04
Np-237	3.405E-07
Pa-231	2.096E-14
Pm-147	1.602E-08

c. Personal communication David Thorne, Portage Environmental Inc., with Gregory Andrews, CWI, January 16, 2006.

Table D-32. (continued).

Nuclide	Ci
Pu-238	5.536E-01
Pu-239	1.803E+01
Pu-240	3.437E+00
Pu-241	1.855E+00
Pu-242	2.497E-02
Pu-244	1.948E-17
Ra-226	2.971E-08
Ra-228	1.383E-24
Sr-90	3.055E-01
Y-90	3.055E-01
Tc-99	5.172E-05
Th-228	2.116E-12
Th-229	4.870E-22
Th-230	2.399E-13
Th-232	2.811E-05
U-232	3.510E-12
U-233	8.769E-14
U-234	4.228E+00
U-235	2.993E-01
U-236	1.421E-02
U-238	2.469E+01

Table D-33. PAD A screening results for 2010 radionuclide inventory.

Nuclide	Inventory 2010 (Ci)	Inhalation (rem)	Ingestion (rem)	External (rem)	Total Dose (rem)	Dose Fraction	Total Dose Percent
Pu-239	1.80E+01	7.74E+09	6.38E+07	1.89E+06	7.80E+09	4.14E-01	4.14E+01
Am-241	1.15E+01	5.13E+09	4.20E+07	2.48E+08	5.42E+09	2.87E-01	7.01E+01
U-238	2.47E+01	2.92E+09	6.29E+06	2.04E+06	2.93E+09	1.55E-01	8.56E+01
Pu-240	3.44E+00	1.48E+09	1.22E+07	3.98E+05	1.49E+09	7.89E-02	9.35E+01
U-234	4.23E+00	5.60E+08	1.20E+06	7.98E+05	5.62E+08	2.98E-02	9.65E+01
Ba-137m	4.23E-01	0.00E+00	0.00E+00	2.97E+08	2.97E+08	1.57E-02	9.81E+01
Pu-238	5.54E-01	2.17E+08	1.77E+06	6.56E+04	2.19E+08	1.16E-02	9.92E+01
U-235	2.99E-01	3.68E+07	7.96E+04	5.31E+07	8.99E+07	4.77E-03	9.97E+01
Co-60	8.11E-03	1.77E+03	2.19E+02	2.30E+07	2.30E+07	1.22E-03	9.98E+01
Pu-241	1.85E+00	1.53E+07	1.27E+05	3.33E+03	1.54E+07	8.18E-04	9.99E+01
Pu-242	2.50E-02	1.03E+07	8.39E+04	2.44E+03	1.03E+07	5.48E-04	1.00E+02

Table D-34. PAD A retrieval enclosure radionuclide release rates.

Nuclide	Pad A (Ci)	Pad A[a] (Ci/ft^3)	Enclosure[b] (Ci/yr)	HEPA[c] (Ci/yr)	0.5% Loss[d] (Ci/yr)	Total[e] (Ci/yr)
Am-241	1.15E+01	3.19E–05	7.70E–03	2.30E–06	3.85E–05	4.08E–05
Co-60	8.11E–03	2.24E–08	5.41E–06	1.61E–09	2.70E–08	2.87E–08
Cs-137	4.23E–01	1.17E–06	2.82E–04	8.41E–08	1.41E–06	1.49E–06
Ba-137m	4.23E–01	1.17E–06	2.82E–04	8.41E–08	1.41E–06	1.49E–06
Eu-152	2.15E–05	5.94E–11	1.43E–08	4.28E–12	7.17E–11	7.59E–11
Eu-154	2.24E–03	6.19E–09	1.49E–06	4.46E–10	7.47E–09	7.91E–09
Pu-238	5.54E–01	1.53E–06	3.69E–04	1.10E–07	1.85E–06	1.96E–06
Pu-239	1.80E+01	4.98E–05	1.20E–02	3.59E–06	6.01E–05	6.37E–05
Pu-240	3.44E+00	9.49E–06	2.29E–03	6.84E–07	1.15E–05	1.21E–05
Pu-241	1.85E+00	5.12E–06	1.24E–03	3.69E–07	6.18E–06	6.55E–06
Pu-242	2.50E–02	6.90E–08	1.66E–05	4.97E–09	8.32E–08	8.82E–08
Sr-90	3.05E–01	8.44E–07	2.04E–04	6.08E–08	1.02E–06	1.08E–06
Y-90	3.06E–01	8.44E–07	2.04E–04	6.08E–08	1.02E–06	1.08E–06
U-234	4.23E+00	1.17E–05	2.82E–03	8.41E–07	1.41E–05	1.49E–05
U-235	2.99E–01	8.27E–07	2.00E–04	5.96E–08	9.98E–07	1.06E–06
U-236	1.42E–02	3.93E–08	9.47E–06	2.83E–09	4.74E–08	5.02E–08
U-238	2.47E+01	6.82E–05	1.65E–02	4.91E–06	8.23E–05	8.72E–05

a. 361,972 ft^3.
b. (Ci/ft^3 × 241,314 ft^3/yr) × 1E-3, where: 241,314 ft^3/yr is 361,972 ft^3 over 1.5 years and 1E–3 is the airborne fraction for particulate matter based on 40 CFR 61, App. D.
c. Enclosure Ci/yr × 0.995 × 3E-4, where 0.995 assumes 99.5% goes through HEPAs and 3E–4 is the HEPA efficiency (i.e., 99.97%).
d. Enclosure Ci/yr× 0.005, where 0.005 is 0.5% of loss from enclosures due to wind, HEPA loss, etc.
e. Total release rate per year is release through the HEPA plus 0.5% loss from enclosures due to wind, HEPA loss, etc.

D-3. RADIONUCLIDE DOSE AND RISK TABLES

The radionuclide dose and risk tables for each retrieval alternative module assessed quantitatively are provided in Tables D-35 through D-50. These tables provide the dose and risk by radionuclide.

Table D-35. Two-acre dose to collocated worker.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	1.99E+00	3.33E+01	3.53E+01
Ce-144	1.27E-06	2.13E-05	2.26E-05
Co-58	2.74E-08	4.61E-07	4.89E-07
Co-60	3.47E-03	5.82E-02	6.17E-02
Cs-137	5.78E-07	9.68E-06	1.03E-05
Ba-137m	6.48E-09	1.09E-07	1.15E-07
Mn-54	2.35E-07	3.95E-06	4.18E-06
Np-237	1.42E-05	2.40E-04	2.54E-04
Pa-234m	2.20E-11	3.68E-10	3.90E-10
Pu-238	4.09E-03	6.83E-02	7.24E-02
Pu-239	1.48E-01	2.47E+00	2.61E+00
Pu-240	3.31E-02	5.53E-01	5.86E-01
Pu-241	1.97E-03	3.29E-02	3.48E-02
Sr-90	2.56E-06	4.27E-05	4.53E-05
Y-90	1.08E-07	1.81E-06	1.92E-06
Total	**2.18E+00**	**3.65E+01**	**3.87E+01**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-36. Two-acre cancer risk[c] to collocated worker.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	5.58E-06	9.33E-05	9.89E-05
Ce-144	3.55E-12	5.96E-11	6.32E-11
Co-58	7.67E-14	1.29E-12	1.37E-12
Co-60	9.72E-09	1.63E-07	1.73E-07
Cs-137	1.62E-12	2.71E-11	2.87E-11
Ba-137m	1.82E-14	3.04E-13	3.22E-13
Mn-54	6.58E-13	1.11E-11	1.17E-11

Table D-36. (continued).

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Np-237	3.99E-11	6.71E-10	7.11E-10
Pa-234m	6.15E-17	1.03E-15	1.09E-15
Pu-238	1.14E-08	1.91E-07	2.03E-07
Pu-239	4.14E-07	6.90E-06	7.32E-06
Pu-240	9.27E-08	1.55E-06	1.64E-06
Pu-241	5.52E-09	9.21E-08	9.76E-08
Sr-90	7.16E-12	1.20E-10	1.27E-10
Y-90	3.02E-13	5.08E-12	5.38E-12
Total	**6.11E-06**	**1.02E-04**	**1.08E-04**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

c. c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 3.5yr two-acre)

Table D-37. Two-acre dose to the public.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	6.93E-02	1.16E+00	1.23E+00
Ce-144	4.42E-08	7.42E-07	7.86E-07
Co-58	9.88E-10	1.65E-08	1.75E-08
Co-60	1.25E-04	2.09E-03	2.22E-03
Cs-137	2.01E-08	3.37E-07	3.57E-07
Ba-137m	4.81E-13	8.07E-12	8.56E-12
Mn-54	8.47E-09	1.42E-07	1.50E-07
Np-237	4.96E-07	8.31E-06	8.81E-06
Pa-234m	7.47E-18	1.25E-16	1.32E-16
Pu-238	1.42E-04	2.38E-03	2.52E-03
Pu-239	5.14E-03	8.60E-02	9.12E-02
Pu-240	1.15E-03	1.92E-02	2.03E-02
Pu-241	6.86E-05	1.15E-03	1.22E-03
Sr-90	8.87E-08	1.49E-06	1.58E-06
Y-90	3.73E-09	6.26E-08	6.63E-08
Total	**7.60E-02**	**1.27E+00**	**1.35E+00**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-38. Two-acre cancer risk[c] to the public.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	1.94E-07	3.25E-06	3.44E-06
Ce-144	1.24E-13	2.08E-12	2.20E-12
Co-58	2.77E-15	4.62E-14	4.89E-14
Co-60	3.49E-10	5.85E-09	6.20E-09
Cs-137	5.64E-14	9.42E-13	9.99E-13
Ba-137m	1.35E-18	2.26E-17	2.40E-17
Mn-54	2.37E-14	3.97E-13	4.21E-13
Np-237	1.39E-12	2.33E-11	2.47E-11
Pa-234m	2.09E-23	3.49E-22	3.70E-22
Pu-238	3.97E-10	6.66E-09	7.06E-09
Pu-239	1.44E-08	2.41E-07	2.55E-07
Pu-240	3.22E-09	5.37E-08	5.69E-08
Pu-241	1.92E-10	3.22E-09	3.41E-09
Sr-90	2.48E-13	4.16E-12	4.41E-12
Y-90	1.04E-14	1.75E-13	1.86E-13
Total	**2.13E-07**	**3.56E-06**	**3.77E-06**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 3.5yr two-acre)

Table D-39. Four-acre dose to the collocated worker.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	1.95E+00	3.26E+01	3.46E+01
Ce-144	1.09E-06	1.83E-05	1.94E-05
Co-58	2.37E-08	3.97E-07	4.21E-07
Co-60	2.99E-03	5.00E-02	5.30E-02
Cs-137	4.98E-07	8.31E-06	8.81E-06
Ba-137m	5.57E-09	9.32E-08	9.87E-08
Mn-54	2.03E-07	3.40E-06	3.60E-06
Np-237	1.35E-05	2.25E-04	2.39E-04
Pa-234m	1.83E-11	3.06E-10	3.24E-10
Pu-238	3.77E-03	6.32E-02	6.70E-02

Table D-39. (continued).

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Pu-239	1.37E-01	2.28E+00	2.42E+00
Pu-240	3.06E-02	5.14E-01	5.44E-01
Pu-241	1.88E-03	3.15E-02	3.34E-02
Sr-90	2.19E-06	3.68E-05	3.89E-05
Y-90	9.27E-08	1.56E-06	1.65E-06
Total	**2.13E+00**	**3.56E+01**	**3.77E+01**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-40. Four-acre cancer risk[c] to the collocated worker.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	9.37E-06	1.57E-04	1.66E-04
Ce-144	5.23E-12	8.77E-11	9.29E-11
Co-58	1.14E-13	1.91E-12	2.02E-12
Co-60	1.44E-08	2.40E-07	2.54E-07
Cs-137	2.39E-12	3.99E-11	4.23E-11
Ba-137m	2.67E-14	4.47E-13	4.74E-13
Mn-54	9.73E-13	1.63E-11	1.73E-11
Np-237	6.47E-11	1.08E-09	1.15E-09
Pa-234m	8.80E-17	1.47E-15	1.56E-15
Pu-238	1.81E-08	3.04E-07	3.22E-07
Pu-239	6.56E-07	1.10E-05	1.16E-05
Pu-240	1.47E-07	2.47E-06	2.61E-06
Pu-241	9.03E-09	1.51E-07	1.60E-07
Sr-90	1.05E-11	1.76E-10	1.87E-10
Y-90	4.45E-13	7.47E-12	7.92E-12
Total	**1.02E-05**	**1.71E-04**	**1.81E-04**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 6 years four-acre)

Table D-41. Four-acre dose to the public.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	6.79E-02	1.14E+00	1.21E+00
Ce-144	3.80E-08	6.37E-07	6.75E-07
Co-58	8.46E-10	1.42E-08	1.50E-08
Co-60	1.07E-04	1.79E-03	1.90E-03
Cs-137	1.74E-08	2.89E-07	3.06E-07
Ba-137m	4.14E-13	6.92E-12	7.34E-12
Mn-54	7.27E-09	1.22E-07	1.29E-07
Np-237	4.69E-07	7.83E-06	8.30E-06
Pa-234m	6.23E-18	1.05E-16	1.11E-16
Pu-238	1.31E-04	2.20E-03	2.33E-03
Pu-239	4.76E-03	7.98E-02	8.45E-02
Pu-240	1.06E-03	1.79E-02	1.90E-02
Pu-241	6.55E-05	1.09E-03	1.16E-03
Sr-90	7.62E-08	1.28E-06	1.35E-06
Y-90	3.20E-09	5.38E-08	5.70E-08
Total	**7.40E-02**	**1.24E+00**	**1.32E+00**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-42. Four-acre cancer risk[c] to the public.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	3.26E-07	5.48E-06	5.80E-06
Ce-144	1.82E-13	3.06E-12	3.24E-12
Co-58	4.06E-15	6.81E-14	7.22E-14
Co-60	5.16E-10	8.61E-09	9.12E-09
Cs-137	8.33E-14	1.39E-12	1.47E-12
Ba-137m	1.99E-18	3.32E-17	3.52E-17
Mn-54	3.49E-14	5.85E-13	6.19E-13
Np-237	2.25E-12	3.76E-11	3.99E-11
Pa-234m	2.99E-23	5.02E-22	5.32E-22
Pu-238	6.31E-10	1.05E-08	1.12E-08
Pu-239	2.28E-08	3.83E-07	4.06E-07

Table D-42. (continued).

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Pu-240	5.11E-09	8.61E-08	9.12E-08
Pu-241	3.14E-10	5.25E-09	5.56E-09
Sr-90	3.66E-13	6.12E-12	6.49E-12
Y-90	1.54E-14	2.58E-13	2.74E-13
Total	**3.55E-07**	**5.97E-06**	**6.33E-06**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 6 years four-acre)

Table D-43. Full retrieval, treatment, and disposal dose to the collocated worker.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	2.04E+00	3.42E+01	3.63E+01
Ce–144	3.15E-04	5.30E-03	5.61E-03
Co-58	3.79E-06	6.35E-05	6.73E-05
Co-60	4.02E-01	6.74E+00	7.14E+00
Cs-137	7.81E-05	1.31E-03	1.39E-03
Ba-137m	8.74E-07	1.47E-05	1.56E-05
Ni-63	2.99E-05	5.00E-04	5.30E-04
Mn-54	1.32E-05	2.21E-04	2.34E-04
Pu-238	8.20E-03	1.37E-01	1.46E-01
Pu-239	2.88E-01	4.86E+00	5.15E+00
Pu-240	6.58E-02	1.10E+00	1.17E+00
Pu-241	2.14E-02	3.58E-01	3.80E-01
Sr-90	4.34E-04	7.26E-03	7.69E-03
Y-90	1.84E-05	3.08E-04	3.27E-04
U-238	3.22E-03	5.41E-02	5.73E-02
Total	**2.83E+00**	**4.75E+01**	**5.03E+01**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-44. Full retrieval, treatment, and disposal cancer risk[c] to the collocated worker.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	4.08E-05	6.85E-04	7.26E-04
Ce–144	6.30E-09	1.06E-07	1.12E-07
Co-58	7.58E-11	1.27E-09	1.35E-09
Co-60	8.04E-06	1.35E-04	1.43E-04
Cs-137	1.56E-09	2.63E-08	2.78E-08
Ba-137m	1.75E-11	2.95E-10	3.12E-10
Ni-63	5.98E-10	1.00E-08	1.06E-08
Mn-54	2.64E-10	4.42E-09	4.69E-09
Pu-238	1.64E-07	2.75E-06	2.91E-06
Pu-239	5.75E-06	9.73E-05	1.03E-04
Pu-240	1.32E-06	2.20E-05	2.33E-05
Pu-241	4.27E-07	7.17E-06	7.60E-06
Sr-90	8.68E-09	1.45E-07	1.54E-07
Y-90	3.67E-10	6.16E-09	6.53E-09
U-238	6.44E-08	1.08E-06	1.15E-06
Total	**5.66E-05**	**9.50E-04**	**1.01E-03**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 25 years full retrieval)

Table D-45. Full retrieval, treatment, and disposal dose to the public.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	7.10E-02	1.19E+00	1.26E+00
Ce–144	1.58E-08	1.85E-04	1.85E-04
Co-58	1.93E-10	2.27E-06	2.27E-06
Co-60	2.07E-05	2.42E-01	2.42E-01
Cs-137	3.88E-09	4.56E-05	4.56E-05
Ba-137m	9.30E-14	1.09E-09	1.09E-09
Ni-63	1.49E-09	1.75E-05	1.75E-05
Mn-54	6.77E-10	7.93E-06	7.93E-06
Pu-238	4.08E-07	4.78E-03	4.79E-03
Pu-239	1.44E-05	1.69E-01	1.69E-01

Table D-45. (continued).

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Pu-240	3.27E-06	3.83E-02	3.83E-02
Pu-241	1.06E-06	1.25E-02	1.25E-02
Sr-90	2.15E-08	2.53E-04	2.53E-04
Y-90	9.05E-10	1.06E-05	1.06E-05
U-238	1.60E-07	1.89E-03	1.89E-03
Total	**7.10E-02**	**1.66E+00**	**1.73E+00**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-46. Full retrieval, treatment, and disposal cancer risk[c] to the public.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	1.42E-06	2.38E-05	2.52E-05
Ce–144	3.15E-13	3.70E-09	3.70E-09
Co-58	3.86E-15	4.55E-11	4.55E-11
Co-60	4.14E-10	4.83E-06	4.83E-06
Cs-137	7.75E-14	9.13E-10	9.13E-10
Ba-137m	1.86E-18	2.19E-14	2.19E-14
Ni-63	2.99E-14	3.49E-10	3.49E-10
Mn-54	1.35E-14	1.59E-10	1.59E-10
Pu-238	8.16E-12	9.57E-08	9.57E-08
Pu-239	2.88E-10	3.38E-06	3.38E-06
Pu-240	6.55E-11	7.65E-07	7.65E-07
Pu-241	2.13E-11	2.49E-07	2.49E-07
Sr-90	4.30E-13	5.06E-09	5.06E-09
Y-90	1.81E-14	2.13E-10	2.13E-10
U-238	3.21E-12	3.78E-08	3.78E-08
Total	**1.42E-06**	**3.31E-05**	**3.46E-05**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 25 years full retrieval)

Table D-47. Pad A dose to the collocated worker.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	1.54E-03	2.58E-02	2.73E-02
Co-60	1.12E-08	1.88E-07	1.99E-07
Cs-137	3.22E-09	5.39E-08	5.71E-08
Ba-137m	3.61E-11	6.05E-10	6.41E-10
Eu-152	3.11E-11	5.21E-10	5.52E-10
Eu-154	2.60E-09	4.34E-08	4.60E-08
Pu-238	4.32E-05	7.26E-04	7.69E-04
Pu-239	1.51E-03	2.53E-02	2.69E-02
Pu-240	2.88E-04	4.84E-03	5.13E-03
Pu-241	2.37E-06	3.97E-05	4.21E-05
Pu-242	1.99E-06	3.33E-05	3.53E-05
Sr-90	1.67E-08	2.81E-07	2.98E-07
Y-90	7.08E-10	1.18E-08	1.26E-08
U-234	1.37E-04	2.31E-03	2.44E-03
U-235	9.20E-06	1.54E-04	1.63E-04
U-236	4.36E-07	7.33E-06	7.76E-06
U-238	7.12E-04	1.19E-02	1.27E-02
Total	**4.25E-03**	**7.12E-02**	**7.54E-02**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-48. Pad A cancer risk[c] to the collocated worker.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	1.85E-09	3.10E-08	3.28E-08
Co-60	1.35E-14	2.26E-13	2.39E-13
Cs-137	3.86E-15	6.47E-14	6.85E-14
Ba-137m	4.33E-17	7.26E-16	7.69E-16
Eu-152	3.73E-17	6.25E-16	6.62E-16
Eu-154	3.12E-15	5.21E-14	5.52E-14
Pu-238	5.18E-11	8.71E-10	9.23E-10
Pu-239	1.82E-09	3.04E-08	3.22E-08
Pu-240	3.45E-10	5.81E-09	6.15E-09

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Pu-241	2.85E-12	4.77E-11	5.05E-11
Pu-242	2.39E-12	4.00E-11	4.24E-11
Sr-90	2.00E-14	3.37E-13	3.57E-13
Y-90	8.49E-16	1.42E-14	1.51E-14
U-234	1.65E-10	2.77E-09	2.93E-09
U-235	1.10E-11	1.85E-10	1.96E-10
U-236	5.23E-13	8.79E-12	9.32E-12
U-238	8.55E-10	1.43E-08	1.52E-08
Total	**5.10E-09**	**8.54E-08**	**9.05E-08**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 1.5 years Pad A removal

Table D-49. Pad A dose to the public.

Nuclide	HEPA[a] (mrem/yr)	0.5% Loss[b] (mrem/yr)	Total (mrem/yr)
Am-241	5.37E-05	8.98E-04	9.52E-04
Co-60	4.03E-10	6.75E-09	7.15E-09
Cs-137	1.12E-10	1.88E-09	1.99E-09
Ba-137m	2.68E-15	4.50E-14	4.77E-14
Eu-152	1.11E-12	1.87E-11	1.98E-11
Eu-154	9.29E-11	1.55E-09	1.65E-09
Pu-238	1.51E-06	2.53E-05	2.68E-05
Pu-239	5.27E-05	8.82E-04	9.35E-04
Pu-240	1.01E-05	1.69E-04	1.79E-04
Pu-241	8.25E-08	1.38E-06	1.46E-06
Pu-242	6.93E-08	1.16E-06	1.23E-06
Sr-90	5.80E-10	9.78E-09	1.04E-08
Y-90	2.44E-11	4.09E-10	4.34E-10
U-234	4.78E-06	8.01E-05	8.48E-05
U-235	3.20E-07	5.36E-06	5.68E-06
U-236	1.52E-08	2.55E-07	2.70E-07
U-238	2.48E-05	4.16E-04	4.41E-04
Total	**1.48E-04**	**2.48E-03**	**2.63E-03**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.

Table D-50. Pad A cancer risk[c] to the public.

Nuclide	HEPA[a] Risk	0.5% Loss[b] Risk	Total Risk
Am-241	6.44E-11	1.08E-09	1.14E-09
Co-60	4.83E-16	8.10E-15	8.58E-15
Cs-137	1.35E-16	2.26E-15	2.39E-15
Ba-137m	3.22E-21	5.40E-20	5.72E-20
Eu-152	1.33E-18	2.24E-17	2.38E-17
Eu-154	1.12E-16	1.86E-15	1.98E-15
Pu-238	1.81E-12	3.04E-11	3.22E-11
Pu-239	6.33E-11	1.06E-09	1.12E-09
Pu-240	1.21E-11	2.03E-10	2.15E-10
Pu-241	9.90E-14	1.66E-12	1.76E-12
Pu-242	8.32E-14	1.39E-12	1.48E-12
Sr-90	6.96E-16	1.17E-14	1.24E-14
Y-90	2.92E-17	4.91E-16	5.21E-16
U-234	5.73E-12	9.61E-11	1.02E-10
U-235	3.84E-13	6.43E-12	6.82E-12
U-236	1.83E-14	3.06E-13	3.24E-13
U-238	2.98E-11	4.99E-10	5.29E-10
Total	**1.78E-10**	**2.98E-09**	**3.15E-09**

a. 99.5% of releases assumed to be through HEPA filtration.
b. 0.5% of releases assumed to be lost from enclosure without HEPA filtration.
c. Risk = mrem/yr x 1rem/1000mrem x 8E-4risk/rem x duration (duration = 1.5 years Pad A removal)

Table D-51. Maximally exposed individual remediation worker cancer risks.

Module Name (Number)	Module Task	Duration (yr)	Maximally Exposed Individual Annual Cancer Risk[a]	Maximally Exposed Individual Cancer Risk for Project Duration[b]	Total Maximally Exposed Individual Cancer Risk for Project Duration[b]
Preloading Compaction (2)	Proof-roll SDA for stability	0.5	2.40E-05	2.40E-05	2.4E-05
Evapotranspiration Cap (3)	Demolish monitoring equipment	0.5	2.40E-05	2.40E-05	1.7E-04
	Other site preparation activities	0.5	2.40E-05	2.40E-05	
	Install grading fill	0.5	2.40E-05	2.40E-05	
	Install 24-in. cobble layer	0.5	2.40E-05	2.40E-05	
	Install 12-in gravel and sand layers	0.5	2.40E-05	2.40E-05	
	Install 48-in. fine soil layer	1.5	4.80E-05	7.20E-05	
	Install top soil, above grade piping, armor and sampling wells	0.5	2.40E-05	2.40E-05	
Evapotranspiration Cap w/o Gas Vent Layer (4)	Site preparation	0.5	2.40E-05	2.40E-05	7.2E-05
	Grading fill	0.5	2.40E-05	2.40E-05	
	Install top soil, above grade piping, and sampling wells	0.5	2.40E-05	2.40E-05	
RCRA Type C Cap (5)	Demolish monitoring equipment	0.5	2.40E-05	2.40E-05	1.9E-04
	Other site preparation	0.5	2.40E-05	2.40E-05	
	Install grading fill	0.5	2.40E-05	2.40E-05	
	Install 6-in. sand layer	0.5	2.40E-05	2.40E-05	
	Install 20-in. compacted top soil layer[a]	1	4.80E-05	4.80E-05	
	Install 20-in. top soil layer and vegetate[a]	1	4.80E-05	4.80E-05	
	Organic contamination in vadose zone above grade piping to probes	0.5	2.40E-05	2.40E-05	
	Install side slope, armor layers, and sampling wells	0.5	2.40E-05	2.40E-05	
Gas Vent Layer Extraction Pipe (6)	Install gas vent lines within gas collection layer of cap	0.5	2.40E-05	2.40E-05	4.8E-05

Module Name (Number)	Module Task	Duration (yr)	Maximally Exposed Individual Annual Cancer Risk[a]	Maximally Exposed Individual Cancer Risk for Project Duration[b]	Total Maximally Exposed Individual Cancer Risk for Project Duration[b]
	Manifold and connect 6 vent pipes to organic contamination in vadose zone offgas treatment units	0.5	2.40E-05	2.40E-05	
Shallow Extraction Pipe (7)	Drill and install shallow extraction wells	0.5	2.40E-05	2.40E-05	4.8E-05
	Connect wells to organic contamination in vadose zone offgas treatment units	0.5	2.40E-05	2.40E-05	
Dynamic Compaction: Pits (8)	18.7-acre dynamic compaction	1	4.80E-05	4.80E-05	4.8E-05
Dynamic Compaction: Pad A (9)	Pad A dynamic compaction	0.5	1.15E-05	1.15E-05	1.2E-05
Foundation Grouting (10)	18.7-acre foundation grouting	1	4.80E-05	4.80E-05	4.8E-05
Contaminant Grouting (11)	0.7-acre foundation grouting	1.5	4.80E-05	7.20E-05	7.2E-05
Two-acre Excavation (12)	Waste excavation within the retrieval enclosure and 46 tents (packaging, retrieval, sampling, tent moves)	3.5	4.80E-04	1.68E-03	2.4E-03
	Deactivate, decontaminate, and decommission tents and retrieval enclosure	1.5	4.80E-05	7.20E-05	
	Assay waste drums	3.5	4.80E-05	1.68E-04	
	Store and ship transuranic waste to Waste Isolation Pilot Plant	4.5	4.80E-05	2.16E-04	
	Store and ship nontransuranic waste to Idaho CERCLA Disposal Facility	4.5	4.80E-05	2.16E-04	

Module Name (Number)	Module Task	Duration (yr)	Maximally Exposed Individual Annual Cancer Risk[a]	Maximally Exposed Individual Cancer Risk for Project Duration[b]	Total Maximally Exposed Individual Cancer Risk for Project Duration[b]
Four-acre Excavation (13)	Waste excavation within the retrieval enclosure and 83 tents (packaging, retrieval, sampling, tent moves)	6	4.80E-04	2.88E-03	3.0E-03
	Deactivate, decontaminate, and decommission tents and retrieval enclosure	2	4.80E-05	9.60E-05	
	Assay waste drums	6	4.80E-05	2.88E-04	
	Store and ship transuranic waste to Waste Isolation Pilot Plant	7	4.80E-05	3.36E-04	
	Store and ship non-transuranic waste to Idaho CERCLA Disposal Facility	7	4.80E-05	3.36E-04	
Full Excavation (14)	Waste excavation within the retrieval enclosure and 83 tents (packaging, retrieval, sampling, tent moves)	25	4.80E-04	1.20E-02	1.2E-02
	Deactivate, decontaminate, and decommission tents and retrieval enclosure	5.5	4.80E-05	2.64E-04	
	Assay waste drums	25	4.80E-05	1.20E-03	
	Store and ship transuranic waste to Waste Isolation Pilot Plant	26	4.80E-05	1.25E-03	
	Store and ship nontransuranic waste to Idaho CERCLA Disposal Facility	26	4.80E-05	1.25E-03	
	Store and ship nontransuranic waste to off-Site facility	26	4.80E-05	1.25E-03	
	Store and ship remote-handled waste	24.5	4.80E-05	1.18E-03	

Module Name (Number)	Module Task	Duration (yr)	Maximally Exposed Individual Annual Cancer Risk[a]	Maximally Exposed Individual Cancer Risk for Project Duration[b]	Total Maximally Exposed Individual Cancer Risk for Project Duration[b]
Pad A Removed w/o Treatment + Ship to Low-Level Waste Pit (15)	Waste excavation	1	4.80E-04	4.80E-04	5.0E-04
	Deactivate, decontaminate, and decommission new retrieval enclosure	0.5	2.40E-05	2.40E-05	
	Store and ship waste to Low-Level Waste Pit	1.5	4.80E-05	7.20E-05	
Pad A Removed w/o Treatment + Ship to Idaho CERCLA Disposal Facility Pit (16)	Waste excavation	1.5	4.80E-04	7.20E-04	7.4E-04
	Deactivate, decontaminate, and decommission new retrieval enclosure	0.5	2.40E-05	2.40E-05	
	Store and ship waste to Idaho CERCLA Disposal Facility Pit	1.5	4.80E-05	7.20E-05	
Pad A Removed w/o Treatment + Ship to Off-Site Pit (17)	Waste excavation	1.5	4.80E-04	7.20E-04	7.4E-04
	Deactivate, decontaminate, and decommission new retrieval enclosure	0.5	2.40E-05	2.40E-05	
	Store and ship waste to off-Site facility	1.5	4.80E-05	7.20E-05	
Pad A Ex Situ Grout Treatment (18)	Waste excavation and treatment	1.5	4.80E-04	7.20E-04	7.4E-04
	Deactivate, decontaminate, and decommission new retrieval enclosure	0.5	2.40E-05	2.40E-05	
	Store and ship waste to Low-Level Waste Pit	1.5	4.80E-05	7.20E-05	

[a] MEI annual cancer risk = mrem/hr x 2000 hr/yr x 8E-07 cancers/mrem

[b] MEI Cancer Risk for Project Duration = mrem/hr x 2000 hr/yr x duration (years) x 8.7E-7