0082076

DOE/RL-2009-22
Draft A

Hexavalent Chromium Focused Feasibility Study for 100 Area

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States
Department of Energy
P.O. Box 550
Richland, Washington 99352

RECEIVED
JUN 17 2009
EDMC

Approved for Public Release
Further Dissemination Unlimited

attached to: 0082075, 0082077

DOE/RL-2009-22
Draft A

Hexavalent Chromium Focused Feasibility Study for 100 Area

Date Published
June 2009

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States Department of Energy
P.O. Box 550
Richland, Washington 99352

Release Approval 06/03/2009
Date

Approved for Public Release
Further Dissemination Unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Executive Summary

This report contains the results of a focused feasibility study (FFS) in which remedial alternatives for treating hexavalent chromium contamination in the 100 Area in the vadose zone and groundwater were re-examined and evaluated. Subsurface hexavalent chromium contamination in the 100 Area are at levels that pose a risk to human health and/or the environment. In an effort to control and mitigate these risks, existing interim action record of decisions (ROD) for the operable units (OU) in the 100 Area allow for removal, treatment, and disposal (RTD); pump-and-treat; and institutional controls (IC). Many of the ongoing 100 Area RTD and pump-and-treat remedial actions are meeting the remedial action objectives (RAO) established in the interim action RODs and reducing the risks associated with hexavalent chromium. During the time these remedial actions have been operating, numerous scientific and engineering studies and field investigations have been completed which suggest that biological or chemical in situ reduction (ISR) can be a highly effective remedial technology for treating soils and groundwater contaminated with hexavalent chromium. In situ reduction was not identified or evaluated during the initial feasibility studies leading to the selection of the current 100 Area source removal and groundwater remedial actions. Evaluation of ISR as part of a viable remedial alternative to enhance 100 Area interim remedial actions is the focus of this feasibility study. The U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy may use the results of this FFS to select a preferred alternative and develop a Proposed Plan for amending the 100 Area interim action RODs to allow the implementation of ISR at the 100 Area.

The basic elements of a feasibility study were followed for this FFS; consistent with *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] evaluation process described in EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*[2]. Background information on the 100 Area hexavalent chromium contamination areas, including site description, site history, nature and extent of hexavalent chromium contamination, and qualitative risk assessment was collected from the existing 100 Area remedial action decision documents and presented in Chapter 2. Qualitative risk assessments for each of the 100 Area source and groundwater OUs were completed prior to the initiation of this FFS and documented in the associated limited field investigation reports and other decision documents. Collectively, these assessments

[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq.

[2] EPA/540/G-89/004, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*, OSWER 9355.3-01, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

determined that hexavalent chromium poses a risk to human health and/or the environment and is a contaminant of potential concern requiring remediation.

Applicable or relevant and appropriate requirements (ARAR) and RAOs, identified during the earlier 100 Area remedial investigation/feasibility study activities, were reviewed for applicability to this evaluation. A detailed discussion and listing of the preliminary RAOs and potential federal and state ARARs applicable to this FFS are provided in Chapter 3.

Technology identification and screening activities were conducted in 2008 as part of a Remedial Process Optimization (RPO) effort for the 100-D Area[3]. These efforts included an exchange meeting on April 8-10, 2008; follow-on meetings on June 4-6, October 3-4, and October 17, 2008 for the 100-D Area; and a workshop that focused on potential applications to treat hexavalent chromium in the soils in the 100-B/C Area on November 12-13, 2008. A treatability test was conducted during the summer of 2005 to evaluate calcium polysulfide as an in situ treatment for hexavalent chromium in the 100-K Area; the results of this test were also considered. It was anticipated that the results of the technology screening and alternative development process would ultimately be applicable to chromium remediation efforts for the source waste sites in the 100-D Area and the underlying 100-HR-3 groundwater OU, as well as other hexavalent chromium contaminated waste sites and groundwater in the 100 Area. A detailed discussion of the basis and results of the technology screening and alternative development process and treatability test is provided in Chapter 4.

Treatment technologies carried forward from the screening process were assembled to create the following remedial action alternatives. Detailed descriptions of the alternatives are provided in Chapter 5.

- Alternative 1 – Continue Current Actions: Existing ICs would remain in place and RTD and pump-and-treat operations would continue and possibly be expanded or enhanced. This alternative is consistent with existing interim action RODs for the 100 Area.
- Alternative 2 – Continue Current Actions with Selective Application of ISR: This remedial action alternative retains all the technology components of Alternative 1; however, ISR is added as an option for the remediation of soil and groundwater. Implementation of this alternative would require an amendment to the interim action RODs.

In addition to the standard elements for a feasibility study, this FFS also presents suggested criteria and a general strategy for employing ISR to augment or replace RTD and/or pump-and-treat interim remedial

[3] SGW-38338, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document* Rev. 0, Fluor Hanford, Inc., Richland, Washington.

actions to treat hexavalent chromium contaminated soils and groundwater in the 100 Area. These criteria and implementation strategy are presented in Chapter 5.

In this FFS, the remedial action alternatives are evaluated against the two threshold and five balancing criteria defined by CERCLA with careful consideration of the two modifying criteria. The threshold criteria (criteria that each alternative being evaluated must meet) are (1) overall protection of human health and/or the environment and (2) compliance with ARARs. The balancing criteria (primary criteria upon which the individual and comparative analyses are based) are (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost. The modifying criteria (criteria that will be addressed once a final decision is made) are (1) regulatory acceptance and (2) community acceptance.

Both Alternatives 1 and 2 meet threshold criteria. Alternatives 1 and 2 protect human health using ICs to prevent inadvertent exposure. Protection of human health over time is achieved by maintaining ICs until the RAOs are achieved. Protection of the environment under Alternative 1 is achieved by removing and consolidating source material at the Environmental Restoration Disposal Facility (ERDF), and treating groundwater to remove hexavalent chromium. Groundwater treatment residuals are also consolidated at the ERDF. Alternative 2 protects the environment by treating contaminated soil and groundwater in situ to convert hexavalent chromium to its less toxic and essentially immobile trivalent form. The treatment process has been demonstrated to be irreversible under typical environmental conditions such as those present on the Hanford Site; therefore, protection over time is maintained. Both alternatives minimize untreated waste.

The long-term effectiveness and permanence for both alternatives are categorized as moderate because associated residuals (in the form of excavated soil and spent ion exchange resins or other groundwater treatment residuals) must be managed indefinitely. Alternative 2 is superior to Alternative 1 because through treatment it reduces toxicity, mobility, and volume of hexavalent chromium while reducing worker risk and being less intrusive; it also accomplishes this in a shorter timeframe. Where Alternatives 1 and 2 differ most significantly is in short-term effectiveness and cost and in both cases Alternative 2 is expected to perform more successfully. The CERCLA 5-year review process will be employed to be sure that the ISR technology is adequately meeting the RAOs established within this FFS.

The application of ISR relies on the introduction of a reducing agent that moves downward by gravity from the point of application at ground surface or in the vadose zone soils to groundwater. Thus, implementability and short-term effectiveness are much improved. Groundwater extraction flow rates needed to supply water to the ISR system are much lower than those required for pump-and-treat systems. Unlike RTD and groundwater pump-and-treat, a large portion of the ISR treatment residuals (in the form

of trivalent chromium) will remain in the subsurface, precluding the need for management aboveground for indefinite periods. All of these factors translate to lowered worker risk and greatly reduced costs relative to removal strategies at many parts of the 100 Area.

Because removal strategies may be needed at locations that do not possess characteristics appropriate for the application of ISR, all the components of Alternative 1 will be needed to meet the RAOs. Alternative 2 adds ISR as a potential additional remedial technology that can be used where applicable and advantageous. In situ reduction has the potential to substantially reduce worker risk and cost while accelerating the achievement of RAOs for the 100 Area. In situ reduction also has greatly reduced ancillary impacts compared to the removal technologies (that is, lower energy consumption and greenhouse gas emissions; fewer site disruptions; lower risks to workers, the community, and the environment; and smaller volumes of residuals that must be managed aboveground). The details of the individual and comparative analyses of these alternatives, along with the evaluation of the required No Action Alternative, are provided in Chapters 6 and 7, respectively. The background cost information supporting the remedial alternative cost estimates is provided in Appendix B.

Contents

1. Introduction 1-1
1.1 Purpose and Basis 1-1
1.2 Scope 1-2
1.3 Integration with Other Hexavalent Chromium Remediation Activities 1-2
2. Background Information 2-1
2.1 Site Description 2-1
2.2 Site History 2-1
2.2.1 Operable Unit Background 2-1
2.3 Nature and Extent of Hexavalent Chromium Contamination 2-3
2.3.1 100-B/C Area 2-6
2.3.2 100-D Area 2-7
2.3.3 100-H Area 2-7
2.3.4 100-F Area 2-10
2.3.5 100-K Area 2-10
2.3.6 100-N Area 2-12
2.3.7 Other Areas 2-12
2.4 Risk Evaluation 2-12
3. Remedial Action Objectives and Applicable or Relevant and Appropriate Requirements 3-1
3.1 Remedial Action Objectives 3-1
3.2 Potential Applicable or Relevant and Appropriate Requirements 3-1
4. Technology Screening and Alternative Development Process 4-1
4.1 Hexavalent Chromium Remediation Technology Exchange Workshop 4-1
4.2 100-D RPO Technology Screening and Alternative Development Process 4-2
4.2.1 Final Technology Screening Results 4-3
4.3 Remedial Action Alternatives 4-17
4.3.1 Treatability Testing of ISR Technologies 4-17
4.3.2 Selection of Alternatives for Evaluation 4-18
5. Description of Alternatives 5-1
5.1 Alternative 0 – No Action 5-1
5.2 Alternative 1 – Continue Current Actions 5-1
5.2.1 Institutional Controls 5-1
5.2.2 Pump-and-Treat Contaminated Groundwater 5-1
5.2.3 Removal, Treatment, and Disposal 5-2
5.3 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction 5-3
5.4 Design Basis for Comparison of Alternative 1 and Alternative 2 5-3

5.4.1 Hypothetical Application of Pump-and-Treat and RTD for the 100-D Hot Spot Area 5-5
5.4.2 Hypothetical Application of ISR to the 100-D Hot Spot Area 5-6
5.5 In Situ Reduction Site Selection Criteria 5-9
5.5.1 Application of In Situ Reduction to Hexavalent Chromium in Groundwater Applications 5-9
5.5.2 Application of In Situ Reduction to Hexavalent Chromium in Soil 5-12
6. Detailed Analysis of Alternatives 6-1
6.1 Description of Evaluation Criteria 6-1
6.1.1 Overall Protection of Human Health and the Environment 6-2
6.1.2 Compliance with Applicable or Relevant and Appropriate Requirements 6-2
6.1.3 Long-Term Effectiveness and Permanence 6-2
6.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment 6-3
6.1.5 Short-Term Effectiveness 6-3
6.1.6 Implementability 6-4
6.1.7 Cost 6-4
6.1.8 Regulatory Acceptance 6-4
6.1.9 Community Acceptance 6-4
6.2 Alternative 0 – No Action 6-4
6.2.1 Overall Protection of Human Health and the Environment 6-5
6.2.2 Compliance with Applicable or Relevant and Appropriate Requirements 6-5
6.2.3 Long-Term Effectiveness and Permanence 6-5
6.2.4 Reduction of Toxicity, Mobility, and Volume Through Treatment 6-5
6.2.5 Short-Term Effectiveness 6-5
6.2.6 Implementability 6-5
6.2.7 Cost 6-5
6.3 Alternative 1 – Continue Current Actions 6-5
6.3.1 Overall Protection of Human Health and the Environment 6-5
6.3.2 Compliance with Applicable or Relevant and Appropriate Requirements 6-11
6.3.3 Long-Term Effectiveness and Permanence 6-11
6.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment 6-11
6.3.5 Short-Term Effectiveness 6-11
6.3.6 Implementability 6-11
6.3.7 Cost 6-11
6.4 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction 6-13
6.4.1 Overall Protection of Human Health and the Environment 6-13
6.4.2 Compliance with Applicable or Relevant and Appropriate Requirements 6-13
6.4.3 Long-Term Effectiveness and Permanence 6-14
6.4.4 Reduction of Toxicity, Mobility, and Volume Through Treatment 6-14
6.4.5 Short-Term Effectiveness 6-14

6.4.6 Implementability 6-14
6.4.7 Cost 6-19
6.5 *National Environmental Policy Act of 1969* Values Evaluation 6-19
6.5.1 Description of *National Environmental Policy Act of 1969* Values 6-19
6.5.2 Detailed Evaluation of the *National Environmental Policy Act of 1969* Criteria 6-20
7. Comparative Analysis of Alternatives 7-1
7.1 Threshold Criteria 7-1
7.1.1 Overall Protection of Human Health and the Environment 7-1
7.1.2 Compliance with ARARs 7-2
7.2 Balancing Criteria 7-2
7.2.1 Long-Term Effectiveness and Permanence 7-2
7.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment 7-2
7.2.3 Short-Term Effectiveness 7-2
7.2.4 Implementability 7-3
7.2.5 Cost 7-3
7.3 Key Tradeoffs 7-3
8. References 8-1

Appendices

A. Summary of November 12-13, 2008 Workshop on the Evaluation of Hexavalent Chromium Remediation Technologies for the 100-B/C Area ..... A-i
B. Supporting Cost Information Hexavalent Chromium Focused Feasibility Study for the 100 Area ..... B-i

This page intentionally left blank

Figures

Figure 2-1. Hexavalent Chromium Groundwater Contamination Plume for Hanford Site, Fiscal Year 2008 2-5
Figure 2-2. Average Hexavalent Chromium Groundwater Contamination in 100-B/C Area, Fiscal Year 2008 2-6
Figure 2-3. Average Hexavalent Chromium Groundwater Contamination in 100-D Area, Fiscal Year 2008 2-8
Figure 2-4. Average Hexavalent Chromium Groundwater Contamination in 100-H Area, Fiscal Year 2008 2-9
Figure 2-5. Average Hexavalent Chromium Groundwater Contamination in 100-F Area, Fiscal Year 2008 2-10
Figure 2-6. Average Hexavalent Chromium Groundwater Contamination in 100-K Area, Fiscal Year 2008 2-11
Figure 5-1. 100-D Area Southern Plume With Groundwater Hot Spot, Fall 2007 5-4
Figure 5-2. Schematic Map View of the Proposed 100-D Area Southern Plume Groundwater Hot Spot Pump-and-Treat Well Field Design 5-6
Figure 5-3. Schematic Map View of the Combined Vadose Zone and Groundwater In Situ Reduction System for the 100-D Area Southern Plume Hot Spot 5-7
Figure 5-4. Schematic Cross-Sectional View of a Combined Vadose Zone and Groundwater In Situ Reduction System for the 100-D Area Southern Plume Hot Spot and Overlying Vadose Zone 5-8
Figure 5-5. Logic for Application of In Situ Reduction for Remediation of Hexavalent Chromium in Groundwater 5-11
Figure 5-6. Logic for Application of In Situ Reduction for Remediation of Hexavalent Chromium in Soil 5-14

This page intentionally left blank.

Tables

Table 1-1. Decision Documents Affecting the 100 Area 1-3
Table 3-1. Remedial Action Objectives for the 100 Area 3-2
Table 3-2. Potential Federal Applicable or Relevant and Appropriate Requirements 3-4
Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements 3-7
Table 4-1. Screening Table – Technologies for the River Objective 4-5
Table 4-2. Screening Table – Technologies for Groundwater 4-9
Table 4-3. Screening Table – Technologies for Vadose Zone Sources 4-13
Table 6-1. Detailed Evaluation of Alternative 1 – Continue Current Actions 6-7
Table 6-2. Comparison of Net Present Value Cost of Between Alternative 1 and 2 with Enabling Assumptions at 100-D-12 6-12
Table 6-3. Detailed Evaluation of Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction 6-15

This page intentionally left blank.

Terms

ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ESD	Explanation of Significant Difference
FFS	focused feasibility study
ft	feet
gal	gallon
gal/min	gallons per minute
H&S	health and safety
IC	institutional control
ICP	inductively coupled plasma
ISR	in situ reduction
ISRM	in situ redox manipulation
km^2	square kilometer
L/min	liters per minute
m	meter
MCL	maximum contaminant level
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
mi^2	square mile
MNA	monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300)
NEPA	*National Environmental Policy Act of 1969*
NPL	National Priorities List (40 CFR 300, Appendix B)
O&M	operations and maintenance
OU	operable unit
RA	relevant and appropriate
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RPO	remedial process optimization
RTD	removal, treatment, and disposal
SDWA	*Safe Drinking Water Act of 1974*
TMV	toxicity, mobility, or volume
Tri-Party	*Hanford Federal Facility Agreement and Consent Order* Agreement
Tri-Parties	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
µg/L	micrograms per liter
USC	*United States Code*
WAC	*Washington Administrative Code*

1. Introduction

This focused feasibility study (FFS) evaluates interim remedial action alternatives to address hexavalent chromium contaminated soil and groundwater present in the 100 Area of the U.S. Department of Energy's (DOE) Hanford Site. The information and evaluations presented in this FFS will be used to prepare a proposed plan that will be made available for public review and comment.

The scope of the FFS is similar in many aspects to the feasibility study process described in the National Contingency Plan (NCP) under 40 *Code of Federal Regulations* (CFR) 300.430 (e), "Detailed Analysis of Alternatives." However, it differs in three aspects. First, it evaluates a limited number of interim remedial action alternatives that include various combinations of the existing interim remedial action technologies and the additional technology. Existing soil and groundwater interim remedial action technologies that are currently being used in the 100 Area include institutional controls (IC); removal, treatment, and disposal (RTD), and pump-and-treat. Second, the FFS evaluates each of the alternatives with respect to a single "typical" waste site, yet presents costs for six known hexavalent chromium sites and four "yet-to-be-discovered" (future) waste sites located throughout the 100 Area. The known waste sites include 100-D-12, 100-D-30 SW, 600-334, 116-K-2, 100-C-7:1, and 100-C-7. Lastly, this FFS is specific to hexavalent chromium.

The U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and DOE (Tri-Parties) have agreed on the process for characterization and remediation of waste sites at the Hanford Site as discussed in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989). Submittal of this FFS and the associated proposed plan to EPA by June 30, 2009, will meet Tri-Party Agreement interim Milestone M-016-150. The milestone calls for augmenting previously selected remedies to provide more effective hexavalent chromium remediation in the 100 Area and associated reduction of potential threats to human health and the environment. The recommended remedial action alternative will be presented for public review and comment in a proposed plan.

1.1 Purpose and Basis

The purpose of this FFS is to provide the information and evaluations of hexavalent chromium remediation technologies for soil and groundwater so that the EPA, Ecology, and DOE may use the results to prepare a proposed plan for amending the 100 Area interim action records of decision (ROD) to allow the implementation of the preferred alternative. This FFS is an outgrowth of technology screening activities conducted in 2008 as part of a Remedial Process Optimization (RPO) effort for the 100-D Area as detailed in Section 4.2, and a follow-on workshop that focused on hexavalent chromium remediation in the soils in the 100-B/C Area in November 2008 (Appendix A). The RPO technology screening effort was initiated, in part, because (1) Existing interim actions for the 100-D Area are comprised primarily of pump-and-treat for groundwater and RTD for soil. As currently implemented, these actions are not meeting the groundwater and river protection remedial action objectives (RAO) as effectively or as quickly as originally anticipated; and (2) the RPO technology screening effort was anticipated to identify additional technologies that could be used to augment the existing remedial action alternatives (pump-and-treat and RTD) and thereby, promote the attainment of the RAOs in a more timely and cost-effective fashion.

The technology screening process and results are summarized in Chapter 4. Although several technologies were retained or "conditionally retained" by the screening process, in situ biological and chemical reduction, hereafter called in situ reduction (ISR) technologies were identified as the most appropriate to augment the existing interim soil and groundwater remedial action alternatives for the

100-D Area and the 100 Area as a whole. The remaining retained or conditionally retained technologies, will be further evaluated in the remedial investigation/feasibility study (RI/FS) process for possible inclusion in the final remedy for the 100 Area. Based on technology screening results, three alternatives (see Chapter 4) were developed to serve as a basis for determining whether ISR should be included as an interim action for the 100 Area.

1.2 Scope

The scope of this FFS is as follows:

- Provide the technical and regulatory basis through the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) evaluation process for amending, if warranted, the existing interim action RODs to include a remedial action alternative that contains ISR as a component.
- Develop a strategy and logic for selection of sites where the implementation of ISR will more effectively achieve the interim RAOs.

1.3 Integration with Other Hexavalent Chromium Remediation Activities

Additional remedies would be integrated with ongoing hexavalent chromium remediation in the 100 Area through the implementation of remedial actions that are described in a series of remedial action RODs, amendment to the remedial action RODs, and Explanations of Significant Differences (ESD). These decision documents currently include remediation activities such as RTD, pump-and-treat, and ICs for source and groundwater contamination in the 100 Area as provided Table 1-1. Table 1-1 lists the relevant 100 Area interim action RODs, ROD Amendments, and ESDs in chronological order and has three parts. The first part identifies decision documents associated with source OUs with known or suspected hexavalent chromium contamination in the 100 Area. The next part identifies decision documents associated with groundwater operable units (OU) with known or suspected hexavalent chromium contamination. Finally, for completeness, the third part identifies decision documents associated OUs that have no identified hexavalent chromium contamination. Other activities include waste-site remediation, facility demolition and decommissioning, and interim safe storage of reactors.

Additional activities are underway or planned in the 100 Area as a part of the implementation of interim action RODs. These activities include treatability tests and other activities to either remediate contaminated areas or develop more effective remediation methods.

For a complete list of waste sites, their associated source OU, and status refer to DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Appendix A; DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, Appendix A; and the Tri-Party Agreement, Appendix C (Ecology et al., 1989). A systematic orphan site evaluation is underway to identify potential waste sites in the River Corridor that are not currently listed in existing interim action RODs. This evaluation has been completed for the 100-D and 100-H Areas, is in progress for the "horn" area, and will soon be conducted throughout the rest of the 100 Area. These waste sites will be incorporated into DOE/RL-2008-46, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*, in process, and its subsequent addenda.

Cleanup of waste sites in accordance with the interim action RODs is ongoing and is expected to continue until final RODs replace interim remedial action decisions. Following completion of interim remediation at each waste site in a source OU, cleanup verification sampling and laboratory analysis are used to

confirm attainment of remedial action goals established under the interim action RODs and; therefore, demonstrate that RAOs for interim site closure have been met.

Table 1-1. Decision Documents Affecting the 100 Area

Decision Document	Summary
Source OUs with known or suspected hexavalent chromium contamination	
EPA/ROD/R10-95/126, *Declaration of the Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*, September 1995	Sets two approaches to remediation: Observational approach – relies on historical information and limited field investigations. Plug-in approach – allows for selection and application of remedial actions at similar sites. Selected remedial actions include the following: removal of contaminated soil, structures, and debris using the observational approach; treatment, by thermal desorption and/or soil washing; disposal at the ERDF; backfill followed by revegetation.
EPA/541/R-08/044, *Amended Record of Decision for the 100-BC-1, 100-DR-1 and 100-HR-1 Operable Units*, April 1997	Addition of 34 waste sites throughout the 100-B/C, 100-D, 100-F, 100-H, and 100-K Areas to previous ROD, termination of the soil washing step for volume reduction, and emphasis on revegetation of remediated waste sites.
EPA/541/R-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6 and 200-CW-3 Operable Units (100 Area Remaining Sites), Hanford Site, Benton County, Washington*, July 1999	RTD of contaminated soils, structures and debris for sites where sufficient information exists; plug-in approach for sites with limited information that meet the waste-site profile; disposal of equipment and debris from B, D, H, KE, and KW Reactor buildings consistent with previous CERCLA disposal for areas associated with the C, F, and DR Reactor buildings.
EPA/541/R-00/045, *Explanation of Significant Differences for the 100 Area Remaining Sites Record of Decision: 100-IU-6 Operable Unit*, June 2000	Two waste sites (600-23 and JA Jones #1 waste sites) were added to this OU.
EPA/541/R-00/121, *Declaration of the Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington*, September 2000	Selected remedies include remove contaminated soil, structures, and associated debris; treat these wastes as required to meet disposal facility requirements; dispose of contaminated materials at the ERDF; and backfill excavated areas with clean material, followed by revegetation.
EPA, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision*, April 2004	Addition of 28 waste sites. Addition of 10 CFR 1022, "Compliance with Floodplain and Wetland Environmental Review Requirements," and 40 CFR 6, "Procedures for Implementing the National Environmental Policy Act and Assessing the Environmental Effects Abroad of EPA Actions," Appendix A as ARARs. Revise ICs in accordance with DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*.

Table 1-1. Decision Documents Affecting the 100 Area

Decision Document	Summary
Groundwater OUs with known or suspected hexavalent chromium contamination	
EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington*, March 1996	Initiates the use of ion exchange technology to remove hexavalent chromium from groundwater using a system of extraction and injection wells.
EPA/541/R-00/122, *Interim Remedial Action Record of Decision Amendment: 100-HR-3 Operable Unit*, October 1999	Alters the selected remedial action by deploying a new technology for remediation of the hexavalent chromium plume in the 100-D Area.
OUs that have not identified the presence of hexavalent chromium contamination	
EPA/541/R-99/059, *Declaration of the Record of Decision for the 100-KR-2 Operable Unit, Hanford Site, Benton County, Washington*, September 1999	Selected remedies include remove spent nuclear fuel from the K Basins, remove sludge from the K Basins, treat and remove water from the K Basins, remove debris from the K Basins, deactivate the K Basins, and establish ICs.
EPA/541/R-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, September 1999	Selected remedies include institutional controls; RTD; remove/ex situ bioremediation/dispose; and in situ bioremediation of petroleum contaminated soils.
EPA/541/R-00/120, *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit, Hanford Site, Benton County, Washington*, January 2000	Provides selected remedy for 116-N-1 and 116-N-3 liquid waste disposal facilities (structures, pipelines), and UPR-100-N-31 site.
EPA, 2005, *Interim Remedial Action Record of Decision Amendment: 100 K Area K Basins*, June 2005	Modifies sludge treatment before interim storage, modifies grouting debris in place (removal with basins), sludge treated and packaged for disposal, and shipped off the Hanford Site to a national repository.

NOTES: ARAR = applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
ERDF = Environmental Restoration Disposal Facility
IC = institutional control
OU = operable unit
ROD = Record of Decision
RTD = removal, treatment, and disposal

A CERCLA removal action will be considered for many buildings and structures in the 100 Area. Once these structures are demolished and decommissioned under CERCLA non-time-critical removal actions, residual soil samples may be taken for analysis. If the analytical results indicate that the area is still contaminated, the site will be further evaluated as a potential waste site. If necessary, a remedy will be selected as described in the final ROD.

Integration will continue with River Corridor and Plateau Remediation contractors on remediation efforts at 100 Area source OU waste sites, as well as with other Site contractors as appropriate.

2. Background Information

This chapter provides brief background information on the Hanford Site, as well as relevant information pertaining to source and groundwater OUs in the 100 Area.

2.1 Site Description

The 100 Area National Priorities List (NPL) site covers approximately 68 square kilometers [km^2] (26 square miles [mi^2]) and borders the southern shoreline of the Columbia River. Because of past construction and operation of nine plutonium production reactors, the 100 Area contains 17 OUs for contaminated sources such as soils, structures, debris, and burial grounds and 5 OUs for the underlying groundwater contamination. Land in the 100 Area is currently used for facilities support, waste management, and/or has yet been developed. Facilities support activities include operations such as water treatment and maintenance of the reactor buildings. The contaminated waste site land area resulted from former disposal activities in areas now known as "past-practice waste sites" located throughout the 100 Area. Lastly, undeveloped lands located across the 100 Area comprise approximately 90 percent of the land area. These areas are the least disturbed and contain minimal infrastructure. The shoreline of the Columbia River is a valued ecological area within the Hanford Site and was declared a national monument in 2000 (65 FR 37253, "Establishment of the Hanford Reach National Monument").

2.2 Site History

Hanford Site operations started in 1943 when construction began on three reactor facilities (B, D, and F Reactors) in the 100 Area. Between 1949 and 1963, the additional 100 Area reactor facilities H, DR, C, KE, KW, and N were constructed. Portions of the vadose zone and groundwater located below and adjacent to most of these reactors remain contaminated with various groundwater contaminants of concern (COC). These COCs include, but are not limited to, hexavalent chromium, nitrate, Sr-90, sulfate, Tc-99, tritium, and uranium. In 1989, the 100, 200, 300, and 1100 Areas were added to the NPL shifting the focus of DOE from historical operations to remediation. Each of these areas were subdivided into OUs with each source OU containing a number of individual waste units that share a common geographic area or waste source and the groundwater OU underlying one or more of the source OUs.

2.2.1 Operable Unit Background

A brief background for each of the seven geographic areas within the 100 Area is presented below. The OUs in these geographic areas are divided into two categories: source and groundwater. The source OUs consist of contamination associated with the vadose zone sources and extend from the ground surface to the interface with the saturated zone. Any contamination that is present within the saturated zone is delegated to the associated groundwater OU. Therefore, the source and groundwater OUs do not overlap; rather, a groundwater OU underlies that of one or more source OUs. For a complete list of waste sites, their associated source OU, and status, refer to DOE/RL-96-17, Appendix A; DOE/RL-2005-93, Appendix A; and the Tri-Party Agreement, Appendix C (Ecology et al., 1989).

2.2.1.1 100-B/C Area

The 100-B/C Area consists of two contaminant source OUs, 100-BC-1 and 100-BC-2, and the 100-BC-5 Groundwater OU. The 100-BC-1 OU contains 94 waste sites and the 100-BC-2 OU has 47 waste sites, including sites immediately adjacent to the Columbia River. These OUs include waste sites associated with the operation of the 105-B Reactor from 1944 until its retirement in 1968, the operation of the 105-C Reactor from 1952 until its retirement in 1969, and the cooling water retention basins for the B and C Reactors. The 100-BC-5 Groundwater OU encompasses an area of approximately 3.0 km^2 (1.1 mi^2) within the saturated zone that underlies the two source OUs. Currently, the only active

facilities in the 100-BC-1 and 100-BC-2 OUs are those used as part of the ongoing remedial actions, such as field office trailers, and the facilities that extract and treat water from the Columbia River and transport that water, via pipeline, to other 100 Area and 200 Area facilities (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report of the Hanford Site*).

2.2.1.2 100-D/DR Area

The 100-D/DR Area contains two contaminant source OUs, 100-DR-1 and 100-DR-2, and the groundwater in this area is part of the 100-HR-3 Groundwater OU. The 100-DR-1 OU contains 102 waste sites and the 100-DR-2 OU has 47 waste sites, including sites immediately adjacent to the Columbia River. These OUs include waste sites associated with the original operation of the 105-D Reactor from 1944 until its retirement in 1967, the operation of the 105-DR Reactor from 1950 until its retirement in 1964, and the cooling water retention basins for both the D and DR Reactors. Currently, untreated process and fire protection water is provided to the 100-H and 100-F Areas from the 100-D Area (EPA/541/R-99/039). The 100-D Area water system also serves as a backup for systems in the 100-B Area that supply the 200 Area with process water.

2.2.1.3 100-H Area

The 100-H Area contains two source OUs, 100-HR-1 and 100-HR-2, and the groundwater is part of the 100-HR-3 Groundwater OU (the same groundwater OU as the 100-D Area). The 100-HR-1 OU contains 60 waste sites and the 100-HR-2 OU has 17 waste sites, including sites adjacent to the Columbia River shoreline. Waste sites from both OUs are associated with the original operation of the 105-H Reactor from 1949 until its retirement in 1965, and evaporation basins that received liquid process wastes and non-routine deposits of chemical wastes from the 300 Area, where fuel elements for the N Reactor were produced. The 100-HR-1 and 100-HR-2 OUs do not have any active facilities (DOE/RL-2006-20).

2.2.1.4 100-F Area

The 100-F Area contains two contaminant source OUs, 100-FR-1 and 100-FR-2, and the 100-FR-3 Groundwater OU. The 100-FR-1 OU contains 83 waste sites and the 100-FR-2 OU has 22 waste sites along the southern shoreline of the Columbia River. Waste sites from both OUs are associated with the original operation of the 105-F Reactor from 1945 until its retirement in 1965, as well as the cooling water retention basin systems for the F Reactor, solid waste burial grounds, and the Experimental Animal Farm (studying the effects of radiation on plants and animals). The 100-FR-1 and 100-FR OUs do not have any active facilities (DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*).

2.2.1.5 100-K Area

The 100-K Area contains two contaminant source OUs, 100-KR-1 and 100-KR-2 (100-KR-2 and 100-KR-3 were combined in 1994), and the 100-KR-4 Groundwater OU. The 100-KR-1 OU contains 13 waste sites and the 100-KR-2 OU has 136 waste sites, including sites adjacent to the Columbia River. Waste sites from both OUs are associated with the original operation of the 105-KE and 105-KW Reactors, operating from 1955 until 1970 and 1971, respectively. Currently, there are several active facilities within the 100-K Area, including 105-KE and 105-KW fuel storage basins (DOE/RL-2006-20).

2.2.1.6 100-N Area

The 100-N Area contains one contaminant source OU, 100-NR-1, and the 100-NR-2 Groundwater OU. The 100-NR-1 OU contains 147 waste sites, including sites adjacent to the Columbia River. Waste sites from the 100-NR-1 OU are associated with the 105-N Reactor that operated from 1963 until 1989. The N Reactor differs from the other reactors at the Hanford Site, not only because of its closed-loop cooling system, but because it was designed as a dual-purpose reactor capable of producing special nuclear

material and steam generation for electrical power. From 1966 until shutdown in 1986, steam was piped from the N Reactor core-cooling systems to the Hanford Generating Plant for production of electrical power. The 100-NR-2 Groundwater OU addresses contamination in the aquifer below the 100-NR-1 OU. The 100-N Area decision documents (see Table 1-1) do not identify hexavalent chromium as being present in this area.

2.2.1.7 Other Source Areas

The 100-IU-2 (White Bluffs Townsite) OU was an agriculture-based community of about 500 people that existed before the Manhattan Engineering District project began in 1943. When government operations began, many of the houses were demolished and new temporary buildings were erected; although most of the activities in this OU ceased in the early 1950s, not all the facilities were removed until the 1970s. The 100-IU-6 (Hanford Townsite) OU was another agriculture-based town that existed prior to government operations. Starting in 1943, it was used as a housing camp for more than 45,000 construction workers and ceased to exist in 1945 (DOE/RL-95-108, *Approach and Plan for Cleanup Actions in the 100-IU-2 and 100-IU-6 Operable Units of the Hanford Site*). These OUs cover a large portion of the Hanford Site, known as the 600 Area, including areas between the 100 Area production reactor OUs. There are currently 84 waste site within the 100-IU-2 OU and 64 waste sites in the 100-IU-6 OU, many of which are remnants of the White Bluffs and Hanford Townsites and surrounding farms (DOE/RL-95-108). Waste sites within these OUs are generally not associated with reactor/operational areas, and consist mostly of surface debris, oil spills, trash dumps, building foundations, surface depressions, and ash piles from pre-Hanford activities. These two OUs are being addressed under either EPA/541/R-99/039 or EPA/541/R-00/121.

The 100-IU-1 (Riverland Rail Yard) and 100-IU-3 (Wahluke Slope) OUs were remediated via action memoranda and deleted from the NPL in July 1998. The 100-IU-4 (Sodium Dichromate Barrel Landfill) and 100-IU-5 (White Bluffs Pickling Acid Cribs) OUs were remediated under an expedited response action and closed out in February 1996 (DOE/RL-95-60, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units*).

2.3 Nature and Extent of Hexavalent Chromium Contamination

Hexavalent chromium, as sodium dichromate, was added to the cooling water in the Hanford Site nuclear reactors to retard corrosion in the aluminum process tubes of the reactor-cooling system. The solid chemical feedstock (approximately 90 percent sodium dichromate by weight) was delivered to the reactor areas in bags, barrels, or rail cars, and transferred to points of use through local underground pipelines in stock solutions that contained up to 29 percent sodium dichromate by weight. A highly concentrated acid salt solution (about 70 percent sodium dichromate by weight) replaced the use of solid feedstock around 1959. The solution was diluted so that the reactor coolant contained between 1 to 2 milligrams per liter (mg/L) of sodium dichromate. The reactor process water that was discharged to retention basins (ultimately outfall structures), cribs, and trenches would have contained hexavalent chromium at concentrations from 350 to 700 micrograms per liter (µg/L).

It is known that some of the sodium dichromate feed material was spilled during handling or mixing operations and/or leaked from the transfer pipelines. The spills occurred during the operation period of the reactors from 1944 to 1971. Some leakage from pipelines has been confirmed during remediation efforts, and may have occurred during or after the period of reactor operation. Recent observations have shown that a substantial volume of sodium dichromate concentrate remained in some of the transfer pipelines, at concentrations as high as 359,000 parts per million as total chromium (NOTE: this analytical result exceeds the solution saturation limit for sodium dichromate). As of April 2009, the following

characterization and remediation activities have been performed for sodium dichromate transfer pipeline waste sites:

- 100-B-14:5 – pipeline was found to have been previously flushed and drained; no further interim action was required.
- 100-B-28 – pipeline has been removed and remediation of underlying soils is ongoing; remediation of the pipeline included removal of over 200 gallons (gal) of concentrated sodium dichromate solution (with a maximum analytical result of 359,000 milligrams per liter (mg/L) as total chromium).
- 100-D-56:1 – pipeline has been remediated and is in the process of interim reclassification; no significant residual sodium dichromate liquid was found during remediation.
- 100-D-56:2 – pipeline has been remediated and is in the process of interim reclassification; remediation of the pipeline included removal of approximately 850 gallons of concentrated sodium dichromate solution (with a maximum analytical result of 40,800 mg/L as total chromium).
- 100-F-26:7 – pipeline has been characterized and found to have been previously drained; however, the draining is believed to have been incomplete, resulting in a small volume of residual liquid within the pipeline; remediation is currently planned for fiscal year 2011.
- 100-K-79 – portions of the pipeline are planned for removal via demolition activities during fiscal year 2010; the potential need for any further remediation has not yet been determined.

Hexavalent chromium associated with spills, leaks, or discharges has moved through the vadose zone to the water table by natural precipitation, perhaps assisted by artificial recharge (for example, leaks in buried water lines, retention basins and reservoirs, or concentrated runoff from roads or buildings). Once in the groundwater, the natural hydraulic gradient carries the hexavalent chromium toward the Columbia River. The locations and lateral extent of the 100 Area hexavalent chromium-contaminated groundwater plumes are depicted in Figure 2-1. The figures presented in this section show the distribution of hexavalent chromium in groundwater. This is based on the assumption that filtered total chromium results are equivalent to hexavalent chromium in Hanford groundwater samples (DOE/RL-2008-01).

Records of spills in the 100 Area generally were not kept during the production years; therefore, locating the sites of these spills must be done through direct field investigation. Several likely source locations have been identified and investigated since 1999. Although hexavalent chromium has been found near the surface in many of these areas, zones of elevated hexavalent chromium in the subsurface vadose zone that are acting as notable continuing sources to groundwater have not yet been identified in the 100-D Area (BHI-01185, *100-D Area Chromium Study Summary Report*; PNNL-13107, *Identification of a Hanford Waste Site for Initial Deployment of the In Situ Gaseous Reduction Approach*; PNNL-13486, *Characterization Activities Conducted at the 183-DR Site in Support of the In Situ Gaseous Reduction Demonstration*; BHI-01747, *Results of Hexavalent Chromium Sampling Near 100-D Area Sodium Dichromate Transfer Station Railroad Tracks*; DOE/RL-2006-74, *Field Investigation Plan for the Source of the Southwestern Chromium Plume in the 100-D Area*). The failure to locate the hexavalent chromium source(s) in the vadose zone by drilling or excavation indicates that the source(s) may be highly localized and concentrated (or present deeper than completion depths). Extensive RTD is being performed throughout the 100-D Area, focusing on locations where sodium dichromate was handled.

For a detailed description of the nature and extent of hexavalent chromium contamination in the vadose zone and groundwater, and transport and discharge of sodium dichromate materials at each of the 100 Areas, refer to DOE/RL-2008-46 and its subsequent addenda. A summary is provided in the following subsections.

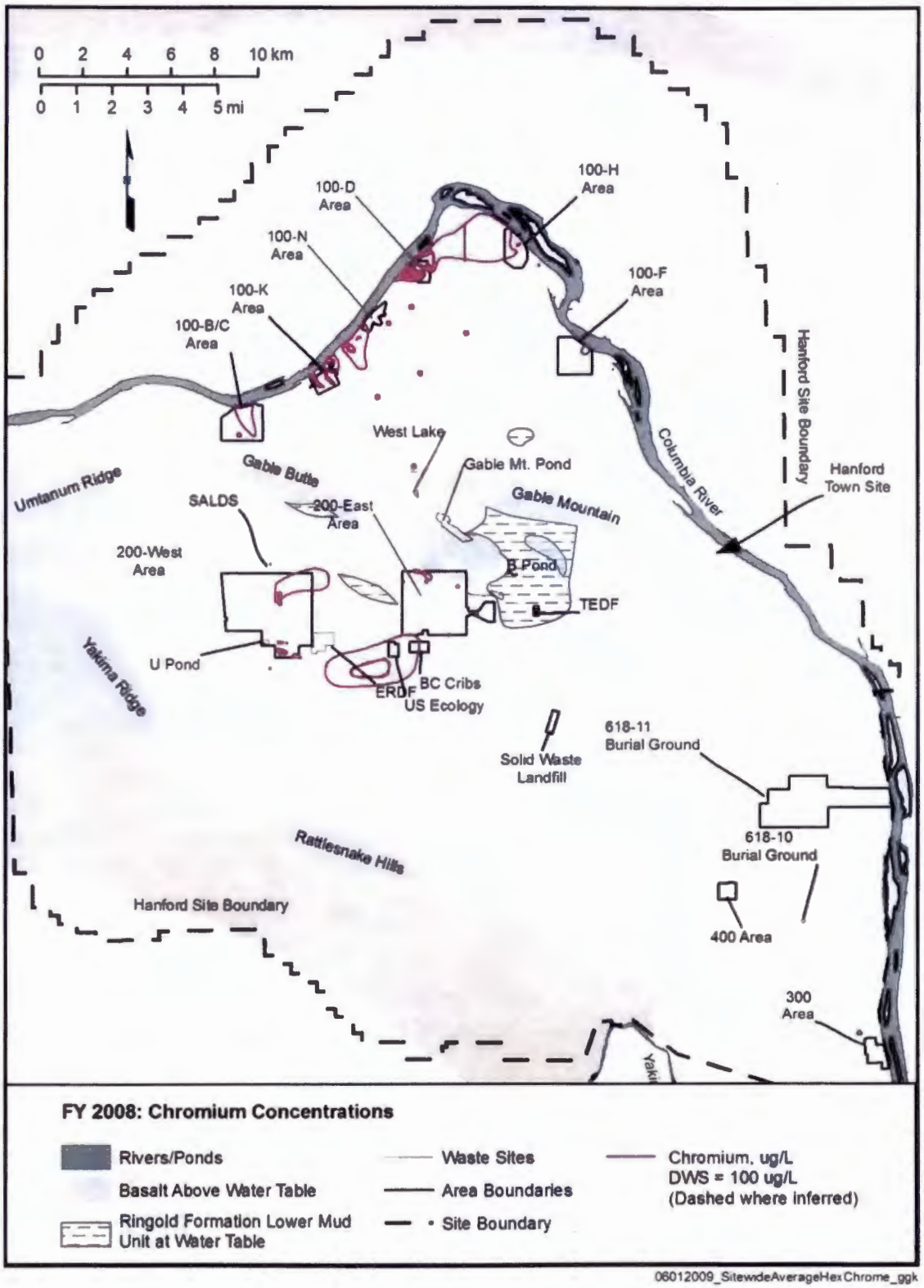

Figure 2-1. Hexavalent Chromium Groundwater Contamination Plume for Hanford Site, Fiscal Year 2008

2.3.1 100-B/C Area

A disbursed low-concentration plume of hexavalent chromium-contaminated groundwater (generally less than 50 µg/L) is located near the central portion of the 100-B/C Area, with the highest concentration of 64 µg/L in a well downgradient of the 116-B-11 retention basin. In 2003, hexavalent chromium was detected in the vadose zone soil at the 100-C-7 waste site that may have contributed to the small plume underlying this waste site, as illustrated by the isolated, circular plume depicted in Figure 2-2. Another hexavalent chromium-contaminated waste site was discovered in the 100-B/C Area in 2005, 100-B-27. This waste site is located west of the 126-B-3 dumping area and northwest of well 199-B5-1 (17 µg/L in 2008). Further exploration is anticipated in this area, which may lead to refining the hexavalent chromium groundwater plume in the 100-B/C Area. The current approximate size and shape of the groundwater plume in the 100-B/C Area is shown in Figure 2-2.

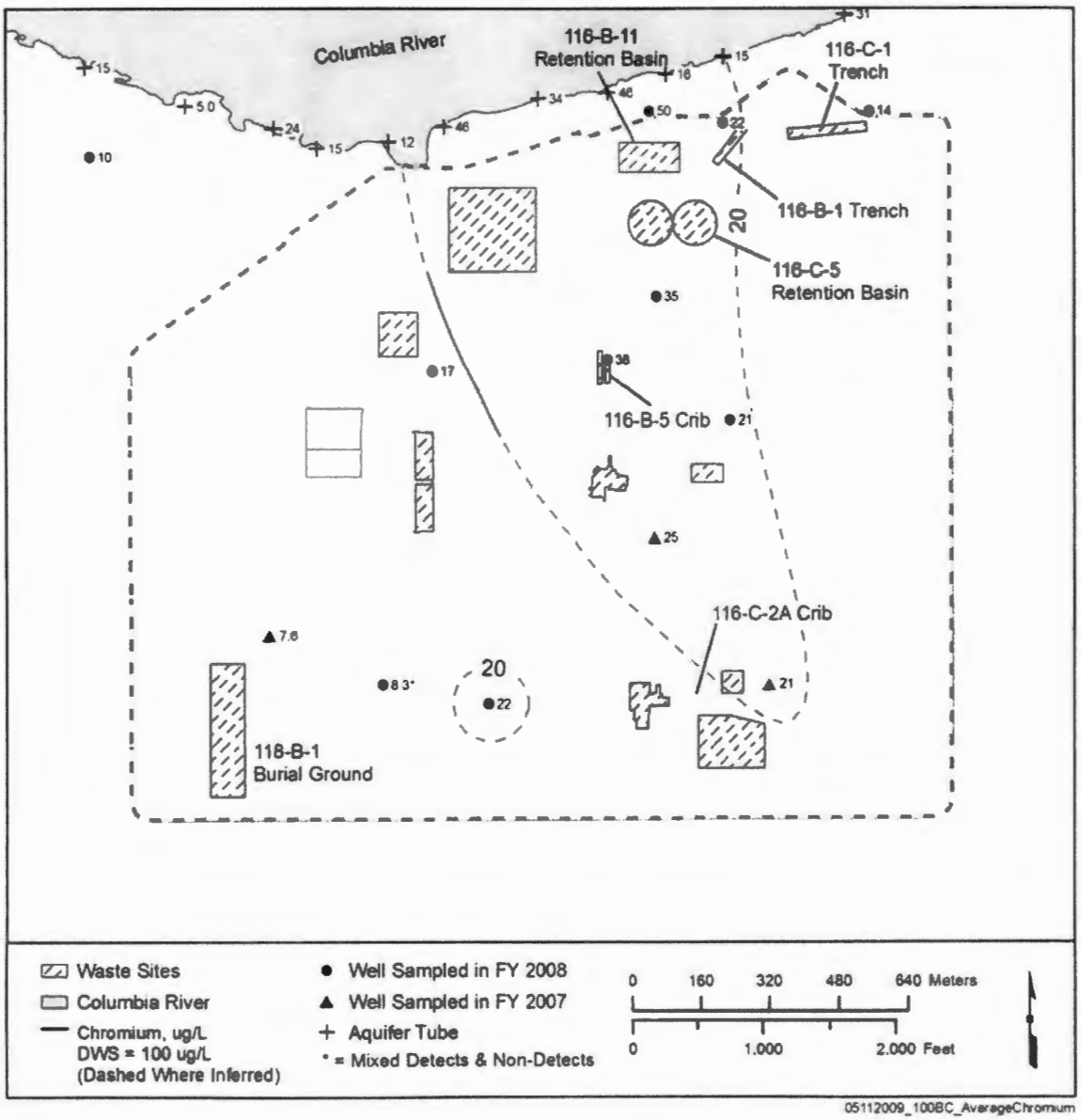

Figure 2-2. Average Hexavalent Chromium Groundwater Contamination in 100-B/C Area, Fiscal Year 2008 (Source: DOE/RL-2008-66, Hanford Site Groundwater Monitoring for Fiscal Year 2008, Figure 2.2-7)

2.3.2 100-D Area

Concentrated sodium dichromate feed materials were provided in both solid and liquid form. From 1944 to 1950, solid sodium dichromate (about 90 percent by weight) was stored and mixed with water at the 108-D Building Chemical Pumphouse to form a less-concentrated solution. In 1950, this process moved from the 108-D Chemical Pumphouse to the 185-D De-aerating Plant and continued there for about 9 years. Beginning in 1959, mixing of solid sodium dichromate with water was abandoned in favor of delivering a highly concentrated acid salt solution by railcar or tanker to 100-D-12, the sodium dichromate pumping station located west of the 105-D Reactor. This solution contained about 70 percent by weight sodium dichromate and was transferred by overhead pipeline to the 185-D De-aerating Plant where it was diluted to a 10 to 15 percent by weight solution. This process continued until the reactors were retired in 1967. The 10 to 15 percent by weight solution was pumped to the 190-D Building for final dilution, approximately 1 to 2 mg/L sodium dichromate added, and the cooling water pumped to the D Reactor. The reactor process water contained hexavalent chromium concentrations of approximately 350 to 700 μg/L which was discharged to retention basins, cribs, and trenches.

Hexavalent chromium has been found in much of the groundwater underlying the 100-D Area (Figure 2-3) and forms two separate plumes called the northern plume and the southern plume. The relatively uncontaminated area separating these two plumes reflects leakage of river water from the 182-D Reservoir, a source of artificial recharge within the 100-D Area. The northern and southern plumes appear to have originated from multiple sources in the 100-D Area, yet the source locations remain undefined. Remediation of the northern plume currently is being conducted using the DR-5 Pump-and-Treat System in the 100-D Area and by the 100-HR-3 Pump-and-Treat System in the 100-H Area. The southern plume is being remediated by the DR-5 Pump-and-Treat System and by the in situ redox manipulation (ISRM) permeable reactive barrier. The ISRM barrier was designed to intercept the highest concentrations of hexavalent chromium in the southern plume before the contaminant enters the river. A new, larger pump-and-treat system, 100-DX, is being designed to address the hexavalent chromium contamination in both the northern and southern groundwater plumes. Concentrations of hexavalent chromium in the southern plume upgradient of the ISRM barrier have remained high since their initial discovery in 1999, suggesting that one or more active sources of hexavalent chromium are contributing contamination to the plume. The location of the source(s), whether in the vadose zone or aquifer or both, have not been fully discovered. The fact that hexavalent chromium concentrations in upgradient groundwater have been measured above 4,000 μg/L and as high as approximately 40,000 μg/L establishes that the source is not cooling water itself (which typically contained approximately 1,000 to 2,000 μg/L of hexavalent chromium), but originates from a considerably more concentrated solution.

2.3.3 100-H Area

A process similar to that of the 100-D Area was employed to introduce dilute sodium dichromate solution to the 105-H Reactor. Unlike the multiple mixing steps at 100-D, the 100-H Area used a one-step process of mixing treated river water with sodium dichromate at the 190-H Building. Given the operational history of the 100-H Reactor (1949 to 1965), it is reasonable to assume that both the solid sodium dichromate and liquid solutions were used as feed materials. It may also be inferred that the transition from solid to liquid occurred around the same time as 100-D and 100-F.

The hexavalent chromium-contaminated groundwater plume within the 100-D and 100-H Areas of the 100-HR-3 groundwater OU can be seen in Figure 2-3 and Figure 2-4, respectively. These figures illustrate that the average concentration of hexavalent chromium was less than 100 μg/L in fiscal year 2008. The area to the left of the 100-H Area and to the right of the 100-D Area in the figures is referred to as the "horn" area. Current investigations are being conducted to address the hexavalent chromium contamination with this region.

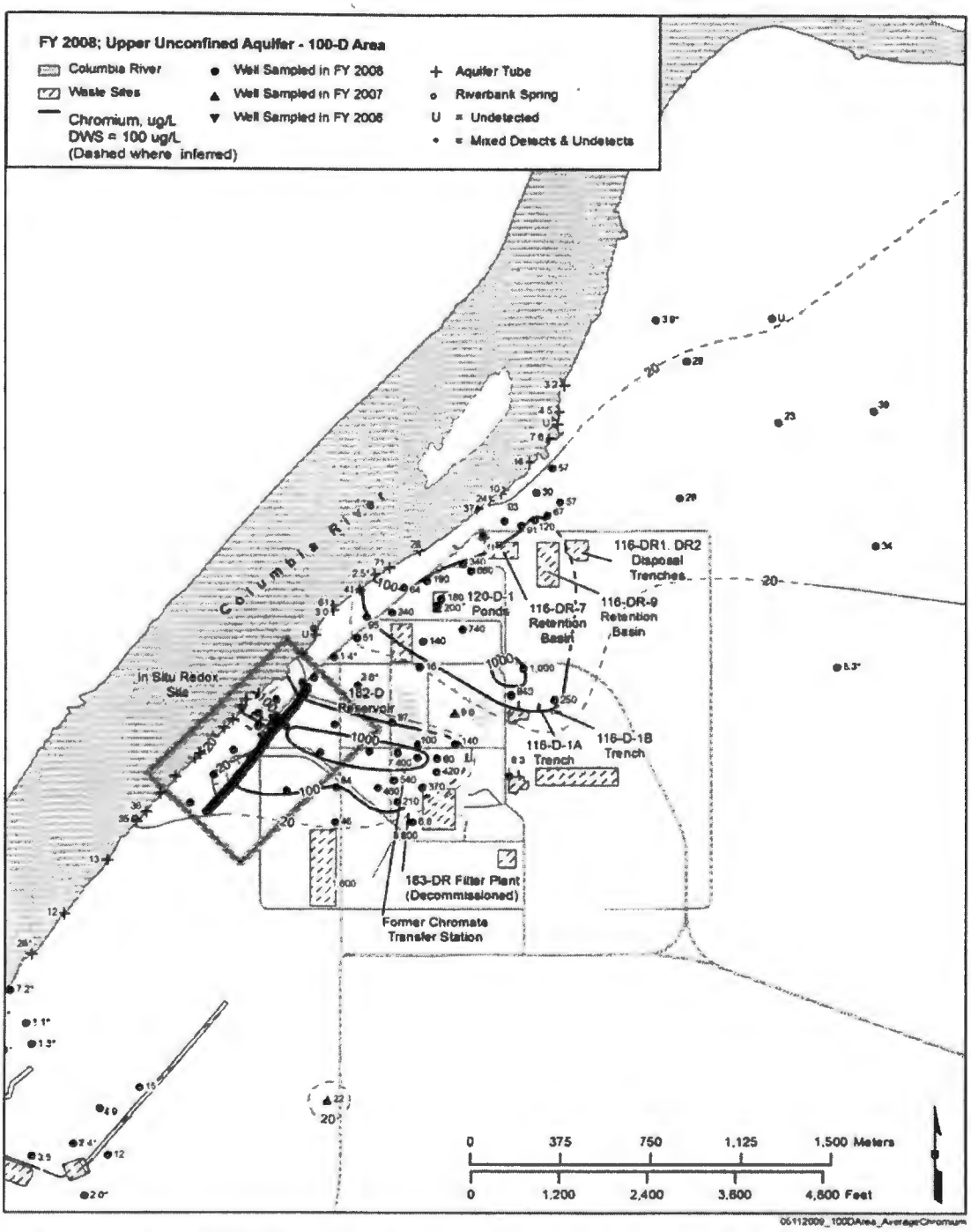

Figure 2-3. Average Hexavalent Chromium Groundwater Contamination in 100-D Area, Fiscal Year 2008
(Modified from DOE/RL-2008-66, Figure 2.5-4)

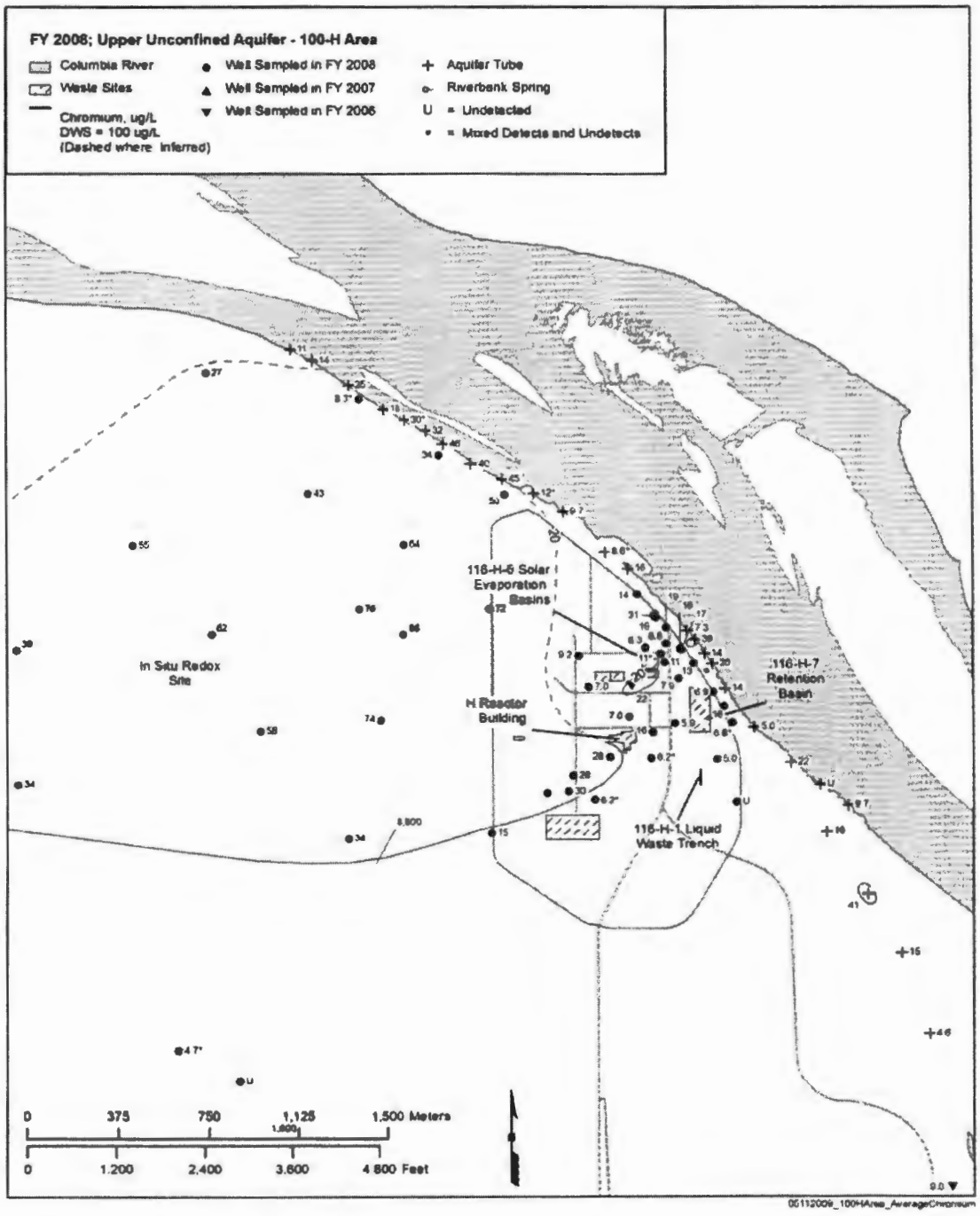

Figure 2-4. Average Hexavalent Chromium Groundwater Contamination in 100-H Area, Fiscal Year 2008
(Modified from DOE/RL-2008-66, Figure 2.5-4)

2.3.4 100-F Area

Only three wells (199-F5-6, 199-F5-44, and 199-F5-46) located within the 100-FR-3 Groundwater OU had hexavalent chromium levels greater than 20 µg/L in fiscal year 2008; the highest concentration was observed in well 199-F5-6 at 49.7 µg/L. These results have produced a relatively small, circular groundwater plume around these wells, north and west of the 116-F-14 retention basins, as depicted in Figure 2-5.

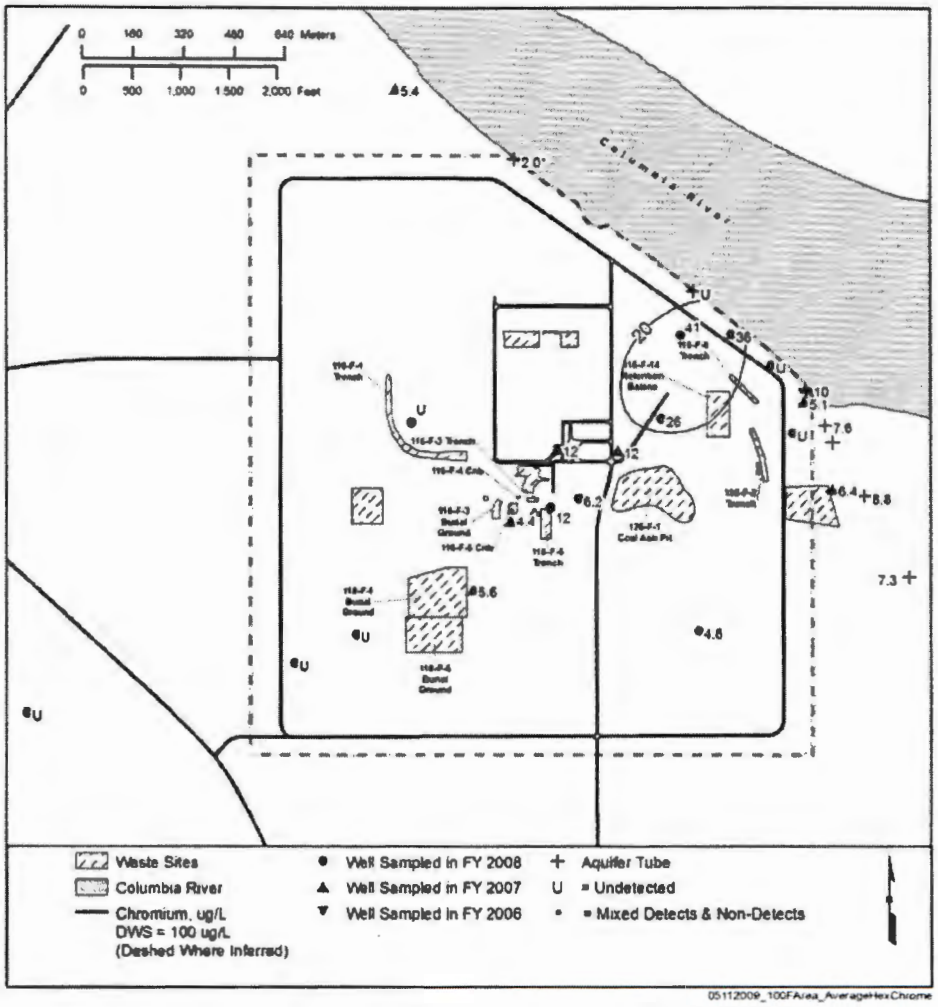

Figure 2-5. Average Hexavalent Chromium Groundwater Contamination in 100-F Area, Fiscal Year 2008 (Source: DOE/RL-2008-66, Figure 2.7-8)

2.3.5 100-K Area

An extensive low-concentration plume of hexavalent chromium-contaminated groundwater (with concentrations generally less than 100 µg/L) is present in the vicinity of the 116-K-2 Trench. This resulted from reactor process water being discharged to the trench during reactor operations. A plume also extends from the southeast side of the water treatment plant basins to the southwest corner of the 105-KE Reactor building with an unknown source. Another plume, with concentrations exceeding 3,000 µg/L, is present in the groundwater near the KW Water Treatment Plant. The plumes within the 100-K Area are presented in Figure 2-6.

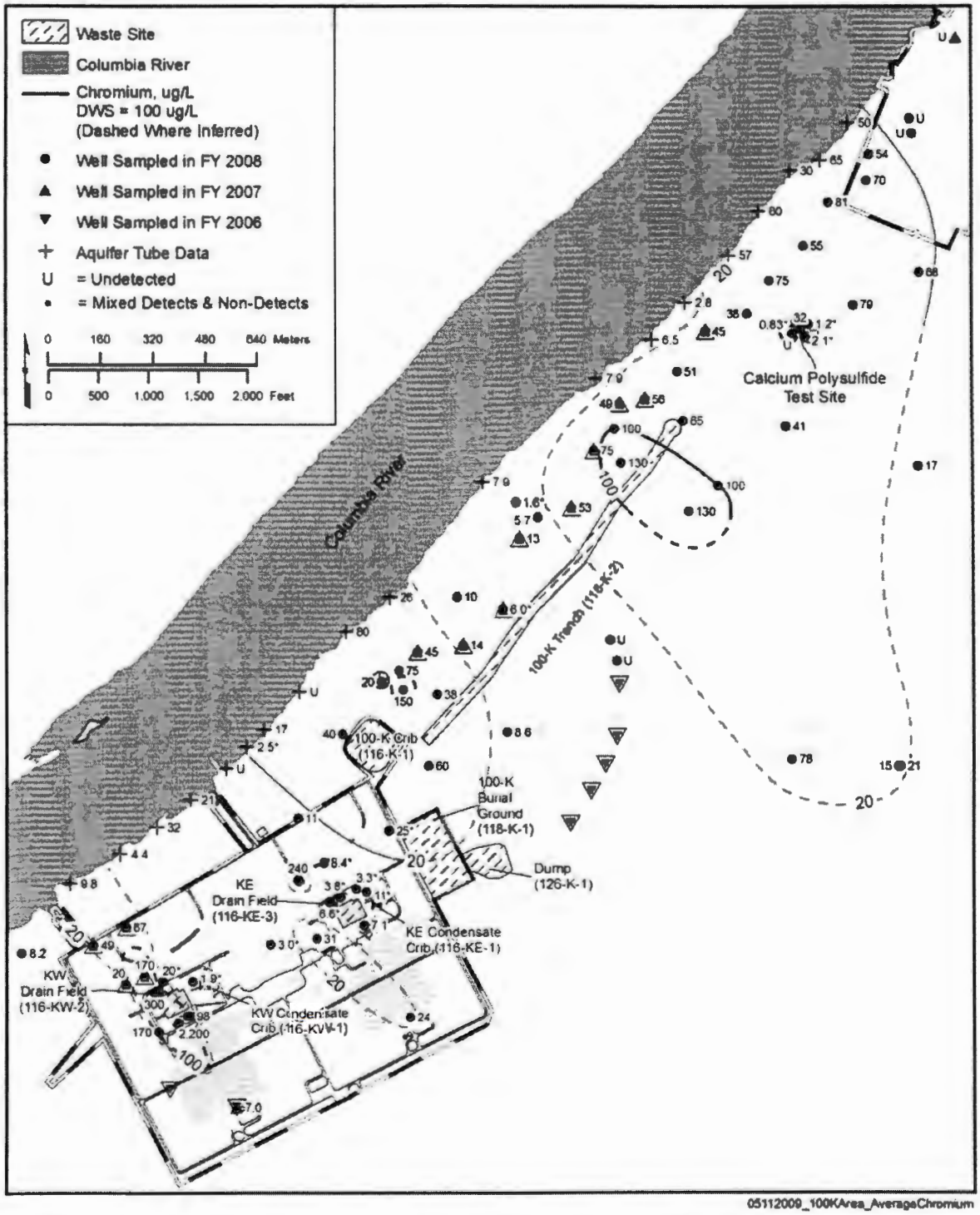

Figure 2-6. Average Hexavalent Chromium Groundwater Contamination in 100-K Area, Fiscal Year 2008
(Source: DOE/RL-2008-66, Figure 2.3-3)

2.3.6 100-N Area

There is no known hexavalent chromium-contaminated groundwater plume within the 100-NR-2 OU; therefore, a hexavalent chromium plume map has not been developed for this area.

2.3.7 Other Areas

The Waste Information Data System database lists one waste site outside of the previously identified areas as also receiving hexavalent chromium waste. This site, the 600-105 Sodium Dichromate Barrel Disposal Landfill, was located in the 100-IU-4 OU along with the underlying 100-HR-3 Groundwater OU. The landfill has been remediated and is not considered a significant source of contamination. In 1993, approximately 5,000 crushed 208 liter (55-gallon) drums were removed from the landfill site. Fifty-seven soil samples were collected in and around the site and analyzed for hexavalent and total chromium. Results indicated that the total chromium concentrations were below the regulatory cleanup level, current at that time, of 100 milligrams per kilogram (mg/kg) (*Washington Administrative Code* [WAC] 173-340-740(2), "Method A Soil Cleanup Levels for Unrestricted Land Use") (DOE/RL-93-64, *Sodium Dichromate Expedited Response Action Assessment*). Well 699-91-46A, which is adjacent to the barrel disposal site, has shown hexavalent chromium concentrations below 10 μg/L since 2006 (Hanford Environmental Information System database).

2.4 Risk Evaluation

Qualitative risk assessments for each of the 100 Area source and groundwater OUs completed prior to this FFS were documented in limited field investigation reports. Collectively, these assessments determined that hexavalent chromium poses a risk to human health and the environment and is a COC requiring remediation.

This remedial action is focused on addressing hexavalent chromium contamination within the 100 Area. The existing interim action RODs for these areas addressed chromium to a limited extent; however, the CERCLA 5-year review identified that additional technologies would be needed to fully address the risk associated with this contaminant.

3. Remedial Action Objectives and Applicable or Relevant and Appropriate Requirements

This chapter identifies RAOs and potential applicable or relevant and appropriate requirements (ARAR) applicable to the 100 Area. The RAOs are used throughout the feasibility study process, first to aid in identifying technologies and later as a basis for evaluating their effectiveness. The objectives for protection of human health and the environment are achieved by reducing or eliminating exposure routes, as well as by reducing contaminant concentrations and mass.

3.1 Remedial Action Objectives

The "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300) (NCP) specifies that RAOs be developed to address COCs, media of concern, potential receptors, and exposure pathways.

A list of RAOs has been prepared for the 100 Area based on existing interim action RODs associated with possible hexavalent chromium contamination (see Table 1-1) for both source and groundwater OUs, as summarized in Table 3-1. The actual RAO wording may vary slightly between the interim action RODs.

3.2 Potential Applicable or Relevant and Appropriate Requirements

The ARARs identification process is based on CERCLA guidance (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*; EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*; and EPA/540/G-89/009, *CERCLA Compliance with Other Laws Manual: Part I*). Section 121 of the CERCLA guidance, requires, in part, that any applicable or relevant and appropriate standard, requirement, criterion, or limitation promulgated under any federal environmental law, or any more stringent state requirement promulgated pursuant to a state environmental statute, be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain on site after completion of remedial action. Section 121(e)(1) specifies that CERCLA response actions conducted on site are subject only to the substantive requirements and standards of other environmental laws and regulations, but not to procedural or administrative requirements. These substantive requirements are the ARARs.

A review was conducted of the ARARs presented in previous decision documents and of the current requirements that may apply to the investigation and remediation of contamination within the 100 Area. This review included the preliminary ARARs that are applicable to the preliminary remedial action alternatives identified in this FFS.

The chemical-specific ARARs likely to be relevant to remediation of the 100 Area include the federal maximum contaminant levels (MCL) for groundwater or surface water that is a current or potential source of drinking water, state cleanup levels for chemical contaminants established in accordance with WAC 173-340, "Model Toxics Control Act – Cleanup" and various other requirements. Potential federal and state ARARs are presented in Tables 3-2 and 3-3, respectively.

Table 3-1. Remedial Action Objectives for the 100 Area

Source
RAO 1 – *Protect human and ecological receptors from exposure to contaminants in soils, structures, and debris by dermal exposure, inhalation, or ingestion of radionuclides, inorganics or organics.* [a,b,c]
RAO 2 – *Control the sources of groundwater contamination to minimize the impacts to groundwater resources, protect the Columbia River from further adverse impacts, and reduce the degree of groundwater cleanup that may be required under future actions.* [a,b,c]
RAO 3 – *To the extent practicable, return soil concentrations to levels that allow for unlimited future use and exposure. Where it is not practicable to remediate to levels that will allow for unrestricted use in all areas, institutional controls and long-term monitoring will be required.* [a,c]
Groundwater
RAO 1 – *Protection of aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.* [d]
RAO 2 – *Protection of human health by preventing exposure to contaminants in the groundwater.* [d]
RAO 3 – *Provide information that will lead to the final remedy.* [d]

NOTES: RAO = remedial action objective

a. EPA/ROD/R10-95/126, *Declaration of the Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.*

b. EPA/541/R-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6 and 200-CW-3 Operable Units (100 Area Remaining Sites), Hanford Site, Benton County, Washington.*

c. EPA/541/R-00/121, *Declaration of the Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.*

d. EPA/541/R-00/121, *Declaration of the Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.*

Groundwater, surface water, and soil cleanup regulations and terrestrial ecological evaluation procedures establish media cleanup standards for nonradioactive and radioactive contaminants. Federal and state air emission standards identify air emission limits and control requirements for any RAs that produce toxic air emissions. 42 USC 6901, et seq., *Resource Conservation and Recovery Act of 1976* (RCRA) land-disposal restrictions will be important standards during the management of wastes generated during RAs. Standards and guidelines for RCRA Corrective Action, as implemented by CERCLA, as well as treatment, storage, and disposal closure performance standards, will be consulted, when applicable, for cleanup criteria and compliance monitoring requirements that apply to treatment, storage, and disposal units and associated solid waste management units that are located within the 100 Area.

Potential location-specific ARARs that have been identified for the 100 Area include those that protect cultural, historic, and Native American sites and artifacts, and those that protect critical habitats of federally endangered and threatened species that may occur within the 100 Area. Action-specific ARARs that could be pertinent to the 100 Area investigation and remediation include state solid and dangerous waste regulations (for management of characterization and remediation wastes and performance standards for waste left in place).

Section 104(d)(4) of CERCLA states that where two or more non-contiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the facilities can be treated as one for purposes of CERCLA response actions.

Consistent with this, the 100 Area and the Environmental Restoration Disposal Facility (ERDF) would be considered to be onsite for purposes of Section 104 of CERCLA, and waste may be transferred between the facilities without requiring a permit. Also consistent with this, the 100 Area and the ERDF would be considered to be onsite for purposes of Section 121 of CERCLA. Response actions conducted in this onsite area are not subject to permitting, but must comply with the substantive requirements identified in the ARARs. Because the facilities are collectively onsite, the offsite transportation rule of 40 CFR 300.440, "Procedures for Planning and Implementing Off-site Response Actions," does not apply.

Table 3-2. Potential Federal Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
Chemical-Specific ARAR				
Safe Drinking Water Act of 1974 (42 USC 300(f)), 40 CFR 141, "National Primary Drinking Water Regulations"				
40 CFR 141.62/ 141.51, "Maximum Contaminant Levels for Inorganic Contaminants/ Maximum Contaminant Level Goals for Inorganic Contaminants"	Establishes MCLs and nonzero MCL goals as criteria for groundwater and surface water that is or may be used for drinking water. The standards and goals are designed to protect human health from adverse effects of inorganic contaminants in the drinking water.	Groundwater in the 100 Area contains contaminants that require remediation. Groundwater is not currently used for drinking water, but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	RA Chromium (total) 100 µg/L MCL	Groundwater remediation and management; for example, discharge of treated groundwater; ISR of groundwater; MNA.
Clean Water Act of 1977 (33 USC 1251, et seq.), 40 CFR 131, "Water Quality Standards"				
40 CFR 131.36, "Designation of Uses"	Establishes numeric water quality criteria for the protection of human health and aquatic organisms. Toxic criteria for the protection of aquatic life are provided in the water quality criteria regulations in 40 CFR 131.36(b)(1), "EPA's Section 304(a) Criteria for Priority Toxic Pollutants," which supersede criteria adopted by the state, except where the state criteria are more stringent than the federal criteria.	Groundwater in the 100 Area contains contaminants that require remediation; groundwater also discharges into the Columbia River.	RA Cr(VI) 15 µg/L freshwater acute 10 µg/L freshwater chronic Cr(III) 457 µg/L freshwater acute 148 µg/L freshwater chronic	Groundwater remediation and management; for example, discharge of treated groundwater; ISR of groundwater; MNA. Based on a preliminary dilution factor of 1:1, per page 43 of EPA/ROD/R10-96/134, groundwater adjacent to the river must meet 20 µg/L or less of Cr(VI) to comply with 10 µg/L in the river.

Table 3-2. Potential Federal Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
Clean Water Act of 1977, 33 USC 1251 et seg, Section 304(a), Information and Guidelines	Section 304 of the *Clean Water Act of 1977* requires publication of water quality values accurately reflecting the latest scientific knowledge.	Groundwater in the 100 Area contains contaminants that require remediation; groundwater also discharges into the Columbia River.	TBC Cr(VI) 16 µg/L freshwater acute 11 µg/L freshwater chronic Cr(III) 475 µg/L freshwater acute (based on hardness of 80 mg/L) 62 µg/L freshwater chronic (based on hardness of 80 mg/L)	Groundwater remediation and management; for example, discharge of treated groundwater; ISR of groundwater; MNA
Clean Air Act of 1977 (42 USC 7401, et seq.), 40 CFR 61, "National Emission Standard for Hazardous Air Pollutants"				
40 CFR 61.01, "Lists of Pollutants and Applicability of Part 61" 40 CFR 61.05, "Prohibited Activities" 40 CFR 61.12, "Compliance with Standards and Maintenance Requirements" 40 CFR 61.14, "Monitoring Requirements"	Provides general requirements for facility operations that emit regulated hazardous air pollutants. The regulation applies to any stationary source for which a standard has been prescribed.	Target analytes detected in soil and groundwater within the 100 Area include constituents that would constitute hazardous air pollutants if released to the air.	A	Soil and groundwater remediation activities such as treatment systems that have the potential to emit regulated hazardous air pollutants subject to this Part.

Table 3-2. Potential Federal Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
Location-Specific ARAR				
Archaeological and Historic Preservation Act of 1960 (16 USC 469aa-mm)				
16 USC 469aa-mm	Requires that remedial actions at the 100 Area waste sites do not cause the loss of any archaeological or historic data. This act mandates preservation of the data and does not require protection of the actual waste site or facility.	Archeological and historic sites have been identified within the 100 Area; therefore, the substantive requirements of this act are applicable to actions that might disturb these sites.	A	Land surface penetrations such as excavation, well installation, or pipeline installation.
National Historic Preservation Act of 1966 (16 USC 470, Section 106)				
16 USC 470, Section 106	Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation and mitigation processes, and consultation with interested parties.	Cultural and historic sites have been identified within the 100 Area; therefore, the substantive requirements of this act are applicable to actions that might disturb these types of sites.	A	Land surface penetrations such as excavation, well installation, or pipeline installation.
Native American Graves Protection and Repatriation Act (25 USC 3001, et seq.)				
25 USC 3001, et seq.	Establishes federal agency responsibility for discovery of human remains, associated and unassociated funerary objects, sacred objects, and items of cultural patrimony.	Substantive requirements of this act are applicable if remains and sacred objects are found during remediation and will require Native American Tribal consultation in the event of discovery.	A	Land surface penetrations such as excavation, well installation, or pipeline installation.
Endangered Species Act of 1973 (16 USC 1531, et seq., Subsection 16 USC 1536(c))				
16 USC 1531, et seq., Subsection 16 USC 1536(c)	Prohibits actions by federal agencies that are likely to jeopardize the continued existence of listed species or to result in the destruction or adverse modification or critical habitat. If remediation is within critical habitat or buffer zones surrounding threatened or endangered species, mitigation measures must be taken to protect the resource.	Substantive requirements of this act are applicable if threatened or endangered species are identified in areas where remedial actions will occur.	A	Any land disturbance such as vehicular traffic (such as by drill rigs) or land surface penetrations. Any activity with the potential for erosion or surface water runoff to the river.

Table 3-2. Potential Federal Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
Action-Specific ARAR				
Safe Drinking Water Act of 1974 (42 USC 300(f)), 40 CFR 144, "Underground Injection Control Program," and 40 CFR 146, "Underground Injection Control Program: Criteria and Standards"				
40 CFR 144, "Underground Injection Control Program" 40 CFR 146, "Underground Injection Control Program: Criteria and Standards"	Establishes criteria and standards for an underground injection control program.	Groundwater in the 100 Area contains contaminants that require remediation; treated groundwater, groundwater or other freshwater amended with reducing agents may be discharged through underground injection wells.	A	Groundwater remedial activities may involve underground injection.

EPA/ROD/R10-96/134, Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington.

NOTES: A = applicable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
Cr(III) = trivalent chromium
Cr(VI) = hexavalent chromium
MNA = monitored natural attenuation
MCL = maximum contaminant level
RA = relevant and appropriate
TBC = to be considered
USC = *United States Code*

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
Chemical-Specific ARAR				

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
"Hazardous Waste Cleanup – Model Toxics Control Act" (RCW 70.105D), WAC 173-340, "Model Toxics Control Act – Cleanup"				
WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards" WAC 173-340-740(1), "General Considerations" WAC 173-340-740(3), "Method B Soil Cleanup Levels for Unrestricted Land Use"	Establishes soil cleanup levels where residential land use represents the reasonable maximum exposure under current and future site use conditions. Cleanup and remediation levels are based on protection of human health and the environment, the location of the site, and other regulations that apply to the site. The standard specifies cleanup goals that implement the strictest federal or state cleanup criteria.	Soil in the 100 Area contains contaminants that require remediation. The human health conceptual exposure model for the 100 Area is considered a rural-residential land use. This land use assumes the reasonable maximum exposure to soil will be unrestricted by future users and therefore corresponds to Method B soil cleanup levels.	RA Method B – Soil Chromium (total) 120,000 mg/kg Cr(III) 120,000 mg/kg Cr(VI) 240 mg/kg Method B – Soil; Protective of Groundwater Chromium (total) 2000 mg/kg [b] Cr(III) 2000 mg/kg [b] Cr(VI) 18.4 mg/kg [a,b]	Soil cleanup actions where concentration of hazardous substances in the soil exceeds Method B cleanup levels at the relevant point of compliance.

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-340-720(4)(b), "Ground Water Cleanup Standards"	Groundwater cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under current and potential future site use conditions. Groundwater cleanup levels are established at concentrations that do not directly or indirectly cause violations of surface water, sediments, soil, or air cleanup standards. The most stringent of either the state or federal drinking water standards are used.	Groundwater in the 100 Area contains contaminants that require remediation; it is not currently used for drinking water but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	RA Method B – Soil; Protective of Surface Water Chromium (total) 2600 mg/kg Cr(III) 2600 mg/kg Cr(VI) 7.7 mg/kg Method B –Ground Water Chromium (total) 100 µg/L Cr(III) 100 µg/L Cr(VI) 48 µg/L	Groundwater remediation and management; for example, discharge of treated groundwater; in situ remediation of groundwater; MNA.
WAC 173-340-730(3)(b)(i), "Surface Water Cleanup Standards"	Surface water cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under current and potential future site use conditions. The most stringent of either the state or federal surface water cleanup standards are used.	Groundwater in the 100 Area contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water.	RA Cr(VI) 15 µg/L freshwater acute 10 µg/L freshwater chronic Cr(III) 457 µg/L freshwater acute (based on hardness of 80 mg/L) 62 µg/L freshwater chronic (based on hardness of 80 mg/L)	Soil, groundwater, and surface water remediation activities that impact surface water.

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-340-750, "Cleanup Standards to Protect Air Quality"	Establishes air cleanup levels where residential land use represents the reasonable maximum exposure under current and future site use conditions. Cleanup and remediation levels are based on protection of human health and the environment, the location of the site, and other regulations that apply to the site. The standard specifies cleanup goals that implement the strictest federal or state cleanup criteria.	Soil in the 100 Area contains contaminants that require remediation. The human-health conceptual exposure model for the 100 Area is considered a rural-residential land use. This land use assumes the reasonable maximum exposure to soil will be unrestricted by future users and therefore corresponds to Method B soil cleanup levels. Air cleanup levels in conjunction with an airborne particulate mass-loading rate can be used to establish a soil cleanup level protective of air quality.	RA Cr(VI) 2.1 mg/kg in soil (based on an airborne mass-loading rate of 0.0001 g/m^3)	Soil remediation activities including containment, RTD, and MNA.
WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures" WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures" WAC 173-340-7494, "Priority Contaminants of Ecological Concern"	Defines goals and procedures for determining whether a release of hazardous substances to soil may pose a threat to the terrestrial environment, characterizes existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil, and establishes site-specific cleanup standards for the protection of terrestrial plants and animals. These values in Table 749-3 are screening levels and not to be considered as cleanup levels. Hanford Site specific values may be calculated in the future.	Soil in the 100 Area contains contaminants that require evaluation to determine if ecological exposures have the potential to cause significant adverse effects.	RA Chromium (total) (Table 749-3) 42 mg/kg soil and plants 67 mg/kg wildlife	Soil remediation activities including containment, RTD, and MNA.

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
Hazardous Waste Management Act of 1976 (RCW 70.105, as amended), WAC 173-303, "Dangerous Waste Regulations"				
WAC 173-303-645(3), "Ground Water Protection Standard"	Provides standards for groundwater protection including background, MCLs, and alternate concentration limits. MCLs are established at the same levels as SDWA MCLs, and, where SDWA MCLs do not exist, health-based alternate concentration limits may be established that are protective of human health and environment.	Some portions of the 100 Area are regulated under state dangerous waste regulations and require groundwater remediation.	RA	Groundwater remediation and management; for example, discharge of treated groundwater, in situ remediation of groundwater, and MNA.
Water Pollution Control Act (RCW 90.48), WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"				
WAC 173-201A-240, "Toxic Substances"	Establishes water quality standards for surface waters of the state of Washington consistent with public health and enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife.	Groundwater in the 100 Area contains contaminants that require remediation and discharges into the Columbia River. The use designations for the Columbia River include aquatic life use (spawning and rearing), primary contact recreation, water supply (drinking, irrigation, and agriculture), and miscellaneous uses (wildlife habitat, harvesting, commerce, boating, and aesthetics).	RA Cr(VI) 15 µg/L freshwater acute 10 µg/L freshwater chronic Cr(III) 457 µg/L freshwater acute (based on hardness of 80 mg/L) 148 µg/L freshwater acute (based on hardness of 80 mg/L)	Soil, groundwater, and surface water remediation activities that impact surface water.

Table 3-3. Potential State of Washington Applicable or Relevant and Appropriate Requirements

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
Action-Specific ARAR				
Hazardous Waste Management Act of 1976 (RCW 70.105, as amended), WAC 173-303, "Dangerous Waste Regulations"				
WAC 173-303-140, "Land Disposal Restrictions"	Establishes treatment requirements and disposal prohibitions for land disposal of dangerous waste and incorporates by reference [in WAC 173-303-140(2)(a), "Applicability"] the federal land disposal restrictions of 40 CFR 268, "Land Disposal Restrictions," that are applicable to solid waste that is designated as dangerous or mixed waste in accordance with WAC 173-303-070(3), "Designation Procedures."	Onsite land disposal may be a selected remedy for 100 Area dangerous waste and debris.	A	Investigative and remediation wastes destined for onsite land disposal.

NOTES: Table 749-3 is found in WAC 173-340-900, "Tables."

A = applicable.
ARAR = applicable or relevant and appropriate requirement.
Cr(III) = trivalent chromium.
Cr(VI) = hexavalent chromium.
MCL = maximum contaminant level.
MNA = monitored natural attenuation.
RA = relevant and appropriate.
RCW = *Revised Code of Washington.*
RTD = removal, treatment, and disposal.
SDWA = *Safe Drinking Water Act of 1974.*
WAC = *Washington Administrative Code.*

a. This value is based on use of the three-phase partitioning model (WAC 173-340-747(4), "Deriving Soil Concentrations for Ground Water Protection") and a Kd of 19 liters per kilogram. Hanford Site specific fate and transport modeling and/or leach testing may be used to develop more accurate cleanup levels.

b. These values are based on the three-phase partitioning model (WAC 173-340-747(4)). Hanford Site specific fate and transport modeling and/or leach testing may be used to develop more accurate cleanup levels.

4. Technology Screening and Alternative Development Process

This section describes the basis for, and the results of, the RPO technology screening and alternative development process conducted in 2008 to facilitate remediation of the 100-D Area within the 100-HR-3 Groundwater OU. This effort was conducted based on the realization that the existing interim actions for the 100-D Area were not working as effectively or as quickly as originally anticipated and that the existing remedial action alternatives may require augmentation with additional actions in order to meet the groundwater and river protection RAOs in a more timely and cost-effective fashion. It was anticipated that the results of the technology screening and alternative development process for the 100-D Area would ultimately be applicable to hexavalent chromium remediation efforts for the 100-HR-3 OU as a whole, and for other sites (e.g., 100-B/C) in the 100 Area.

4.1 Hexavalent Chromium Remediation Technology Exchange Workshop

A hexavalent chromium treatment technology exchange meeting was held on April 8-10, 2008, in Richland, Washington. A follow-on workshop that focused on hexavalent chromium remediation in the 100-B/C Area was held in November 12-13, 2008. Participants at the April 8-10, 2008 workshop included regulators, consultants, and technical experts. The primary objectives of this meeting were to enable U.S. Department of Energy, Richland Operations Office (DOE-RL) and Fluor Hanford staff to gather information regarding the remediation of hexavalent chromium-contaminated soil and groundwater and to identify technologies that would facilitate the remediation of hexavalent chromium in the 100-D Area (Figure 2-3) and ultimately for the 100 Area OUs as a whole (Figure 2-1). A panel of experts (primarily consultants to private industry and one scientist from DOE's Pantex Plant) convened to share their expertise in chromium chemistry and biochemistry and in situ and ex situ treatment approaches, and to present case studies of hexavalent chromium treatment technologies.

The meeting included (1) presentations by DOE, Fluor Hanford, and Pacific Northwest National Laboratory on Hanford Site activities related to hexavalent chromium remediation of groundwater; (2) a field trip to the 100 Area; (3) experts' presentations; and (4) an informal discussion. Geomatrix Consultants, Inc., 2008, *Chromium Treatment Technology Information Exchange for Remediation of Chromium in Groundwater at the Department of Energy Hanford Site,* summarizes the presentations at the meeting. A brief summary of the key findings of this meeting is presented below.

<u>The fate and transport of chromium</u> in groundwater and soil is predominantly controlled by oxidation-reduction processes. Chromium occurs in either the mobile +6 (hexavalent) oxidation state or the less toxic and essentially immobile +3 (trivalent) oxidation state. Many treatment technologies are based on the conversion (reduction) of the hexavalent form to the less mobile and less toxic trivalent form. A number of chemical reductants are available to accomplish this conversion. In addition, microorganisms can accomplish this conversion via anaerobic bioreduction. Chemical mechanisms are believed to be much more rapid than biological mechanisms. However, when considering the reactions for biological versus chemical treatment, it appears that the biological reduction is more efficient. This efficiency may relate to overall treatment system cost, and as such, would be important during remedial action alternative evaluation.

<u>Ex situ technologies</u> for groundwater treatment include chemical reduction using sulfur-containing compounds, coagulation/filtration, ion exchange, membrane treatment (nanofiltration, reverse osmosis, and ultrafiltration), lime softening, electrochemical precipitation using ferrous iron, electrodialysis reversal/electro-coagulation, adsorption/chelation, zero-valent iron, and biological treatment. Technologies were described in terms of performance and waste generation. Selection of ex situ treatment technologies must include consideration of a number of factors, including discharge options, groundwater

ownership, waste generation, schedule, longevity of the treatment system, permitting requirements, and cost, among other factors.

In situ reduction technologies are the primary in situ technologies used for the remediation of hexavalent chromium in soil and groundwater. The two keys to successful remediation of hexavalent chromium using ISR methods are (1) selection of the appropriate amendment based on the aquifer geochemistry and mineralogy, and (2) selection of the appropriate reagent delivery method based on site hydrogeologic conditions. Case studies presented at the meeting indicated that ISR can be utilized for full-scale treatment of hexavalent chromium in soil or groundwater and that the greatest challenge in applying ISR is in achieving adequate distribution of the amendment in the subsurface (Geomatrix Consultants, Inc., 2008).

The evaluation of available hexavalent chromium treatment technologies performed for the 100-D Area was used as a starting point for a similar evaluation performed for hexavalent chromium contamination at the 100-B/C Area at a workshop held November 12-13, 2008. The workshop was attended by individuals from DOE-RL; Ecology; EPA; CH2M HILL Plateau Remediation Company; Pacific Northwest National Laboratory; Washington Closure Hanford, LLC; and others. Technologies that were evaluated and concluded to be non-viable methodologies at 100-D Area were also generally assumed to be non-applicable for use at the 100-B/C Area. The only exception to this were vadose zone-only technologies that for the 100-D Area were determined to be unsuitable because the hexavalent chromium may be too deep in the vadose zone and undesirable subsurface conditions including cobbles and boulders in the 100-D Area. Technologies, such as deep soil mixing, were carried forward for further evaluation at the 100-B/C Area. A summary of the November 12-13, 2008, workshop is provided in Appendix A.

4.2 100-D RPO Technology Screening and Alternative Development Process

As part of the RPO process for the 100-D Area, a series of three meetings were held in Richland, Washington, to identify and evaluate remediation technologies with the potential to be used to optimize and accelerate soil and groundwater remediation in the 100-D Area. The preliminary technology screening meeting for the 100-D Area was held on June 4-6, 2008. The evaluation process, results, and conclusions generated from this meeting are described in detail in SGW-38338, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document*. Two additional meetings were held in Richland, Washington on October 3-4, and October 17, 2008, to review and refine the results obtained from the preliminary evaluation completed during the June 2008 meeting. These meetings were variously attended by a diverse group of individuals from DOE-RL; EPA; Ecology; Fluor Hanford; CH2M HILL Plateau Remediation Company; CH2M HILL; Washington Closure Hanford, LLC; the DOE-RL Assistant Manager for the Central Plateau; Pacific Northwest National Laboratory; Alexco Resource Corporation; S.S. Papadopoulos and Associates, Inc.; and Vista Engineering Technologies, LLC. The process and results that culminated from these meetings are summarized below.

In order to sufficiently assess and select appropriate technologies, working remedial goals, including proposed Tri-Party Agreement milestones for accelerated clean up, were developed and carried forward throughout the RPO screening process. These informal working remedial goals were believed to meet or exceed the protectiveness of the existing interim action ROD RAOs and were intended to serve as a basis for evaluating potential remediation technologies and to serve as a baseline of comparison for the development of potential remediation alternatives.

The evaluation of technologies was conducted in accordance with EPA guidance. This was performed as an iterative process in the June and October meetings, consisting of identifying technologies (including those already part of the existing 100 Area remedial action alternatives) with the potential to contribute to

the attainment of the working remedial goals by addressing one or more of the following targets (1) river protection; (2) vadose zone sources; and (3) source area and downgradient groundwater.

The working remedial goals that were developed for the RPO process are listed below.

1. Provide immediate protection of the aquatic receptors in the Columbia River. The meeting attendees concurred that the term "immediate protection" refers to the goal that all applicable standards are to be met in the river by 2012.
    a. This includes meeting the standard of 10 μg/L for hexavalent chromium in the river. The regulatory agencies have determined that a 1:1 mixing factor is appropriate at the Hanford Site (EPA/ROD/R10-96/134); therefore, groundwater adjacent to the river (which will seep into the river and become mixed with river water) may contain no more than 20 μg/L of hexavalent chromium.
    b. This also includes meeting a standard of at least 6 mg/L of dissolved oxygen in groundwater adjacent to the river.
    c. All other groundwater parameters will need to be sufficiently protective of the river such that the river water complies with all other applicable requirements.
2. Achieve remediation goals for groundwater by 2020.
    a. This includes meeting a standard for hexavalent chromium in groundwater some distance upgradient of the river (values for the standard and the distance will be determined by modeling), to be protective of the river according to the standards above.
    b. This also includes meeting the standards of 48 μg/L for hexavalent chromium and 100 μg/L for total chromium throughout the plume.
    c. Meeting the goals for hexavalent and total chromium will require continued management of the vadose zone in order to restore and protect groundwater.

A detailed summary of the technology identification and selection process will be documented in a technical memorandum as part of the 2009 100-HR-3 RPO effort.

4.2.1 Final Technology Screening Results

This iterative evaluation of technologies culminated in the development of technology screening tables (Tables 4-1, 4-2, and 4-3). These tables summarize the assessment process and identify the candidate technologies as retained, conditionally retained, or rejected as developed for the river objective, groundwater, and vadose zone source area remediation, respectively. Although the source area groundwater and downgradient groundwater technologies were analyzed separately, the conclusions drawn for both were essentially identical. For simplicity and convenience, the results for source area groundwater and downgradient groundwater have been combined and presented in Table 4-2 under the general heading of "technologies for groundwater." The information presented in these tables reflect the current state of knowledge for hexavalent chromium remediation and the results could change with time as certain technologies are further developed and as additional technology performance information becomes available.

The screening tables (Tables 4-1, 4-2, and 4-3) have been structured to present the various levels and types of information presented at the various meetings as follows: general response actions are shown in Column 1, remedial technologies relevant to each general response action are presented in Column 2, and process options for each remedial technologies are presented in Column 3. The process options are described in Column 4 and are evaluated with respect to effectiveness, implementability, and cost in

Columns 5, 6, and 7, respectively. The eighth and final column summarizes the reasons a given process option was retained, conditionally retained, or rejected.

Those process options identified in the tables as "retained" have favorable effectiveness, implementability, and cost ratings. Although not considered a viable action, "No Further Action" was retained in each of the four categories to comply with the NCP. Process options were identified as "conditionally retained" if they were seen as promising technologies but require further testing, or if there was no clear application at the site at the current time. The "conditionally retained" technologies are considered worthy of re-evaluation as the development stage of the technology progresses or if ongoing site characterization efforts identify sites or settings in the 100-HR-3 OU or in other parts of the 100 Area where the application of a conditionally retained technology would be effective. In general, "rejected" process options generally have low or unproven effectiveness, implementability issues, or high cost.

4.2.1.1 Summary of River Objective Screening Results

Retained process options to address the river objective include: no further action, monitored natural attenuation (MNA), expand extraction systems at the river, ion exchange, expand injection of treated water near the river, ISRM barrier maintenance/amendment, and hydraulic barrier (mounding) adjacent to the river. Phytoremediation and slurry wall are conditionally retained. Rejected process options to address the river objective include: bioreactor treatment and chemical and biological barriers.

4.2.1.2 Summary of Groundwater Screening Results

Retained process options to address groundwater include: no further action, MNA, expand extraction systems, ion exchange, groundwater injection, surface reinfiltration with chemical or biological amendments, reactive chemical or biological barrier, in situ biological or chemical treatment, in situ treatment using combined biological and chemical substrates, and hydraulic containment. Electrocoagulation, sub-grade bioreactors, and slurry wall are conditionally retained. Rejected process options to address groundwater include: current extraction system, ferrous reduction, wetland treatment, ex situ bioreactor treatment, phytoremediation, reverse osmosis, and water flushing.

4.2.1.3 Summary of Vadose Zone Screening Results

Retained process options to address vadose zone sources include no further action, MNA, standard excavation, deep excavation, chemical infiltration, combined chemical/biological infiltration, and biological infiltration. Jet grouting with reactive materials, foam delivery of calcium polysulfide, and water flushing are conditionally retained. Rejected technologies to address vadose zone sources include deep soil mixing, in situ gaseous reduction with chemical or biological substrate, surface barrier, and vegetative cap.

Table 4-1. Screening Table – Technologies for the River Objective

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
				oxygenation.			
In Situ Treatment	Chemical Treatment (continued)	ISRM Barrier Maintenance/ Amendment	Inject additional sodium dithionite or nano-zero-valent iron to in-fill treatment zone gaps in the existing ISRM barrier.	LOW to MODERATE Ongoing ISRM barrier maintenance may decrease the amount of Cr(VI) breakthrough to the river.	HIGH	Expected HIGH capital and O&M costs.	Retained, since already in place. Testing of methods for maintenance and amendment of existing ISRM barrier is already occurring at the site. May be a component of a remedy.
	Biological Treatment	Biological Barrier/Air Sparging	Subsurface delivery and recirculation of electron donors along cross-gradient row near shoreline. Cr(VI) is passively removed as groundwater moves through the treatment zone barriers. Air sparging will oxygenate through-flowing groundwater prior to discharge to the river.	HIGH Effective if barrier treatment zone conditions are maintained. Biological reductants are activated by microbial activity, therefore reactive strength is maintained over relatively longer distances compared to reactive chemical barriers. Air sparging is a demonstrated technology that has been used at a large number of sites, although rarely employed solely for groundwater oxygenation.	LOW Well spacing required to achieve desirable air sparge oxygenation of groundwater may be cost-prohibitive (6 m [20-ft] spacing along 1,830 m [6,000 ft] of shoreline).	HIGH capital cost, MODERATE O&M cost.	Not retained. Effective implementation of air sparge component is difficult and cost-prohibitive.
		Phytoremediation	Use of plants and their associated rhizospheric microorganisms to remove, reduce/degrade, or contain chemical contaminants in groundwater.	LOW to MODERATE Process would be used as a polishing step at the shoreline in combination with another remedy. Depth to groundwater upgradient of river may limit effectiveness. Additional research/pilot testing is required to verify effectiveness for site conditions. Less effective in winter.	LOW to MODERATE Access to Lower Terrace shoreline is limited. Requires time for root systems to grow and establish.	HIGH capital cost, LOW O&M cost.	Conditionally retained for future consideration. Possible use as a polishing step in combination with another remedy if river shoreline is suitable and accessible for planting.
Containment	Barrier	Form Hydraulic Plume Barrier (Mounding)	Injection of river water or groundwater parallel to the river. Manages hydraulic gradients to create conditions (landward gradients) throughout the year that mimic natural conditions of low plume discharge encountered during periods of high river stage. Barrier comprising closely spaced injection wells, infiltration trenches, and/or horizontal wells. Source of water from existing permitted Columbia River supply and/or groundwater.	HIGH Provides early protection of the river, and enhances hydraulic performance of plume pump-and-treat remedies. Injected water also mixes with/oxygenates contaminated water downgradient of other in situ plume treatment.	HIGH Can be accomplished using practically achievable injection rates. Injection only required 2-3 seasons (6-9 months). Infiltration trenches will be more cost-effective than injection/horizontal wells but could cause seepage faces to develop along river cliff faces.	MODERATE capital cost, LOW to MODERATE O&M cost.	Retained. Can be coordinated with other remediation technologies.

Table 4-1. Screening Table – Technologies for the River Objective

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
Containment	Barrier	Containing Wall (e.g., slurry wall)	Slurry wall barriers consist of a vertical trench excavated perpendicular to the groundwater flow direction, filled with bentonite slurry to support the trench, and subsequently backfilled with a mixture of low permeability material.	MODERATE Effectiveness is dependent on the continuity of the wall and the ability to key into the Ringold Upper Mud, which will be difficult to achieve because of depth from Upper Terrace. This technology requires groundwater extraction to control groundwater pressures from building up behind the barrier causing groundwater to flow under, over, or around the barrier.	LOW Installation of slurry wall from the Upper Terrace to key into the Ringold Upper Mud is cost-prohibitive and would be challenging in the gravel/cobble formation present. Access is limited at Lower Terrace for installing slurry wall.	HIGH capital cost, LOW to MODERATE O&M cost.	Conditionally retained for future special applications consideration.

NOTES: Gray shading denotes rejected process option. Yellow shading denotes conditionally retained process option.

Cr(VI) = hexavalent chromium
ft = feet
H&S = health and safety
ISRM = in situ redox manipulation
m = meter
MNA = monitored natural attenuation
NCP = National Contingency Plan
O&M = operations and maintenance
RAO = remedial action objective

This page intentionally left blank.

Table 4-2. Screening Table – Technologies for Groundwater

General Response Actions		Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
No Action		No Action	No Action	No remedial actions taken.	LOW	HIGH	LOW.	Retained per the NCP.
MNA		MNA	MNA	Relies on natural attenuation processes such as biological and chemical reduction, adsorption, dilution, and dispersion to remediate site.	LOW to MODERATE MNA alone is not likely to achieve RAOs within a time frame that is acceptable. MNA maybe used in conjunction with active remediation measures.	HIGH	LOW capital and O&M cost.	Retained as a possible component of alternatives with active remediation.
Pump-and-Treat	Collection	Extraction	Expand Extraction Systems	Install additional extraction wells to existing extraction network to control plume migration and remove dissolved Cr(VI) mass.	MODERATE Pump-and-treat is a proven treatment technology for Cr(VI) in groundwater. Expanded pump-and-treat would increase coverage of hot spots and the plume. May not protect the river by 2012, and would not address continuing vadose sources. Uncertainty regarding the ability to achieve the RAOs in a timely manner.	HIGH Compatible with existing infrastructure, and can be designed to work with other remedial technologies.	MODERATE to HIGH capital and O&M costs for well field expansion and increased treatment capacity.	Retained. Expansion of extraction systems is currently under way.
			Current Extraction System	Continued operation of existing groundwater extraction wells.	MODERATE Pump-and-treat is a proven treatment technology for Cr(VI) in groundwater. Existing well field does not capture plume sufficiently to meet RAOs.	HIGH System already in place, but existing well field is not designed to integrate with any new additional treatment technologies.	LOW capital cost for optimizing current well field.	Not retained. Will not meet plume RAOs in a timely fashion.
	Treatment	Chemical Treatment	Ion Exchange	Ions from the aqueous phase are removed by exchange with innocuous ions on the exchange medium.	HIGH Effective for Cr(VI) treatment.	HIGH Vendors and equipment readily available. Currently used at the site.	HIGH capital cost for expansion, MODERATE O&M cost.	Retained. Currently used at the site.
			Electrocoagulation	Electricity is passed through metal plates to reduce the Cr(VI) and precipitate it from solution. Relies on electrochemical generation of ferrous iron. The resulting sludge is settled in a clarifier prior to disposal.	MODERATE Not widely used for Cr(VI) removal. Pilot testing at the site had challenges.	MODERATE Additional development and testing would be required.	MODERATE to HIGH capital cost, HIGH O&M cost.	Conditionally retained for future consideration.
			Ferrous Reduction	Dissolved contaminants are reduced and transformed into an insoluble solid, which is removal by sedimentation and filtration. Usually uses chemical reduction, addition of a chemical precipitant, and flocculation.	HIGH Effective for Cr(VI) treatment.	HIGH Vendors and equipment readily available.	MODERATE to HIGH capital cost, LOW to MODERATE O&M cost.	Rejected in favor of ion exchange to be consistent with other water treatment plants at the Hanford Site.
		Biological Treatment	Wetlands	Groundwater is discharged to a constructed wetland where Cr(VI) is biologically reduced, or is taken up by plants and algae.	MODERATE to HIGH Additional research/pilot testing is required to verify effectiveness for site conditions.	MODERATE May require large surface area for extended period of time.	MODERATE capital cost, LOW O&M cost.	Not retained. Technology is not well demonstrated and may not have flexibility to adapt to increased extraction rates.
			Sub-Grade Bioreactors	Groundwater is amended with electron donor (optional) and injected into a shallow infiltration trench backfilled with organic media (wood chips or mulch). Cr(VI) is biologically reduced as it percolates through the trench and prior to infiltrating back to groundwater.	MODERATE to HIGH Additional research/pilot testing is required to verify effectiveness for site conditions.	HIGH Trenching is easy to implement and trench backfill media is simple to place/replace. Piping can be incorporated into the design to facilitate future delivery of liquid carbon sources (e.g., vegetable oil).	LOW capital and O&M costs.	Conditionally retained pending results of pilot studies.

Table 4-2. Screening Table – Technologies for Groundwater

General Response Actions		Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
	Treatment	Biological Treatment	Ex Situ Bioreactors	Groundwater is amended with electron donor (carbon source) and passes through a matrix (fixed bed, fluidized bed, or membranes) with microbial films, where Cr(VI) is biologically reduced. Effluent is oxygenated, filtered, and amended prior to recharge back into the ground.	MODERATE to HIGH Bioreactors commonly used for nitrate removal, but less commonly for Cr(VI) reduction. No site experience.	HIGH Vendors and equipment readily available.	MODERATE to HIGH capital cost, MODERATE O&M cost.	Not retained at this time in favor of more established aboveground chemical and physical treatment options.
			Phytoremediation	Use of plants and their associated rhizospheric microorganisms to remove, reduce/degrade, or contain chemical contaminants in soil or groundwater.	MODERATE to HIGH Additional research/pilot testing is required to verify effectiveness for site conditions.	LOW to MODERATE Because of large depth to the water table, the plants would have to be irrigated with extracted groundwater. Requires large surface area for plants.	LOW capital and O&M costs.	Not retained. Technology is not well demonstrated and may not have flexibility to adapt to increased extraction rates.
		Physical Treatment	Reverse Osmosis	Water pressure is used to force water molecules through a very fine membrane, leaving the contaminants behind. Purified water is collected from the "clean" or "permeate" side of the membrane, and water containing the concentrated contaminants is disposed of.	LOW Not appropriate for primary treatment of Cr(VI), but is an effective secondary process for the treatment of the reduced chromium.	HIGH Vendors and equipment readily available.	HIGH capital and O&M costs.	Not retained. More effective and less expensive options are available.
Pump-and-Treat	Discharge	Onsite Discharge	Groundwater Injection Wells	Treated groundwater is injected into onsite wells.	HIGH Will enhance contaminant flushing, hydraulic control and capture of plume.	HIGH Readily implementable at the site, currently used in existing pump-and-treat system. The wells may be subject to clogging due to the buildup of chemical precipitates or microbial biofouling.	MODERATE capital cost, LOW to MODERATE O&M cost.	Retained. Currently in use at the site.
			Surface Reinfiltration with Chemical Amendments	Groundwater is amended with chemical reductant (e.g., calcium polysulfide) and then applied to ground surface at an application rate substantially below what would create saturation.	HIGH Chemical reductants are instantly reactive with injected groundwater. Residual reactive strength will not be established a significant distance from injection point.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize Cr(VI) (in first pore volume) toward groundwater. Handling chemical reductants (e.g., calcium polysulfide) is an H&S concern.	LOW to MODERATE capital cost, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.
			Surface Reinfiltration with Biological Amendments	Groundwater is amended with biological carbon source and then applied at the surface through various infiltration methods, to treat Cr(VI) within vadose zone and underlying groundwater.	HIGH Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reductive capacity will be established at depth.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize Cr(VI) (in first pore volume) toward groundwater.	LOW to MODERATE capital cost, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.

Table 4-2. Screening Table – Technologies for Groundwater

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
In Situ Treatment	Chemical Treatment	In Situ Chemical Treatment	Subsurface delivery and recirculation of chemical reductants within plume to stimulate reduction of Cr(VI).	HIGH Along with in situ biological treatment and in situ treatment using combined biological and chemical substrates, the most rapid cleanup approach under consideration. Chemical reductants instantly reactive, thus strongest reduction achieved at injection well, requiring higher loading to maintain reactive strength at distance or tighter spacing of injection wells. Recirculation approach overcomes heterogeneity issues, increases size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface. Less sensitive to rebound from residual sources because of residual reactive phase.	MODERATE to HIGH Recirculation will likely be limited by extraction rate – addition of fresh water can be used to enhance coverage around injection wells. Broad zones of secondary byproduct generation within treatment area may occur – requires re-oxygenation of groundwater prior to discharge to the river. H&S issues with handling calcium polysulfide.	MODERATE to HIGH capital cost depending on number and type of wells, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.
		Reactive Chemical Barrier	Subsurface delivery and recirculation of chemical reductants along cross-gradient rows transecting plume. Cr(VI) is passively removed as groundwater moves through the treatment zone barriers.	MODERATE to HIGH Effective if barrier treatment zone conditions are maintained. Effectiveness of barrier orientation is sensitive to changing plume shape. Chemical reductants instantly reactive, thus strongest reduction achieved at injection well, requiring higher loading to maintain reactive strength at distance or tighter spacing of injection wells.	MODERATE to HIGH Can be implemented with injection wells or recirculation dipole wells - latter option reduces number of wells required and is more cost-effective. Higher chemical loading or tighter injection well spacing needed due to chemical reactivity will increase costs relative to biological barriers. Broad zones of secondary byproduct generation within treatment area may occur – requires re-oxygenation of groundwater prior to discharge to the river. H&S issues for calcium polysulfide.	MODERATE to HIGH capital cost depending on number and type of wells, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.
	Biological Treatment	Reactive Biological Barrier	Subsurface delivery and recirculation of electron donors along cross-gradient rows transecting plume. Cr(VI) is passively removed as groundwater moves through the treatment zone barriers.	MODERATE to HIGH Effective if barrier treatment zone conditions are maintained. Effectiveness of barrier orientation is sensitive to changing plume shape. Biological reductants are activated by microbial activity, therefore reactive strength is maintained over relatively longer distances compared to reactive chemical barrier.	HIGH Can be implemented with injection wells or recirculation dipole wells – latter option reduces number of wells required and is more cost-effective. Broad zones of secondary byproduct generation within treatment area may occur – requires re-oxygenation of groundwater prior to discharge to the river.	MODERATE to HIGH capital cost depending on number and type of wells, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.
		In Situ Biological Treatment	Subsurface delivery and recirculation of electron donors within plume to stimulate anaerobic bioreduction of Cr(VI).	HIGH Along with in situ chemical treatment and in situ treatment using combined biological and chemical substrates, the most rapid cleanup approach under consideration. Biological reductants are activated by microbial activity, therefore reactive strength is maintained over relatively longer distances compared to in situ chemical treatment. Recirculation approach overcomes heterogeneity issues, increases size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface. Less sensitive to rebound from residual sources because of residual reactive phase.	HIGH Recirculation will likely be limited by extraction rate – addition of fresh water can be used to enhance coverage around injection wells. Broad zones of secondary byproduct generation within treatment area may occur – requires reoxygenation of groundwater prior to discharge to the river.	MODERATE to HIGH capital cost depending on number and type of wells, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.

Table 4-2. Screening Table – Technologies for Groundwater

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
In Situ Treatment	Chemical/ Biological Treatment	In Situ Treatment using Combined Biological and Chemical Substrates	Subsurface delivery and recirculation of both chemical reductants and electron donors within plume to stimulate chemical and anaerobic biological reduction of Cr(VI).	HIGH Along with in situ biological treatment and in situ chemical treatment, the most rapid cleanup approach under consideration. Chemical reductants will be used to treat smaller hot spot areas, while biological reductants will be used to sustain treatment over larger dilute plume areas. Recirculation approach overcomes heterogeneity issues, increases size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface. Less sensitive to rebound from residual sources because of residual reactive phase.	MODERATE to HIGH Recirculation will likely be limited by extraction rate – addition of fresh water can be used to enhance coverage around injection wells. Broad zones of secondary byproduct generation within treatment area may occur – requires re-oxygenation of groundwater prior to discharge to the river. H&S issues with handling calcium polysulfide.	MODERATE to HIGH capital cost depending on number and type of wells, MODERATE O&M cost.	Retained. If this is applied near the river, groundwater re-oxygenation may be needed.
	Physical Treatment	Water Flushing	Clean/treated water (applied to the ground surface or in infiltration trenches) to flush out Cr(VI) in vadose zone and groundwater hot spots to expedite remediation of plumes.	MODERATE Water follows source release pathways, but Cr(VI) that remains in adsorbed phase will not be reduced. Cr(VI) is diluted and mobilized, not remediated.	HIGH Drip irrigation system or trenches are simple to install and accessible for O&M.	LOW to MODERATE capital cost, LOW O&M cost.	Not Retained. Similar process with biological/chemical amendments more effective.
Containment and Isolation	Containment	Containing Wall (e.g., slurry wall)	Slurry wall barriers consist of a vertical trench excavated perpendicular to the groundwater flow direction, filled with bentonite slurry to support the trench, and subsequently backfilled with a mixture of low permeability material.	MODERATE Effectiveness is dependent on the continuity of the wall and the ability to key into the Ringold Upper Mud, which will be difficult to achieve because of depth. Does not reduce toxicity or volume of contaminants by itself. This technology requires groundwater extraction to control groundwater pressures from building up behind the barrier and potentially damaging the barrier or causing groundwater to flow under, over, or around the barrier. The barrier has the potential to degrade or deteriorate over time.	LOW Installation of slurry wall to key into the Ringold Upper Mud is cost-prohibitive.	HIGH capital cost, LOW to MODERATE O&M cost.	Conditionally retained for future special applications consideration.
		Hydraulic Containment	Install extraction wells along downgradient edge of plumes to control migration of Cr(VI) to the river and/or use strategically placed injection wells to create a hydraulic mound.	MODERATE Extraction will control plume migration to the river, but upgradient plumes and hot spots are left untreated.	HIGH Compatible with existing infrastructure, and can be designed to work with other remedial technologies.	MODERATE to HIGH capital and O&M costs for well field expansion and increased treatment capacity.	Retained as possible component of remedy.

NOTES: Gray shading denotes rejected process option. Yellow shading denotes conditionally retained process option.

Cr(VI) = hexavalent chromium
H&S = health and safety
MNA = monitored natural attenuation
NCP = National Contingency Plan
O&M = operations and maintenance
RAO = remedial action objective

Table 4-3. Screening Table – Technologies for Vadose Zone Sources

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
No Action	No Action	No Action	Cr(VI) source areas and residual Cr(VI) in vadose zone are left untreated.	LOW	HIGH	LOW.	Retained per the NCP.
MNA	MNA	MNA	Cr(VI) source areas and residual Cr(VI) in vadose zone are left to attenuate over time from natural biological and chemical reductive processes, and flushing from surface water infiltration. Cr(VI) near the groundwater table would be slowly flushed by fluctuating groundwater table.	LOW to MODERATE Cr(VI) leaching into groundwater may be an acceptable component of the vadose zone remedy, if combined with an aggressive plume remedy such that the resultant dissolved Cr(VI) concentrations still meet the groundwater clean up criteria.	HIGH	LOW capital and O&M costs.	Retained as a possible component of alternatives with active remediation.
Removal	Excavation	Standard Excavation (to approximately 6 m [20 ft] bgs)	Shallow soil in identified Cr(VI) source areas is removed using conventional construction equipment.	LOW to MODERATE Shallow sources removed, but residual Cr(VI) maybe present in the deeper vadose zone pore water could continue to impact groundwater due to water table fluctuation and leaching. Difficult to identify all soil that is a risk to groundwater via soil sampling.	HIGH Shallow excavation is typically straightforward.	MODERATE to HIGH.	Retained as potential source removal component of remedy.
		Deep Excavation (for example, large lay back required for open-pit type excavation or alternatively use of shoring).	Soil in identified Cr(VI) source areas is removed to deeper depths (18 to 24 m [60 to 80 ft]).	MODERATE to HIGH Locations of the deep sources will be difficult to identify, meaning large areas would have to excavated to depth to ensure that the deep sources were removed.	LOW to MODERATE Shoring may be difficult with cobbles and boulders. Significant safety issues with very deep excavations.	HIGH.	Retained for special applications consideration.
In Situ Treatment	Physical/Chemical Treatment	Chemical Infiltration	Liquid with chemical reductant (e.g., calcium polysulfide) is applied to ground surface at an application rate substantially below what would create saturation, to treat Cr(VI) within vadose zone prior to reaching groundwater.	MODERATE Chemical reductant follows source release pathways. Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize Cr(VI) (in first pore volume) toward groundwater. Handling chemical reductants (e.g., calcium polysulfide) is an H&S concern.	LOW to MODERATE capital cost, MODERATE O&M cost.	Retained, however similar process with biological amendments likely more effective.
In Situ Treatment	Physical/Chemical Treatment	Deep Soil Mixing	Large mixing augers (1.5 to 3 m [5 to 10 ft] in diameter) or horizontally rotating heads are used to blend and homogenize chemical reductants with soil.	HIGH Chemical reductants are uniformly mixed with soil column, providing good contact and reaction between Cr(VI) and chemical. Cement can also be mixed with the chemical slurry to reduce the hydraulic conductivity and leachability of the soil.	LOW Implementation will be more challenging in gravelly/cobbly lithologies. Although deep soil mixing has been performed to depths of 30 m (100 ft) bgs, most field applications have been limited to approximately 15 m (50 ft) bgs.	HIGH capital cost, LOW O&M cost.	Not retained. Deep soil mixing implementability will be limited by site conditions and required depth of treatment.

Table 4-3. Screening Table – Technologies for Vadose Zone Sources

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
In Situ Treatment	Physical/Chemical Treatment (continued)	Jet Grouting with Reactive Materials	High pressure injection of reactive slurry into soil to hydraulically mix the in situ material with the slurry.	LOW While jet grouting is capable of reaching the required treatment depth, uncertainty of the nature and extent of vadose zone source area would limit effectiveness. Jet grouting is also not likely to achieve effective distribution in this formation.	LOW to MODERATE Implementation will be more challenging in gravelly/cobbly lithologies. Jet grouting has been performed to depths of up to 91 m (300 ft). Limited radius of influence would make jet grouting cost-prohibitive over a large area.	HIGH capital cost, LOW O&M cost.	Conditionally retained for future consideration if technology develops. Currently, jet grouting will be cost-prohibitive and with potentially limited effectiveness.
		Foam Delivery of Calcium Polysulfide	Injection of a foam generating chemical reductant (calcium polysulfide)-surfactant solution into vadose zone.	UNKNOWN Technology evaluation has been limited to laboratory column tests.	UNKNOWN Technology evaluation has been limited to laboratory column tests.	UNKNOWN Technology evaluation has been limited to laboratory column tests.	Conditionally retained for future consideration if technology develops. Currently, the technology has not been demonstrated on a three-dimensional laboratory scale or field scale.
		In Situ Gaseous Reduction with Chemical Substrate	A gaseous mixture of chemical reductants (e.g. hydrogen sulfide) is injected into and drawn through the vadose zone to reduce and immobilize Cr(VI).	LOW to MODERATE Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil.	LOW Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft) – large numbers of wells is required. Due to H&S risks, monitoring and emergency response plan are required for transporting, storing, and handling hydrogen sulfide gas.	MODERATE capital cost, LOW O&M cost.	Not retained. Process may have limited effectiveness and poses H&S issues.
		Water Flushing	Clean/treated water (applied to the ground surface or in infiltration trenches) to flush Cr(VI) out of the vadose zone to the water table, where it would be captured/treated.	MODERATE Water follows source release pathways, but Cr(VI) that remains in adsorbed phase will not be treated.	HIGH Drip irrigation system or trenches are simple to install and accessible for O&M.	LOW to MODERATE capital cost, LOW O&M cost.	Conditionally retained for future consideration.
In Situ Treatment	Chemical/Biological Treatment	Combined Chemical/ Biological Infiltration	Liquid with chemical reductant (e.g., calcium polysulfide) and biological carbon source is applied in combination to ground surface at an application rate substantially below what would create saturation, to treat Cr(VI) within vadose zone prior to reaching groundwater.	HIGH Amendments follow source release pathways. Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize Cr(VI) (in first pore volume) toward groundwater. Handling chemical reductants (e.g., calcium polysulfide) is an H&S concern.	LOW to MODERATE capital cost, MODERATE O&M cost.	Retained.
	Biological Treatment	Biological Infiltration	Liquid with biological carbon source is applied to ground surface at an application rate substantially below what would create saturation, to treat Cr(VI) within vadose zone prior to reaching groundwater.	HIGH Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reactive strength is maintained over relatively longer distances.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize Cr(VI) (in first pore volume) toward groundwater.	LOW to MODERATE capital cost, MODERATE O&M cost.	Retained.

Table 4-3. Screening Table – Technologies for Vadose Zone Sources

General Response Actions	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comment
In Situ Treatment (continued)	Biological Treatment (continued)	In Situ Gaseous Reduction with Biological Substrate	A gaseous mixture of electron donor gases (e.g., propane, butane, ethane, and/or methane) is injected into and drawn through the vadose zone to biologically reduce and immobilize Cr(VI).	LOW to MODERATE Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil.	LOW Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft) – large number of wells is required. Due to H&S risks, monitoring and contingency measures are required for transporting, storing, and handling flammable/explosive gases.	MODERATE capital cost, LOW O&M cost.	Not Retained. Process may have limited effectiveness in heterogeneous sediments and poses H&S issues.
Containment	Containment and Isolation	Surface Barrier	An impermeable cover is placed over ground surface to prevent surface water infiltration through the vadose zone and limit Cr(VI) leaching to groundwater.	LOW to MODERATE Leaching of near-surface source Cr(VI) will be controlled, but residual Cr(VI) in capillary fringe and deeper vadose zone pore water will continue to impact groundwater due to water table fluctuation.	HIGH Surface barrier simple to construct.	LOW capital and O&M costs.	Not Retained. Process has limited effectiveness for mitigating deeper vadose zone sources.
		Vegetative Cap (Evapotranspiration Cap)	A native grass cover is placed over ground surface to increase evapotranspiration rates and decrease the amount of surface water infiltration through the vadose zone and limit Cr(VI) leaching to groundwater.	LOW to MODERATE Leaching of near-surface source Cr(VI) will decrease once grasses have become established, but residual Cr(VI) in capillary fringe and deeper vadose zone pore water may continue impact groundwater due to water table fluctuation.	HIGH Vegetative cap readily installed.	LOW capital and O&M costs.	Not Retained. Process has limited effectiveness for mitigating deeper vadose zone sources.

NOTES: Gray shading denotes rejected process option. Yellow shading denotes conditionally retained process option.

bgs = below ground surface
Cr(VI) = hexavalent chromium
H&S = health and safety
MNA = monitored natural attenuation
NCP = National Contingency Plan
O&M = operations and maintenance
RAO = remedial action objective.

This page intentionally left blank.

4.3 Remedial Action Alternatives

The final 100-D RPO technology screening meeting (October 17, 2008) included discussions of how best to implement the results of the screening process to accelerate the remediation of the 100-HR-3 OU. A consensus was developed among the attendees, including DOE-RL, Ecology, and EPA, to recommend further evaluation of one or more of the highly rated ISR technologies to augment the existing interim soil and groundwater remedial action alternatives for the 100-HR-3 OU (and potentially for the 100 Area as a whole).

4.3.1 Treatability Testing of ISR Technologies

4.3.1.1 *Calcium Polysulfide Treatability Test at 100-K*

A treatability test for in situ reduction of hexavalent chromium in the 100-K Area of the Hanford Site was conducted in 2005 and is summarized in DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*, Rev. 0. The technology involved injecting calcium polysulfide, a strong reducing chemical, into the aquifer to reduce the mobile hexavalent chromium to its less toxic and essentially immobile trivalent form and produce a permeable reactive barrier that serves to continue to remove hexavalent chromium from the groundwater. The objectives of the test were:

- Verify the ability to achieve in situ reduction using an active remediation system involving calcium polysulfide and a carbon source, which together reduce the groundwater and aquifer through inorganic and microbiological processes.
- Determine whether aquifer constituents (e.g., manganese or arsenic) are mobilized because of this reduction, and how other parameters (e.g., nitrate or dissolved oxygen) are affected as a result of the groundwater treatment.
- Obtain operational experience in the treatment of chromium-contaminated groundwater by the use of calcium polysulfide as the reducing medium.

All of the performance goals were met during the testing period from June 28, 2005 until August 11, 2005 in which 1,324,894 L (350,000 gal) of groundwater was treated. The technology effectively reduced chromium in the aquifer, while the permeable reactive barrier that formed continues to remain a reducing environment for chromium under natural groundwater flow conditions. During the treatability test, 25 samples were collected; chemical analysis of these samples showed that manganese and iron were mobilized under the strong reducing conditions, and arsenic was near background levels immediately following test completion. The pre- and post-treatment aquifer tests showed that chemical injections did not degrade the permeability of the aquifer. A well approximately 200 meters (m) (656 feet [ft]) downgradient of the test area is being monitored to evaluate the persistence of the reduced zone and any adverse effects the test may have had on the aquifer chemistry. The costs for this test are summarized in Table 4-4. The test was considered successful and provided sufficient data to scale up the treatment technology.

Table 4-4. Actual Costs for the Treatability Test (in 1,000s).

Category	Planning	Design	Boreholes	Construction	Operations	Subtotals
Labor	$26.2	$91.8	$39.5	$46.7	$73.6	$277.8
Materials	$0.0	$0.0	$0.0	$30.9	$74.4	$105.3
Subcontractors	$19.8	$0.0	$180.8	$161.9	$81.9	$444.4
Other Costs	$0.1	$9.0	$6.1	$38.7	$52.1	$106
TOTALS	**$46.1**	**$100.8**	**$226.4**	**$278.2**	**$282.0**	**$933.5**

4.3.1.2 *Biological ISR at 100-D*

As previously discussed, a treatability test has been conducted to evaluate the effectiveness of chemical-based ISR of hexavalent chromium for the remediation of hexavalent chromium in groundwater in the 100-K Area of the Hanford Site in 2005 (DOE/RL-2006-17). There has been, however, no treatability study of comparable scale conducted at Hanford to evaluate biologically based ISR treatment of elevated concentrations of hexavalent chromium in groundwater or the vadose zone within the 100 Area of the Hanford Site. Consequently, a treatability study of ISR by biological processes has been proposed to obtain information that will allow the comparison of the results and cost-effectiveness of biological ISR with those obtained previously by chemical ISR. The proposed biological ISR treatability test is scheduled for implementation in 2011 and will be designed to treat the groundwater hot spot in the 100-D Area (waste site 100-D-12), as well as any hexavalent chromium remaining in the overlying vadose zone that may be acting as a continuing source of groundwater contamination.

No treatability studies are planned for the remaining retained or conditionally retained technologies not already part of the existing interim remedial action alternatives, and they were not used in the development of new alternatives for the RPO effort. These remaining retained or conditionally retained technologies will be further evaluated in the RI/FS process for possible inclusion in the final remedy for the 100 Area.

4.3.2 Selection of Alternatives for Evaluation

Based on the findings and discussions conducted as part of the technology screening process, the meeting attendees developed the following three alternatives to serve as a basis for determining whether ISR should be included as part of the interim actions for the 100 Area.

Alternative 0 – No Action: No remedial actions would be undertaken and existing ICs would be lifted. Hexavalent chromium would continue to leach from soil to groundwater, and groundwater with unacceptably high hexavalent chromium concentrations would continue to impact the river. Potential exposure to surface soils would also continue. (The No Action Alternative is required by the NCP and it currently exists under the unamended interim action ROD.)

Alternative 1 – Continue Current Actions: Existing ICs would remain in place and pump-and-treat, ISRM barrier maintenance/amendment, and RTD operations would continue. In addition, continuing current actions includes expanding and/or enhancing these activities as appropriate. This Alternative currently exists under the unamended interim action ROD.

Alternative 2 – Continue Current Actions with Selective Application of ISR: This remedial action alternative is identical to Alternative 1 with the exception that ISR (chemical and/or biological reduction) is added to accelerate remediation of hexavalent chromium in soil and groundwater. The option of Alternative 2 however, does not exist under any of the existing interim action RODs and cannot be implemented until the 100 Area interim action RODs are amended.

The description, comparison, and evaluation of these three alternatives in Chapters 5, 6, and 7 of this FFS will be used to determine whether the interim action RODs for the 100 Area should be amended to include ISR as a remedial action option.

5. Description of Alternatives

The primary components of the remedial action alternatives described in Chapter 4 are presented in the following sections. Design components of Alternatives 1 and 2, and their potential application to a representative example of a hexavalent chromium contamination site within the 100 Area, are presented to facilitate detailed and comparative cost analysis. Detailed analysis of each individual alternative against the CERCLA threshold and primary balancing criteria is presented in Chapter 6. The comparative analysis of the relative advantages and disadvantages of each alternative is presented in Chapter 7.

5.1 Alternative 0 – No Action

The CERCLA regulations (40 CFR 300) require the evaluation of a no-action alternative to develop a baseline for comparison with the other remedial action alternatives that are under consideration. Implementation of this remedial action alternative would result in no further action to remediate the source areas or groundwater plumes at the 100 Area. Alternative 0 also presumes that the DOE will relinquish control of the 100 Area to other government or private entities without easements and covenants and without the maintenance or enforcement of access or ICs. Alternative 0 is not considered a viable remedial action alternative for actual implementation.

5.2 Alternative 1 – Continue Current Actions

Alternative 1 is the continuation of the site primary RAs currently being implemented within the 100 Area in accordance with the current interim action RODs (Table 1-1). The primary current actions for the 100 Area are ICs, RTD, and pump-and-treat. Although an ISRM barrier is part of the existing remedial action for the 100-D Site (see Section 2.3), implementation of this action is expected to be limited to this site and it is not further discussed. The primary components of Alternative 1 are summarized below.

5.2.1 Institutional Controls

Institutional controls are an integral component of Alternative 1 and will continue to be required until remedial efforts reduce contaminant concentrations in soils, waste sites, and groundwater to below those considered protective of human health under an unrestricted land-use scenario. Institutional controls could consist of physical and legal barriers to human access to contaminants in soils, waste sites, and groundwater. Physical methods of controlling access to waste sites could include signs, entry control, excavation permits, artificial or natural barriers, and active surveillance. The DOE, or subsequent land managers, could enforce land-use restrictions as long as risks were above unrestricted land-use levels. The DOE could continue to use fencing and the badging program to control access to restricted sites for as long as it maintains control over the land. Land-use restrictions and controls on real property development will, as necessary, contribute to the protection of human health by minimizing the potential for contact with contaminated media.

5.2.2 Pump-and-Treat Contaminated Groundwater

Where necessary to meet the RAOs for groundwater remediation and river protection in the 100 Area, the volume and concentration of hexavalent chromium contamination in groundwater will be reduced by the implementation of a groundwater extraction, treatment, and reinjection system. Future expansions of groundwater treatment capacity will be implemented if found to be necessary to meet RAOs. The expansions include the following activities:

- Extraction wells will be installed at appropriate locations within the plume to maximize capture of the plume and protect the river while minimizing withdrawal of river water.

- Ex situ groundwater treatment will be accomplished primarily by ion exchange. The treatment system will decrease hexavalent chromium concentrations in the influent to the maximum extent practicable (the reinjection limit for hexavalent chromium is less than 50 μg/L).

- After treatment, the effluent will be reinjected using injection wells or other equivalent reinjection or infiltration systems. The injection or infiltration systems will be used to maximize hydraulic capture and containment of the plume by the extraction wells and to minimize discharge of contaminated groundwater to the river.

This pump-and-treat action described above primarily is designed to decrease concentrations of hexavalent chromium in groundwater and to decrease concentrations discharging to river substrate. In some portions of the 100 Area, other groundwater co-contaminants (for example, nitrate, Sr-90, tritium, uranium, and Tc-99) may be present at concentrations above drinking water standards. The ion exchange systems used to remove hexavalent chromium also will reduce concentrations of other anionic contaminants such as nitrate, Tc-99, and uranium. Strontium-90 typically exists in cationic form in groundwater and is not expected to be removed by an ion exchange system targeting hexavalent chromium. Tritium also is not expected to be removed by the treatment system. However, these potential co-contaminants do not exceed the ecological risk criteria for the river and where needed, ICs will limit human exposure to groundwater.

5.2.3 Removal, Treatment, and Disposal

The hexavalent chromium source waste sites and associated contaminated vadose zone soils within the 100 Area are commonly associated with structures used to store, transport, or handle concentrated sodium dichromate liquids and powders used as an anti-corrosion additive for coolant water for the 100 Area reactors. Document DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study*, identified RTD as a cost-effective action for the remediation of waste sites. Consequently, Alternative 1 provides for the RTD of 100 Area waste sites and soils to depths sufficient to meet RAOs, including protection of groundwater and the Columbia River.

Excavation of waste sites follows the observational approach, allowing waste characterization, designation, and treatment to occur as excavation proceeds. Most of the excavated hexavalent chromium – contaminated waste materials and soils are expected to meet the ERDF waste acceptance criteria without treatment (WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*). If the ERDF waste acceptance criteria cannot be achieved, waste treatment would be conducted before disposal at the ERDF.

Verification sampling is performed during and after excavation to evaluate whether the following cleanup criteria have been met for hexavalent chromium (1) remaining concentrations are at or below direct exposure levels for nonradioactive chemicals (WAC 173-340-740(3), "Method B Soil Cleanup Levels for Unrestricted Land Use"), and (2) remaining levels are sufficiently low to provide appropriate protection of the groundwater and the Columbia River (WAC 173-340-720(4), "Method B Cleanup Levels for Potable Ground Water"). It is anticipated that excavation to depths equal to the depth to groundwater will be necessary in order to meet the required cleanup standards at some 100 Area waste sites. Once cleanup has been verified, clean soil from approved borrow pits will be transported to the excavated areas as supplemental backfill material. Recontouring of the area to prevent run-on and either resurfacing or revegetation will occur after remediation to ensure that infiltration is minimized.

5.3 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

Alternative 2 retains all the components of Alternative 1 (the continuation of existing remedial actions at current or expanded levels), but also allows the selective application of ISR where needed to more efficiently or effectively achieve RAOs. The ISR component of Alternative 2 is not intended as a wholesale replacement for pump-and-treat or RTD and it is anticipated that plume-wide remediation of groundwater and the remediation of primary sources of hexavalent chromium contamination (for example, pipelines, storage tanks and surface soils or shallow vadose zone contamination), will continue to be performed by pump-and-treat and RTD, respectively. Rather, ISR is intended as an additional remedial tool that can be used in selected areas (e.g., deep vadose contamination, hot spots, upgradient plume zones etc.) where pump-and-treat and RTD alone may be less effective, more expensive, or too slow to meet clean-up goals. If properly integrated with RTD and pump-and-treat, ISR has the capability to substantially accelerate the achievement of RAOs for those 100 Area locations that contain waste sites or zones of groundwater contamination that meet the ISR treatment selection criteria defined in Section 5.5. Because ISR is anticipated to be implemented (as part of Alternative 2) for the remediation of selected source area and groundwater plume zones, it is necessary to evaluate this technology as a supplement to pump-and-treat and RTD (Alternative 1) as part of the comprehensive large-scale remediation of groundwater and/or soil OUs throughout the 100 Area. For the purposes of this FFS, it was assumed that RTD would be used to address contaminated soil present in the zero to 4.6 m (15 ft) depth range, while ISR would be employed to address contaminated soil present between 4.6 m (15 ft) and the water table. In situ reduction would also be used to address localized hot spots of hexavalent chromium-contaminated groundwater underlying the vadose zone when warranted. Pump-and-treat will be used to address the remaining downgradient groundwater contamination.

5.4 Design Basis for Comparison of Alternative 1 and Alternative 2

The southern plume hot spot within the 100-D Area has been selected as an appropriate site to illustrate the possible implementation of ISR as a supplemental remedial action to pump-and-treat and RTD (Figure 5-1). This "hot spot" site comprises a well-characterized high-concentration zone of hexavalent chromium (dark blue, 5000+ depicted in Figure 5-1) in the groundwater that may be continuing to receive contamination from a suspected source located in the overlying vadose zone (see Section 1.2). This site can be used as an example or representative site for other groundwater or vadose zone sites in the 100 Area that could either be remediated using pump-and-treat and/or RTD or by ISR, based on the site selection criteria described in Section 5.5. The pump-and-treat, RTD and ISR remedial designs presented below for the hypothetical remediation of this hot spot area are used as the basis for the cost analysis in Appendix B.

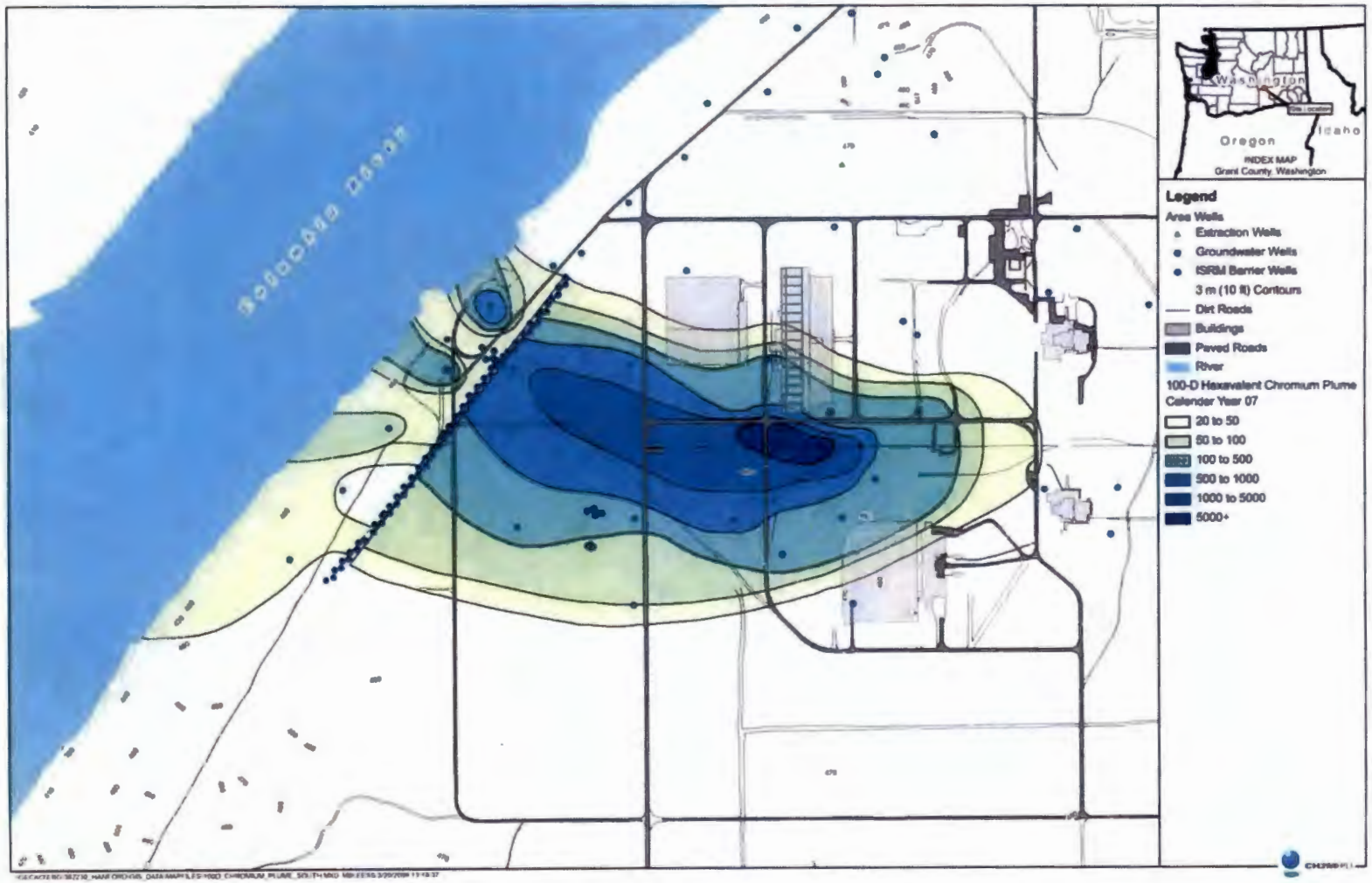

Figure 5-1. 100-D Area Southern Plume With Groundwater Hot Spot, Fall 2007

5.4.1 Hypothetical Application of Pump-and-Treat and RTD for the 100-D Hot Spot Area

A treatment approach that includes the technologies of Alternative 1 is described in this subsection. Alternative 1 provides for the use of pump-and-treat and RTD to address hexavalent chromium contaminated groundwater and vadose zone soils (over a range of assumed depths) to achieve the RAOs described in Chapter 3 of this FFS report. One of the main areas of concern in the 100-D Area consists of the hexavalent chromium hot spot located in the southern plume (Figure 5-1). Although no significant remaining vadose zone contamination has been identified to date by direct methods (for example, core sampling), the long-lived presence of the groundwater hot spot suggests the possible presence of one or more continuing sources within the vadose zone and/or within the aquifer in the vicinity of the hot spot (SGW-38338).

5.4.1.1 Hot Spot Pump-and-Treat System

The 100-DR-5 ion exchange-based treatment pump-and-treat system (hereafter the DR-5 System) is currently operating in the 100-D Area and is used to illustrate application of this component of Alternative 1. In July of 2004, the 189 liters per minute (L/min) (50 gallons per minute [gal/min]) DR-5 System was installed in the 100-D Area. Since that time, the DR-5 System has been used for mass removal and for partial containment of the northern and southern plumes of hexavalent chromium in the 100-D Area. For the purposes of this evaluation, it is assumed that the extraction network of the DR-5 System will be re-targeted to accelerate the remediation of the 100-D Southern Plume Hot Spot (Figure 5-2). The base information such as plume configuration, roads and building is scaled from Figure 5-1 and used at an expanded scale on Figure 5-2.

In the proposed design, the DR-5 pump-and-treat system will use four extraction wells. Each well will extract groundwater at a rate of up to 47.5 L/min (12.5 gal/min) for a total of 189 L/min (50 gal/min). The extracted water will be piped to the DR-5 System for treatment and an existing injection well will be used to dispose of the treated water. Three of the proposed extraction wells will be converted from monitoring wells located within the hot spot. The fourth well is an existing extraction well (199-D5-39) located approximately 120 m (400 ft) downgradient of the center of the hot spot (Figure 5-2). This extraction well array will maximize capture of the hot spot and allow capture of some of the substantial mass of hexavalent chromium (e.g., at 1,000 to 2,000 µg/L) that has already migrated downgradient of the main body of the hot spot, where concentrations can substantially exceed 5,000 µg/L hexavalent chromium.

5.4.1.2 Hot Spot Vadose Zone RTD

The excavation of this site will follow the observational approach, allowing waste characterization, designation, and treatment to occur as excavation proceeds. For the purposes of this evaluation of the RTD component of Alternative 1, the hypothetical vadose zone contamination over the hot spot is assumed to have an areal extent of 9.1 m by 9.1 m (30 ft by 30 ft) and to extend through the vadose zone to groundwater, 24.4 m (80 ft). This approach allows for a cost evaluation of RTD at this depth and a comparison of costs with the costs of implementing ISR for vadose zone remediation (including RTD to 4.5 m [15 ft]). Sampling will be performed during and after excavation to confirm that the remediation goals for hexavalent chromium have been met. Most of the excavated waste and soil are expected to meet the ERDF waste acceptance criteria without treatment (BHI-01237, *Description of Work for Fiscal Year 1999 Drilling Within the Chromium Plume West of the 100 D/DR Reactors*). If the ERDF waste acceptance criteria are not met, waste treatment would be conducted before disposal at the ERDF.

Once cleanup has been verified, clean soil from approved borrow pits will be transported to the excavated area as supplemental backfill material. Re-contouring of the area to prevent run on and either re-surfacing or re-vegetation occurs after remediation to ensure that infiltration is minimized.

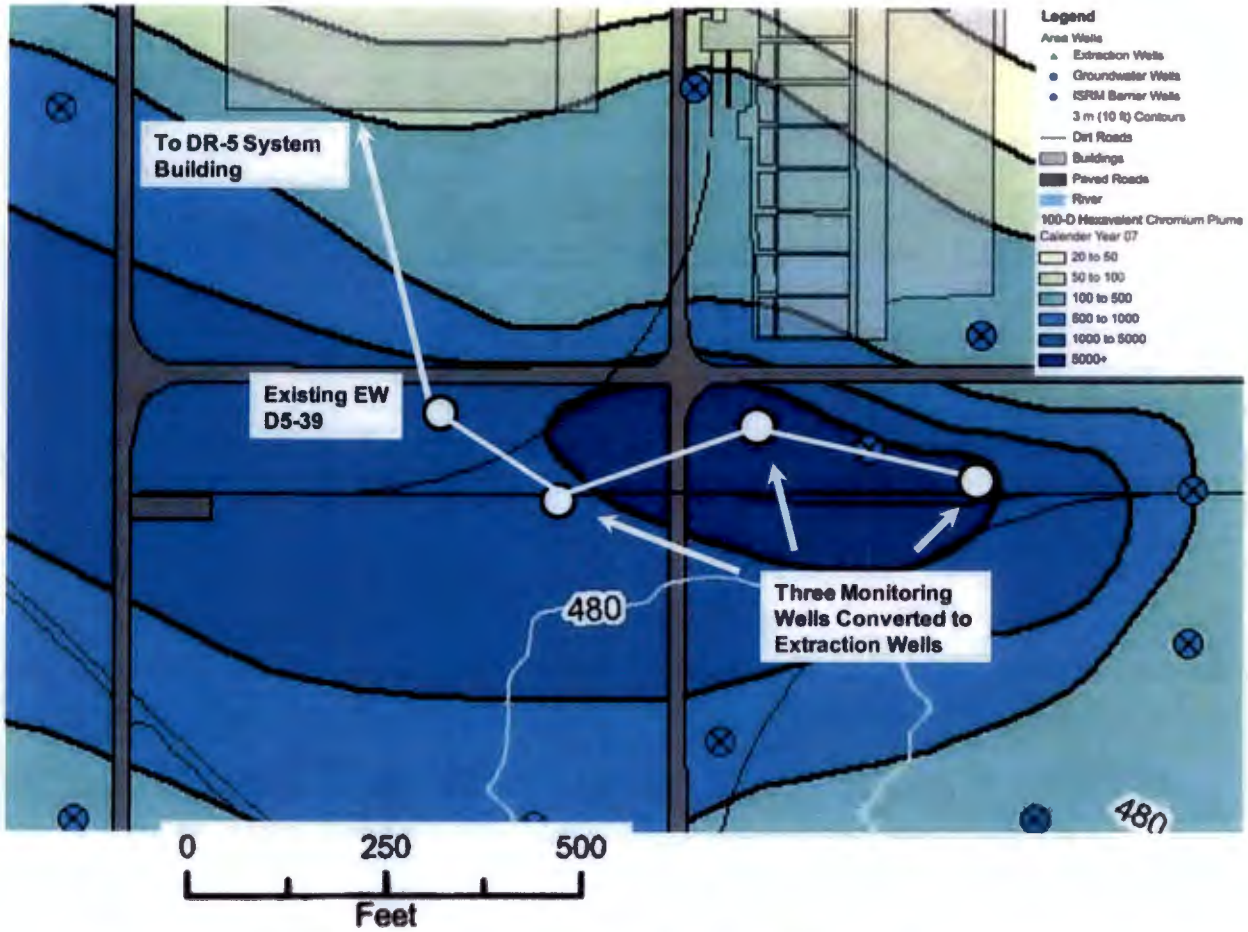

Figure 5-2. Schematic Map View of the Proposed 100-D Area Southern Plume Groundwater Hot Spot Pump-and-Treat Well Field Design

5.4.2 Hypothetical Application of ISR to the 100-D Hot Spot Area

The 100-D Area Southern Plume Groundwater Hot Spot and overlying vadose zone site is a good candidate for application of ISR for remediation of hexavalent chromium in the groundwater and, if present, in the vadose zone based on application of the site selection criteria discussed in Section 5.5. A source or sources are assumed to exist in the vadose zone and/or the aquifer because of the long-lived presence of the groundwater hexavalent chromium hot spot (see Figure 5-1) (SGW-38338). The importance of the uncertainty in the depth and location of the suspected vadose zone contamination is minimized by the proposed ISR approach. The approach will treat an approximately 0.4-hectare (1-acre) area that covers the highest concentration zone of the groundwater hot spot and consequently, the probable location of the hexavalent chromium in the vadose zone, if present.

5.4.2.1 ISR System Design

The design of the proposed ISR treatment system for remediation of the southern plume groundwater hot spot and overlying vadose zone has two main components. A drip irrigation system would be installed over an approximately 0.4-hectare (1-acre) area over the groundwater hot spot and the vadose zone that is suspected to have deep source(s) of hexavalent chromium contamination (Figure 5-3). The drip system would consist of a series of flexible drip lines spaced 0.6 to 1 m (2 to 3 ft) apart. The drip system would be connected to a header line from a mixing tank containing extracted groundwater or optional freshwater

source that is continuously amended with ISR reagent (Figure 5-4). The reducing agent(s) will be determined during the remedial design process. As the ISR-amended aqueous solution infiltrates through the vadose zone, residual hexavalent chromium remaining in the extracted groundwater and in the targeted area of the vadose zone would be converted to the less toxic and essentially immobile trivalent form of chromium.

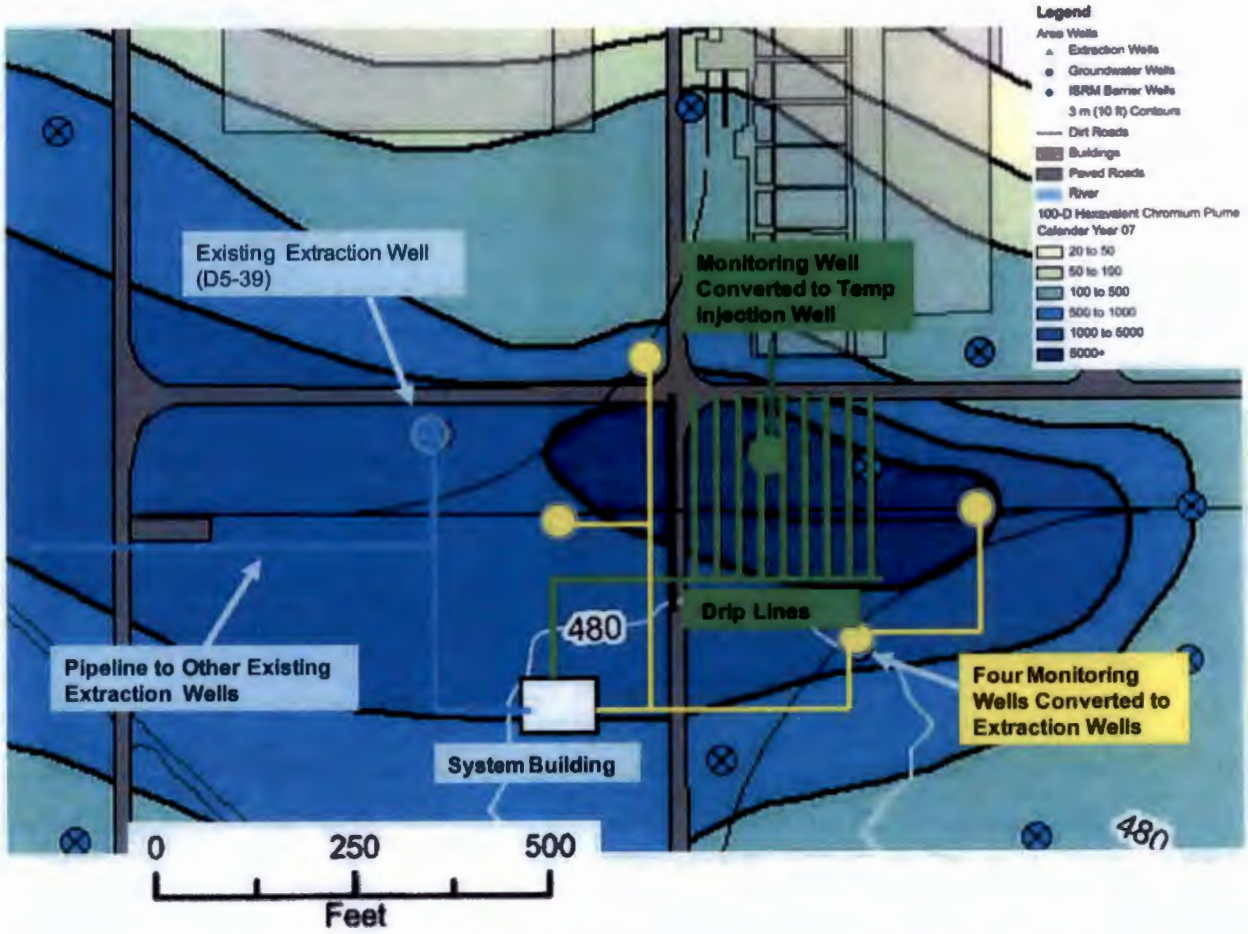

Figure 5-3. Schematic Map View of the Combined Vadose Zone and Groundwater In Situ Reduction System for the 100-D Area Southern Plume Hot Spot

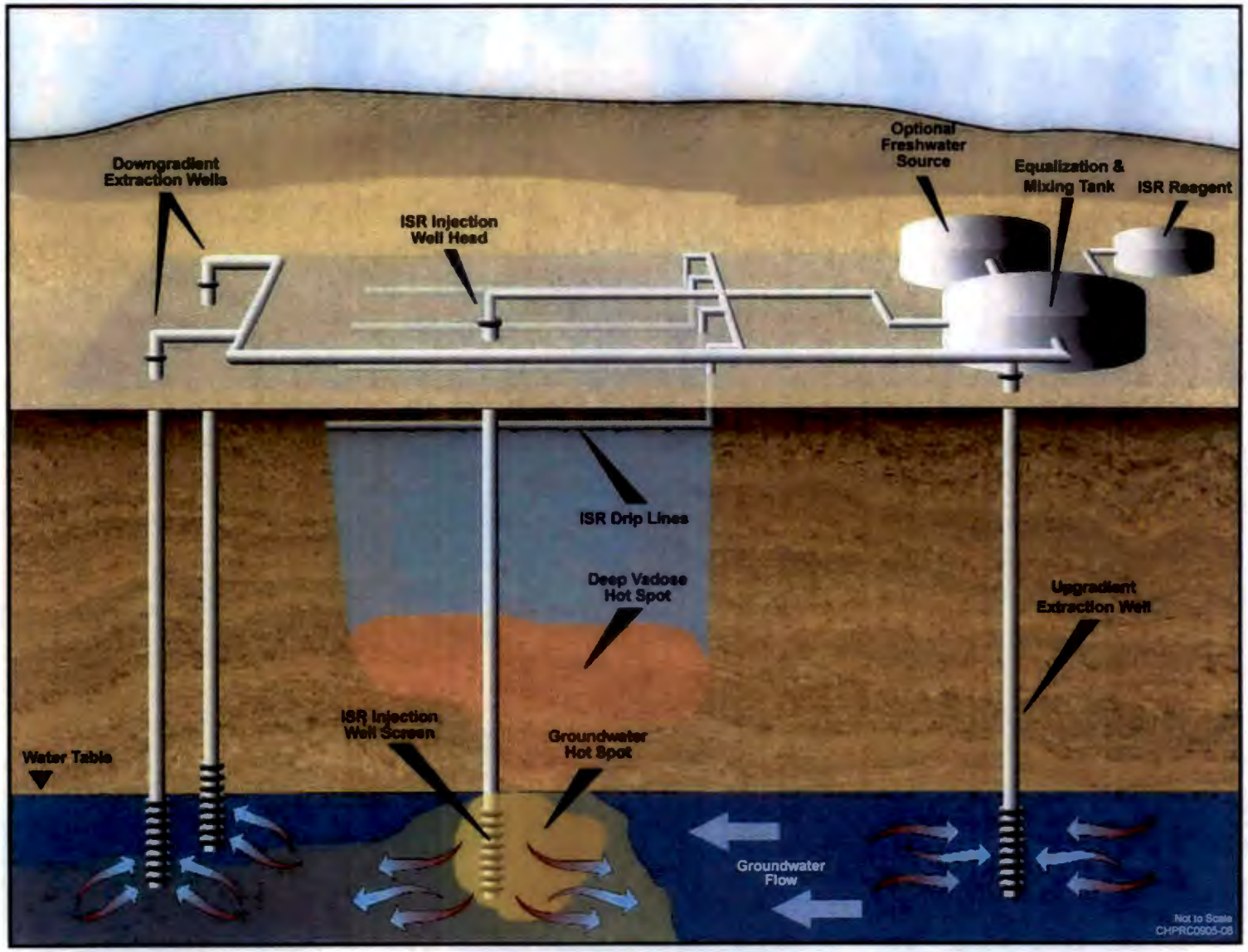

Figure 5-4. Schematic Cross-Sectional View of a Combined Vadose Zone and Groundwater In Situ Reduction System for the 100-D Area Southern Plume Hot Spot and Overlying Vadose Zone

Sufficient ISR reagent would be added to the infiltration solution to ensure that the treatment would penetrate through the full vadose zone and into the underlying groundwater. Conversion of hexavalent chromium to trivalent chromium has been demonstrated to be an irreversible process under typical environmental conditions such as those present on the Hanford Site. This will minimize the potential for the treated vadose zone to continue as a source of hexavalent chromium to groundwater. However, to ensure adequate remediation of the underlying groundwater, an existing monitoring well would be converted to an injection well and used to inject ISR amendment into the center of the hot spot. Four existing monitoring wells located upgradient, downgradient, and cross-gradient of the injection well could be converted to low-yield extraction wells (approximately 38 L/min [10 gal/min] each) to supply water for the injection components of the ISR treatment system. The hydraulic effects of the four converted extraction wells also would promote the vertical and lateral dispersion of the injected and infiltrated ISR amendments throughout the hot spot (Figures 5-3 and 5-4). Existing extraction wells located downgradient of the hot spot could be used to supply water to the drip infiltration component of the ISR system (Figures 5-3 and 5-4). The combined drip infiltration and injection of ISR-amended water would be expected to remediate the contaminated vadose zone and the groundwater of the southern plume groundwater hot spot and overlying vadose zone area within nine months of system startup.

5.5 In Situ Reduction Site Selection Criteria

This section presents a remedy selection criteria and a general strategy for identifying sites within the 100 Area where ISR could be used to augment or replace RTD and/or pump-and-treat technologies. The criteria below are indicative of many settings where ISR should be considered, but they are not intended to preclude the use of ISR at other settings where site conditions may warrant the application of ISR (e.g., large areas of low concentration plumes where pump-and-treat alone may be insufficient to meet cleanup milestones).

5.5.1 Application of In Situ Reduction to Hexavalent Chromium in Groundwater Applications

Generally, ISR should be considered for implementation whenever the RAOs for hexavalent chromium contamination in the target aquifers would be difficult to meet in a timely and cost-effective manner with the existing groundwater remedial systems. The following represent some of the site settings or conditions where the implementation of ISR could be an appropriate action for supplementing the existing groundwater remedial systems (for example, pump-and-treat via ion exchange; the ISRM barrier located in the 100-D Area).

- The implementation of ISR for groundwater remediation (for example, at hot spots) would substantially reduce operations and maintenance (O&M) costs for new or existing ion exchange treatment plants by substantially reducing the mass of hexavalent chromium requiring treatment by ion exchange.
- Substantial contamination is present in lower yielding aquifer zones in the 100 Area (for example, those areas or strata containing more than 10 percent by weight of fine-grained silts and clays). Remediation of these zones using pump-and-treat potentially would require numerous closely spaced extraction wells and longer periods of system operation, resulting in higher capital and O&M costs than would the implementation of ISR.
- The application of ISR would augment the existing treatment systems on a sufficient scale to ensure achievement of the RAOs for river protection and groundwater remediation.

Based on the above site settings and other conditions (for example, the potential presence of other COCs), a logic diagram has been constructed to help determine when ISR should be considered as an appropriate remedial action (Figure 5-5). This logic diagram is summarized as follows:

Step 1. Has a remedy been implemented for the hexavalent chromium contaminated groundwater?

Yes (proceed to Step 2):

- MNA, pump-and-treat, or ISRM.

No (skip to Step 3):

- No remedy has been selected for contamination.

Step 2. Is the remedy that was selected for hexavalent chromium contaminated groundwater adequately addressing the plume?

Yes (no change to remedial action):

- There is no need to change or augment the existing remedial action.

No (proceed to Step 3):

- Is not meeting RAOs.
- Does not address the full extent of groundwater plume.

Step 3. Are other COCs present within this groundwater plume?

Yes (proceed to Step 4):

- Any contaminant other than hexavalent chromium.

No (skip to Step 5):

- Hexavalent chromium is the only COC present.

Step 4. Can ISR be an effective treatment for the additional COC(s)?

Yes (select ISR).

No (skip to Step 7).

Step 5. Could this hexavalent chromium contaminated groundwater plume be a hot spot?

Yes (select ISR):

- The plume has high hexavalent chromium concentrations that may be highly localized.

No (proceed to Step 6):

- The plume has relatively low hexavalent chromium concentrations that may have a vast lateral extent.

Step 6. Does the aquifer have low permeability?

Yes (Select ISR):

- Infiltration of the ISR amendments would more widely address hexavalent chromium. Extraction wells would have a small area of influence.

No (proceed to Step 7).

Step 7. Would ISR likely enhance the effectiveness of the current pump-and-treat systems?

Yes (Select combined pump-and-treat and ISR).

No (No change to remedial action):

- If other COCs are present that cannot be effectively treated by ISR or the current treatment technologies described in the interim action RODs, the additional technology evaluation may be required.

Steps 1 and 2 are included to acknowledge interim actions have been ongoing and ISR need not be included when all goals have been met. Logic from Figure 5-5 is applied to the 100-D southern plume groundwater hot spot area because interim actions have been in place and cleanup goals are not yet reached. The answer to Step 3 is "No," proceeding to Step 5 to determine if a hexavalent chromium groundwater hot spot is present. The answer to Step 5 is "Yes" leading to the selection of ISR. Implementation details of ISR, including continuation of pump-and-treat and additional RTD, is anticipated in the RDR/ remedial action Work Plan phase that follows ROD amendment.

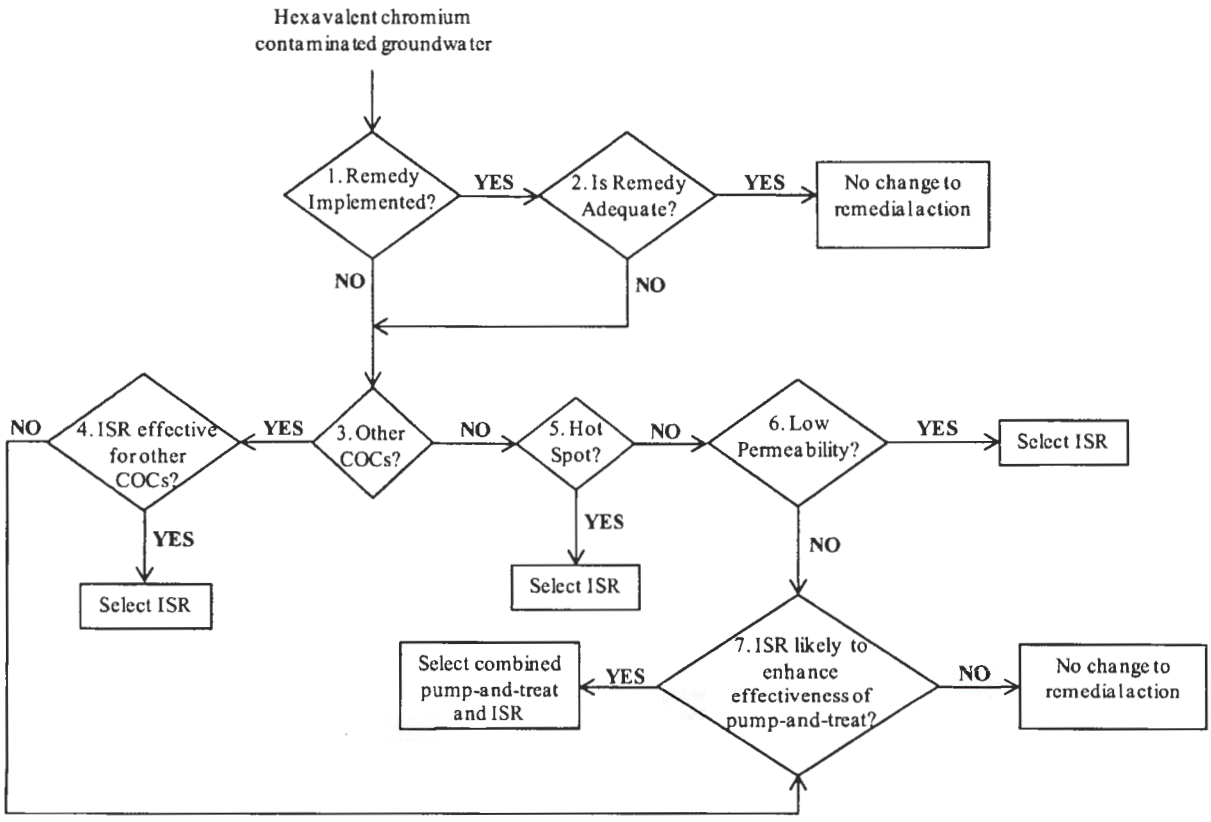

Figure 5-5. Logic for Application of In Situ Reduction for Remediation of Hexavalent Chromium in Groundwater

Additional factors may affect cost and technical feasibility and will need to be considered in selecting an appropriate remedy for a given location. These include distance to the river, distance to water treatment plant, access, availability of feed source(s), and location of cultural and historical resources. For example, locations near the river may require groundwater reoxygenation following ISR to meet dissolved oxygen requirements, which would increase the cost of the ISR option at that location. It is anticipated that total

chromium concentrations will not exceed appropriate ARARs in groundwater as the conversion of hexavalent chromium to its trivalent form produces a solid phase precipitate with a high soil-partitioning affinity, ultimately desorbing from the groundwater to surrounding soils. Once adsorbed to the soil, the trivalent chromium has a very low aqueous solubility, resulting in it remaining in the vadose zone.

5.5.2 Application of In Situ Reduction to Hexavalent Chromium in Soil

In situ reduction should be considered as an alternative to (or in addition to) RTD for the remediation of hexavalent chromium-contaminated soils under the following settings or conditions:

- At sites containing exceedances of hexavalent chromium in deep soils (for example, greater than about 9.1 m [30 ft] below ground surface [bgs]), sufficient to make RTD more difficult or expensive to implement than ISR (Sections 6.3.7 and 6.4.7)
- In areas where attempts to precisely identify the locations of deep subsurface hexavalent chromium soil contamination have failed, yet substantial subsurface contamination is inferred to be present because of the presence of underlying groundwater hot spots or other indirect indicators of the existence of secondary sources in the vadose zone
- In areas adjacent to or beneath existing surface infrastructure (for example, active buried utilities, buildings) where remediation of shallow or deep soil contamination by RTD is not cost-effective or may not be implementable
- In areas where the sole contaminant is hexavalent chromium
- In areas where other COCs requiring remediation also are amenable to remediation via ISR and if other COCs are likely present, they would not be mobilized and potentially transported, untreated, to groundwater during the implementation of ISR.

Based on the considerations noted above, a logic that can be used to determine when to include ISR as a soil remediation option is shown in Figure 5-6 and summarized below.

Step 1. Has an effective remedy been implemented for the hexavalent chromium contaminated soil?

Yes (proceed to Step 2):

- MNA or RTD.

No (skip to Step 3):

- No remedy has been selected for contamination.

Step 2. Is there the potential for continued groundwater impact?

Yes (proceed to Step 3):

- The vadose zone hexavalent chromium has the potential for further impacts to groundwater.

No (proceed to Step 3):

- There is no need to change or augment the existing remedial action.

Step 3. Are other COCs present within the vadose zone source area?

Yes (proceed to Step 4):

- RTD will be implemented to remove the vadose contamination.

No (skip to Step 5):

- Hexavalent chromium is the only COC present.

Step 4. Following RTD, is there continued hexavalent chromium potential?

Yes (proceed to Step 5):

- Hexavalent chromium is present above RAOs.

No (no change to remedial action):

- There is no need to augment the existing remedial action.

Step 5. Does the vadose hexavalent chromium exist at depths greater than approximately 9.1 m (30 ft) bgs?

Yes (select ISR):

- ISR is capable of addressing hexavalent chromium at any depth within the vadose zone.

No (no change to remedial action):

- There is no need to change or augment the existing remedial action.

Additional factors may affect cost and technical feasibility and will need to be considered in selecting an appropriate remedy for a given location. These include access to soils, availability of feed source(s), location of cultural and historical resources, and concentration of hexavalent chromium in the vadose zone. The conversion of hexavalent chromium to its trivalent form produces a solid-phase precipitate with a high soil-partitioning affinity, ultimately adsorbing to surrounding soils. This will serve to increase the localized total chromium concentration; therefore, consideration should be taken to be sure appropriate ARARs for total chromium are not exceeded during implementation of ISR.

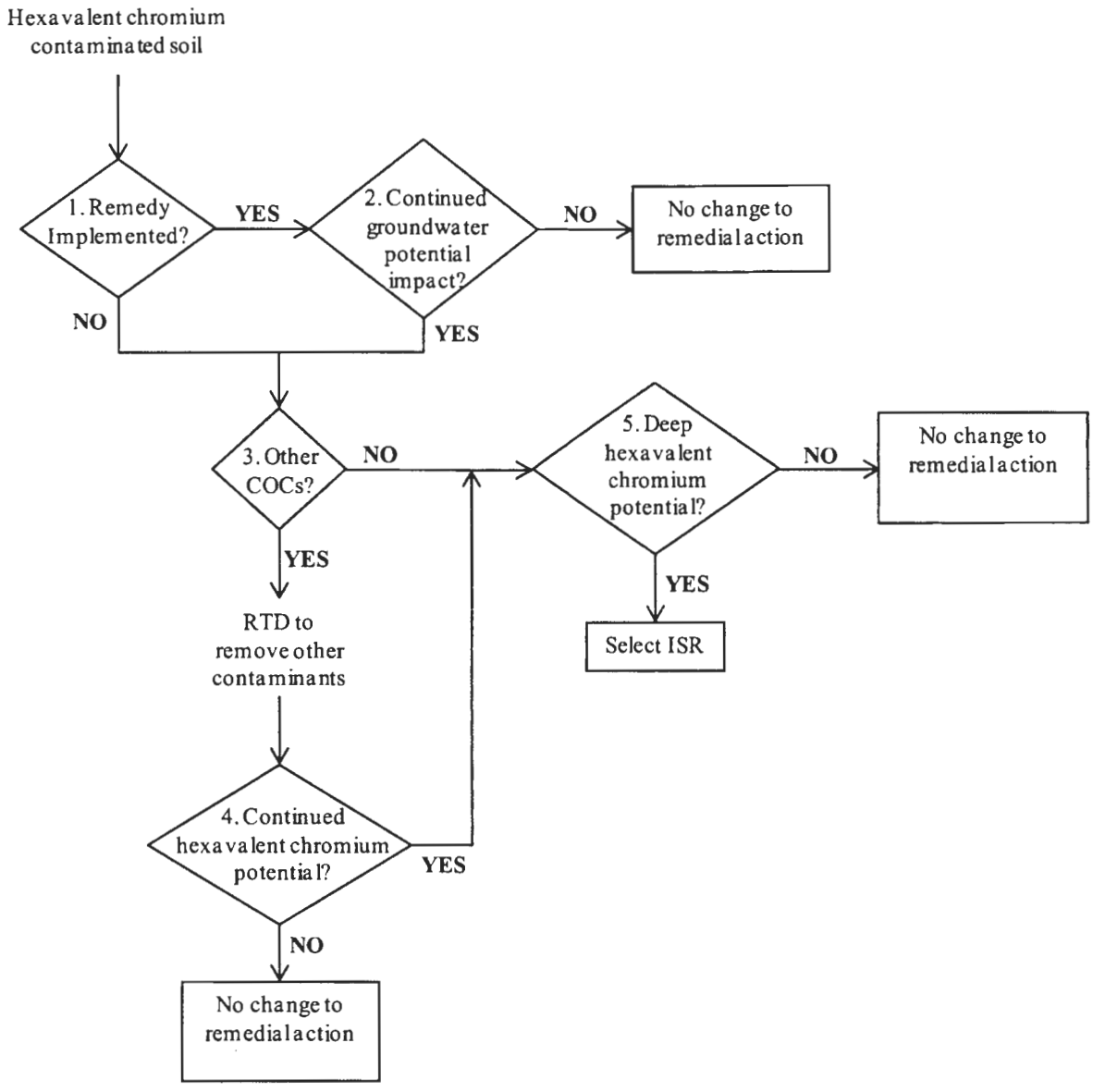

Figure 5-6. Logic for Application of In Situ Reduction for Remediation of Hexavalent Chromium in Soil

6. Detailed Analysis of Alternatives

This chapter presents a detailed analysis of the remedial alternatives presented in Chapter 5 of this FFS relative to the CERCLA evaluation criteria identified in 40 CFR 300.430(e)(9), "*Detailed Analysis of Alternatives*." Tables 6-1 and 6-3, provided later in this chapter, provide the results of the detailed analyses for Alternatives 1 and 2, respectively. Supporting cost information for the alternatives is presented in Appendix B. This analysis uses the 100-D Area south plume and overlying vadose zone as a site that is typical of the 100 Area and thus the analysis applies to the other selected 100 Area hexavalent chromium-contaminated waste sites.

The purpose of the detailed analysis is to develop the necessary information to enable the Tri-Parties to select the most appropriate remedy for hexavalent chromium-contaminated sites (vadose zone and groundwater media) in the 100 Area. The remedy must meet CERCLA statutory requirements and the NCP program goal, which is to select remedies that are protective of human health and the environment, maintain protection over time, and minimize untreated waste.

The detailed analysis of alternatives takes into account the nature of the contaminants, the potential threat to human health and the environment, and the anticipated future land use.

6.1 Description of Evaluation Criteria

Section 121(b)(1) of CERCLA (EPA, 1980) indicates that selected remedial actions should (1) be protective of human health and the environment; (2) be cost-effective; (3) use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and (4) employ treatments that permanently reduce the toxicity, mobility, or volume (TMV) of the principal threats posed by a site. To address these statutory requirements, EPA developed nine criteria as defined in 40 CFR 300.430(e)(9)(iii), "Nine Criteria for Evaluation." These criteria provide the framework for conducting the detailed and comparative analyses of remedial alternatives in this FFS and, subsequently, for selecting an appropriate interim remedial action in the appropriate 100 Area interim action RODs that meets the statutory requirements.

The nine CERCLA evaluation criteria are as follows:

<u>Threshold Criteria</u>

1. Overall protection of human health and the environment
2. Compliance with ARARs

<u>Balancing Criteria</u>

1. Long-term effectiveness and permanence
2. Reduction of TMV through treatment
3. Short-term effectiveness
4. Implementability
5. Cost

<u>Modifying Criteria</u>

1. Regulatory acceptance
2. Community acceptance

The first two criteria, overall protection of human health and the environment and compliance with ARARs, are threshold criteria. The remedial action alternatives that do not protect human health and the environment or do not comply with ARARs (or justify a waiver) do not meet statutory requirements and are eliminated from further consideration in this FFS.

The next five criteria (long-term effectiveness and permanence, reduction of TMV through treatment, short-term effectiveness, implementability, and cost) are balancing criteria upon which the remedy selection is based. The CERCLA guidance lists appropriate questions to be answered when evaluating a remedial action alternative against the balancing criteria. The detailed analysis in Sections 6.2 through 6.4 evaluate each remedial action alternative against these criteria.

The detailed analysis associated with the seventh criterion, cost, is based on cost evaluation for a representative site (100-D Hot Spot Area) as described in Section 5.4. The results of this detailed analysis for cost are applicable to the other hexavalent chromium sites in the 100 Area.

The final two criteria, regulatory acceptance and community acceptance, are modifying criteria that will be evaluated after public review of the selected remedial alternative documented in the proposed plan. There may be some criteria against which none of the remedial action alternatives perform well. A qualitative assessment of remedial action alternative performance relative to a particular criterion is based on engineering judgment when quantitative information is not available.

6.1.1 Overall Protection of Human Health and the Environment

This criterion determines whether adequate protection of human health and the environment, including preservation of natural systems and biological diversity, is achieved through implementation of the remedial action alternative. Protection includes reduction of risk to acceptable levels (either by reduction of concentrations or the elimination of potential routes for exposure) and minimization of exposure threats introduced by actions during remediation. Environmental protection includes avoiding or minimizing impacts to natural, cultural, and historical resources. Additionally, this criterion evaluates the potential for human-health risks, the extent of those risks, and whether a net environmental benefit will exist as a result of implementing the remedial action alternative.

This first criterion is a threshold requirement and the primary objective of the remedial action program. As indicated in EPA guidance, overlap exists between this criterion and the criteria for compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness (EPA/540/G-89/004).

6.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion addresses whether a remedial action alternative attains the federal and State of Washington ARARs and/or whether a waiver is justified. When an ARAR is not met, the basis for justifying a waiver must be presented. No ARAR waiver is proposed for any of the remedial action alternatives identified in this FFS.

6.1.3 Long-Term Effectiveness and Permanence

This criterion addresses the results of a proposed remedial action alternative in terms of risks that remain at the site after RAOs are met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The following components of the criterion are considered for each remedial action alternative:

- Magnitude of residual risk to human and ecological receptors. This factor assesses the residual risk from untreated waste or treatment residuals after completion of remedial activities. The characteristics

of the residual wastes are considered to the degree that they remain hazardous, taking into account their TMV and propensity to bioaccumulate.

- Adequacy and reliability of controls. This factor assesses the adequacy and suitability of controls used to manage treatment residuals or untreated wastes that remain at the site. It also assesses the long-term reliability of management controls for providing continued protection from residuals. Additionally, this factor includes an assessment of the potential need for replacement of the technical components associated with a remedial action alternative.

Residual risk to natural and cultural resources after conclusion of remedial activities also is evaluated. Current environmental conditions are assessed against the remedial action alternative's long-term and permanent solutions. The assessment considerations are based on whether lasting environmental losses would be incurred for the sake of short-term cleanup gains, including whether environmental restoration and/or mitigation options would be precluded if a remedial action alternative were to be implemented.

6.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the degree to which a remedial action alternative uses treatment to reduce the TMV of hazardous substances. Significant overall reduction can be achieved by destroying toxic contaminants or by reducing total mass, contaminant mobility, or total volume of contaminated media.

The evaluation focuses on the following factors for each remedial action alternative:

- The treatment processes used and the materials treated
- Whether there is recycling, reuse, or waste minimization in the treatment process
- The type and quantity of treatment residuals that remain following treatment, and whether any special treatment actions will be needed
- Whether the remedial action alternative satisfies the statutory preference for treatment as a principal element.

6.1.5 Short-Term Effectiveness

This criterion evaluates the potential effects on human health and the environment during the construction and implementation phases of a remedial action. This criterion also considers the time required to achieve protection. The following factors are considered for each remedial action alternative:

- The health and safety (H&S) of remediation workers and the public, and reliability of protective measures taken
- Physical, biological, and cultural impacts that may result from the construction and implementation of the remedial action, and whether the impacts can be controlled or mitigated
- The amount of time for the RAOs to be met.

Short-term human-health impacts are closely related to the duration of exposure to hazardous wastes and risks associated with removal of wastes. Typically, the greater the exposure time, the greater the risk. As-low-as-reasonably-achievable guidelines will be practiced during implementation of the remedial action to minimize worker risks.

Since the EPA issued EPA/540/G-89/004 in 1988, the concept of "sustainability" has emerged as a possible new criterion worthy of consideration in the evaluation of each remedial action alternative. Various definitions of sustainability have been proposed. For this FFS, however, sustainability is defined

as a measure of the ability of an action to meet the needs of the present without compromising the ability of future generations, or of people in other locations, to meet their own needs. Feasibility studies that have included this concept in the evaluation have variously evaluated sustainability as a tenth feasibility study criterion or as a subset of one of the nine established feasibility study criteria (or not at all). In this FFS, sustainability is included as part of short-term effectiveness. A comprehensive evaluation of sustainability has not been undertaken in this FFS, but considered here in a qualitative manner are the following elements relative to the proposed remedial action alternatives: energy consumption, greenhouse gas emissions, site disruption, and generation of treatment residuals that must be managed during the remedial action.

6.1.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedial action alternative and the availability of the required services and materials. The following factors are considered for each remedial action alternative:

- Technical feasibility, such as the likelihood of technical difficulties in constructing and operating the remedial action alternative, the likelihood of delays due to technical problems, and uncertainties related to technologies
- Administrative feasibility, such as the ability to coordinate activities with other offices and agencies and the potential for regulatory constraints to develop
- Availability of services and materials, such as the availability of adequate treatment, storage capacity, and disposal services and the availability of necessary equipment, specialists, and provisions.

6.1.7 Cost

This criterion considers the cost of implementing a remedial action alternative, including capital and O&M.

The cost estimates prepared for this FFS (Appendix B) are presented as present-worth dollars and were prepared using currently available information. The actual cost of the project will depend on additional information gained during the remedial design phase, the final scope and design of the selected remedial action, the schedule of implementation, the competitive market conditions, and other variables. However, most of these factors are not expected to significantly affect the relative cost differences of remedial action alternatives.

6.1.8 Regulatory Acceptance

This criterion is addressed and/or further evaluated after regulator review of the proposed plan. This criterion evaluates the technical and administrative issues and concerns that the EPA and Ecology may have regarding a remedial action alternative. The regulatory acceptance process involves a review and concurrence by the EPA and Ecology.

6.1.9 Community Acceptance

This criterion is addressed and/or further evaluated after public review of the proposed plan. This criterion evaluates the issues and concerns the public and other interested stakeholders may have regarding a remedial action alternative.

6.2 Alternative 0 – No Action

Under 40 CFR 300.430(e)(6), "The No-Action Alternative," Alternative 0 is included in the FFS to provide a baseline for comparison against the other alternatives and, in accordance with the NCP, must be

evaluated even if it fails to meet the two threshold criteria. Under Alternative 0, no active remedial action would be taken at the hexavalent chromium waste sites to address potential threats to human health and the environment.

6.2.1 Overall Protection of Human Health and the Environment

Alternative 0 would fail to provide overall protection of human health and the environment, because hexavalent chromium concentrations would remain on site above applicable standards.

6.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

The ARARs for chromium concentrations in soil and groundwater would not be met because no action would be taken.

6.2.3 Long-Term Effectiveness and Permanence

Alternative 0 would not be effective in the long term. Rather, the risk would remain because hexavalent chromium in soil and groundwater would remain untreated.

6.2.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

There would be no treatment under Alternative 0 and thus no reduction of TMV.

6.2.5 Short-Term Effectiveness

Alternative 0 would require no removal, transfer, or treatment of hexavalent chromium in the 100 Area. Therefore, the potential for releases and remediation worker exposure would not increase over current operations in the short term. However, Alternative 0 also would fail to reduce occupational exposure and risks to workers and others at the site.

6.2.6 Implementability

Alternative 0 could be implemented immediately, but would fail to comply with decisions within interim action RODs, Tri-Party Agreement milestones, and commitments made to the regulatory agencies, oversight agencies, the public, and other interested stakeholders. Thus, Alternative 0 would not be administratively feasible.

6.2.7 Cost

Alternative 0 would involve no cost; thus, it receives a high rating with respect to cost.

6.3 Alternative 1 – Continue Current Actions

The primary current actions are RTD and pump-and-treat. In addition, current actions include some variation of ICs, depending on site-specific conditions, and could include the ISRM barrier in the 100-D Area.

A detailed analysis of the components of Alternative 1 with respect to the seven NCP criteria has been conducted in previous feasibility study and FFS documents, and is reiterated in Table 6-1 and summarized in the following subsections.

6.3.1 Overall Protection of Human Health and the Environment

Alternative 1 would achieve overall protection of human health and the environment, provided the technologies are applied aggressively to remove a sufficient volume of soil and extract a sufficient volume of groundwater.

This page intentionally left blank.

Table 6-1. Detailed Evaluation of Alternative 1 – Continue Current Actions

	Shallow Soil	Deep Soil	Source Area Groundwater	Downgradient Groundwater	River Pump-and-Treat
Description of remedy	Hexavalent chromium-contaminated soils and/or debris would be excavated, treated as required, and disposed of in the ERDF.	Deep excavation (for example, large layback required for open-pit type of excavation or using caissons or other shoring methods). Excavated soils would be treated as required and disposed of in the ERDF.	Groundwater extraction and ex situ treatment using ion exchange or other effective ex situ treatment technology.	Same as for source area groundwater.	Same as for source area groundwater.
1. Overall Protection of Human Health and the Environment					
	Excavation would remove contaminant mass leaching to groundwater and would minimize potential exposure to contaminated soils through direct contact and ingestion.	Excavation would reduce contaminant mass leaching to groundwater.	Groundwater would be extracted from the subsurface and hexavalent chromium would be removed by ion exchange or some other process. Treated groundwater would be reinjected to the subsurface far enough upgradient of the river, and with sufficiently low hexavalent chromium concentrations, that it would be safe for human health and the environment.	Same as for source area groundwater.	Provided sufficient volumes of groundwater are extracted, treated, and reinjected such that groundwater discharging to the river met the 20 µg/L requirement, groundwater pump-and-treat would provide overall protection of human health and the environment.
2. Compliance with ARARs					
	ARARs would be met because soil with hexavalent chromium concentrations exceeding safe levels for human health and the environment would be removed, treated, and disposed in a secure facility (ERDF).	Same as for shallow soil.	Would meet ARARs of 48 µg/L hexavalent chromium in inland groundwater, 20 µg/L hexavalent chromium in groundwater discharging to the river, and 100 µg/L total chromium in all Site groundwater.	Same as for source area groundwater.	Same as for source area groundwater.
3. Long-Term Effectiveness and Permanence					
(a) Magnitude of residual risks	Residual risk may remain for soils not excavated.	Same as for shallow soil.	Groundwater pump-and-treat would continue until standards for hexavalent and total chromium in groundwater are achieved. Ex situ treatment residuals, such as ion exchange resin and ion exchange brine, would be handled appropriately to minimize their residual risks.	Same as for source area groundwater.	Same as for source area groundwater.
(b) Adequacy and reliability of controls	Excavation is adequate and reliable.	Same as for shallow soil.	Groundwater pump-and-treat has been proven to be adequate and reliable for hexavalent chromium at this Site and others.	Same as for source area groundwater.	Same as for source area groundwater.

Table 6-1. Detailed Evaluation of Alternative 1 – Continue Current Actions

	Shallow Soil	Deep Soil	Source Area Groundwater	Downgradient Groundwater	River Shoreline
4. Reduction of TMV through Treatment					
(a) Treatment process used	Excavated soils may be treated before disposal in the ERDF, as necessary, to meet land-disposal requirements.	Same as for shallow soil.	Ion exchange, ferrous chloride treatment, or other appropriate ex situ treatment technology.	Same as for source area groundwater.	Same as for source area groundwater.
(b) Degree and quantity of TMV reduction	TMV of hexavalent chromium in the 100 Area would be decreased by removal of impacted soils and/or debris. Soils and/or debris removed during excavation would be treated before disposal in the ERDF, as necessary, to meet land-disposal requirements.	Same as for shallow soil.	TMV of hexavalent chromium in groundwater would all be decreased by groundwater extraction. TMV of the hexavalent chromium extracted via groundwater may be decreased depending on details of the ex situ treatment system employed. For example, if ion exchange resins are regenerated on site, the brine may be treated using ferrous chloride to reduce hexavalent to trivalent chromium, decreasing its toxicity and mobility. If "throw away" resin is used and disposed of in the ERDF, it may be pretreated to decrease toxicity and mobility. If the ferrous chloride process is used to treat groundwater, toxicity and mobility would be decreased by reducing hexavalent to trivalent chromium. Volume ultimately will not be decreased because chromium is an element.	Same as for source area groundwater.	Same as for source area groundwater.
(c) Irreversibility of TMV reduction	Excavation of soils is irreversible.	Same as for shallow soil.	Groundwater extraction is irreversible. Ex situ treatment may be reversible depending on the specific technology employed. For example, adsorption onto ion exchange resins is reversible, and resins often are regenerated by desorbing the adsorbed contaminants. If ferrous chloride treatment is used, reduction of hexavalent to trivalent chromium is irreversible under typical environmental conditions such as those that exist at the Site.	Same as for source area groundwater.	Same as for source area groundwater.
(d) Type and quantity of treatment residuals	Treatment residuals would consist of excavated hexavalent chromium-contaminated soils and/or debris and any amendments needed to treat the soil before disposal in the ERDF in order to meet land-disposal requirements. The quantities of soil to be excavated, and treated, would be established by Washington Closure Hanford, LLC during RTD operations.	Same as for shallow soil.	Treatment residuals will depend on the specific ex situ treatment process employed and could consist of spent ion exchange resin, ion exchange brine, sludge from the ferrous chloride process, or other residuals if some other ex situ treatment process is used.	Same as for source area groundwater.	Same as for source area groundwater.
(e) Statutory preference for treatment	Preference would be met because excavated soils would be treated appropriately if needed and appropriately disposed of in the ERDF.	Same as for shallow soil.	Preference would be met because hexavalent chromium would be removed from the aquifer and treated.	Same as for source area groundwater.	Same as for source area groundwater.

Table 6-1. Detailed Evaluation of Alternative 1 – Continue Current Actions

	Shallow Soil	Deep Soil	Source Area Groundwater	Downgradient Groundwater	River Protection
5. Short-Term Effectiveness					
(a) Protection of workers during remedial action	Risk to workers during remedial construction would be mitigated by adherence to site-specific H&S plans and engineering controls (for example, dust suppression).	Same as for shallow soil. However, risks to workers increase significantly with excavation depth.	Risk to workers during well and piping installation would be mitigated by adherence to site-specific H&S plans and engineering controls (for example, dust suppression).	Same as for source area groundwater.	Same as for source area groundwater.
(b) Protection of community during remedial action	Risks to the community during remedial construction include dust and safety risks from the presence of open excavations. These risks would be mitigated during implementation through use of engineering controls.	Same as for shallow soil.	Risks to the community would be mitigated by keeping community members away from work areas.	Same as for source area groundwater.	Same as for source area groundwater.
(c) Environmental impacts of remedial action	Minimal risks to the environment will occur during excavation assuming implementation of adequate monitoring and engineering controls (for example, erosion controls).	Same as for shallow soil.	Minimal risks to the environment during construction activities assuming implementation of adequate erosion controls.	Same as for source area groundwater.	Same as for source area groundwater.
(d) Time until RAOs are achieved	Excavation will assist in meeting the groundwater protection RAO by 2020.	Same as for shallow soil.	Groundwater pump-and-treat would meet the river protection RAO by 2012 and the groundwater protection RAO by 2020 as long as the technology is applied with sufficient intensity.	Same as for source area groundwater.	Groundwater treatment or pump-and-treat would meet the river protection RAO by 2012 as long as the technology is applied with sufficient intensity.
(e) Sustainability	High-energy use and greenhouse gas emissions will occur from excavation equipment. Moderate energy use and greenhouse gas emission by transporting soil to the nearby ERDF. Generates large volume of residuals that would need to be managed indefinitely.	Same as for shallow soil; however, energy use and greenhouse gas emissions increase significantly with excavation depth.	High-energy use and increased greenhouse gas emissions from groundwater extraction. Treatment residuals require disposal. Minimal site disruption.	Same as for source area groundwater.	Same as for source area groundwater. Water restored for ecological reuse in the river.
6. Implementability					
(a) Technical feasibility	Feasible.	Feasible. Challenges increase with depth.	Feasible.	Feasible.	Feasible.
(b) Administrative feasibility	Administratively feasible; however, access is not possible in some areas, such as culturally sensitive areas and near buildings and utilities.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.
(c) Availability of services and materials	Necessary engineering services and materials are readily available.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.
7. Present-Worth Cost to Remediate 100 Area					
Present-worth cost*	100-D-12: $11.8 million 100-D-30 SW: $11.7 million 600-334: $2.3 million 116-K-2: $11.2 million 100-C-7:1 $38.0 million	100-C-7: $13.3 million Future Site #1: $11.8 million Future Site #2: $11.8 million Future Site #3: $2.3 million Future Site #4: $13.3 million	100-D Hot Spot: $12.3 million 100-K Plume: $39.2 million	Same as for source area groundwater.	Not applicable.

NOTES: *The information in this preliminary cost estimate is based on the best available information regarding the anticipated scope of potential remedial action alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the feasibility study and/or during engineering design of the remedial action alternatives. The range presented is +50 to -30 percent of the order-of-magnitude cost estimate provided in the Appendix B for the six known and four future sites selected for comparison. The costs for soil remediation (shallow and deep), RTD, have been combined and determined to extend from ground surface to the water table to meet RAOs; open-pit excavation technology is assumed for RTD.

ARAR = applicable or relevant and appropriate requirement
ERDF = Environmental Restoration Disposal Facility
H&S = health and safety
RAO = remedial action objective
RTD = removal, treatment, and disposal
TMV = toxicity, mobility, or volume

This page intentionally left blank.

6.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1 would comply with ARARs, provided the technologies are applied aggressively to remove a sufficient volume of soil and extract a sufficient volume of groundwater.

6.3.3 Long-Term Effectiveness and Permanence

Alternative 1 would be effective in the long term. However, intensive pump-and-treat would need to continue for a long period unless the primary and secondary hexavalent chromium sources in the vadose zone or aquifer were removed. If hexavalent chromium sources were removed, they would be removed permanently and disposed of in the ERDF. Groundwater treatment residuals also may need to be disposed of permanently in the ERDF, depending on the specific ex situ treatment process employed. The technologies in Alternative 1 are adequate and reliable.

6.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 1 would reduce the toxicity, mobility, and volume of hexavalent chromium in groundwater. Pump-and-treat operations remove contaminated groundwater from the aquifer, while ion exchange is employed to adsorb hexavalent chromium to its resin. The treated water is ultimately reinjected. The resin regeneration process converts chromium from the hexavalent oxidation state to its trivalent form, reducing the toxicity and mobility. Alternative 1 would also reduce the toxicity and mobility of hexavalent chromium in soil removed by RTD that is pretreated before disposal in the ERDF. However, it would not reduce the toxicity and mobility of hexavalent chromium in soil that is was not removed by RTD or pretreated prior to disposal. The overall volume of chromium cannot be reduced because chromium is an element and thus cannot be broken down, but the volume of the more toxic hexavalent chromium can be reduced via conversion to trivalent chromium.

6.3.5 Short-Term Effectiveness

Risks to workers would be significant for deep excavation, but risks can be mitigated via engineering controls. There could be some risks to the community and the environment associated with particulate emissions, but these risks also could be controlled. Sustainability of Alternative 1 is considered poor because excavation, especially deep excavation, and intense groundwater extraction are energy intensive and result in additional greenhouse gas emissions. In addition, both technologies generate considerable residuals that must be managed indefinitely.

6.3.6 Implementability

Administratively feasible at current levels; however, access is not possible in some areas, such as culturally sensitive areas and near buildings and utilities. To achieve RAOs, within desired time frame, the technologies would need to be applied intensively and may to be impractical in restricted areas.

6.3.7 Cost

Supporting cost information, assumptions, and approach to developing the costs are provided in Appendix B. Costs for Alternative 1 remedial components are summarized in Table 6-1, which includes unit costs for six known and four future hexavalent chromium-contaminated waste sites in the 100 Area. Table 6-2 is provided to better illustrate the cost difference between Alternatives 1 and 2 when applied to the known 100-D-12 waste site. The Alternative 1 costs are based on RTD to a depth of 24.4 m (80 ft), plus 100-D hot spot pump-and-treat, and ICs. Alternative 2 costs are based on RTD to a depth of 2.4 m (8 ft), 100-D Hot Spot pump-and-treat, plus ISR, and ICs. These enabling assumptions allow an even comparison of the cost of Alternative 1 to Alternative 2 for the 100-D-12 site in 100-D Area. Estimated RTD costs include the assumption that the contamination "footprint" is 9.1 by 9.1 m (30 by 30 ft). This footprint is assumed to be representative of hexavalent chromium contaminant sites in the 100 Area.

Additionally, it is assumed that no barriers or access issues with RTD exist at the 100-D-12 waste site and groundwater plume.

Table 6-2. Comparison of Net Present Value Cost of Between Alternative 1 and 2 with Enabling Assumptions at 100-D-12

Alternative Summary	Net Present Value	Comments and Assumptions
Alternative 1 – RTD to 24.4 m (80 ft), 100-D Hot Spot pump-and-treat, and ICs	$24,150,900	Assume RTD to 24.4 m (80 ft) and current pump-and-treat levels without additional capacity.
Alternative 2 – RTD to 2.4 m (8 ft), 100-D Hot Spot pump-and-treat, ISR in vadose zone (4.6 m [15 ft] to 24.4 m [80 ft]) and groundwater, and ICs	$15,510,900	Assume RTD to 2.4 m (8 ft), ISR of remaining vadose zone and groundwater hot spot, and pump-and-treat for 5 years; pump-and-treat is the majority of the net present value ($12,320,000).

NOTES: IC = institutional control
ISR = in situ reduction
RTD = removal, treatment, and disposal
See Appendix B for cost information and supporting cost backup.

The general assumptions for ICs are as follows.

- IC costs were estimated using IC cost information supplied by CH2M HILL Plateau Remediation Company (CHPRC) from another OU feasibility study. The cost estimate includes both a capital and an O&M component.

The general assumptions for RTD include:

- RTD excavation costs by Washington Closure Hanford, LLC, include all labor, equipment, and material to excavate soil and debris; size-reduce concrete from the adjacent facility; load out materials; backfill; perform revegetation activities; and prepare waste site closeout documentation.
- RTD treatment and disposal costs include all labor, equipment, and material to transport containers to ERDF; treatment of hexavalent chromium-contaminated soil to meet land-disposal restrictions; and disposal at ERDF. ERDF treatment and disposal costs are estimated at 120 percent of the total excavation, sampling, backfill and site restoration cost.
- Costs for RTD are well-known after years of experience applying this technology at the Hanford Site. They include the following:
  - Density of soil is 1.9 tons per bank cubic yard
  - Excavation cost is $15.00 per ton
  - Offsite backfill material cost is $8.00 per ton. Onsite stockpile material is handled at $2.50 per ton.
  - Soil excavation rates are 90 trucks per day total (15 trucks per day at 6 cycles each)
  - Each truck carries 32 tons per cycle (truck-and-pup operation)
  - Revegetation costs are $5,000 per acre
  - Sampling costs are $700 per sample and assume 22 samples for each of the RTD depth options. Laboratory analysis includes inductively coupled plasma (ICP) metals and hexavalent chromium. Assumes quick turnaround (7-day preliminary and 30-day final).

A one-time allowance (periodic cost) for spot-backfilling an RTD site to offset settlement is included.

The general assumptions for the 100-D Hot Spot pump-and-treat include:

- The extraction, injection, and treatment system configuration includes the following:
  - Three existing monitoring wells are converted to extraction wells and two are converted to an injection well. One existing extraction well would be reconfigured. Well conversion costs were obtained from CHPRC – Field Engineering Lead.
  - Conveyance piping and installation costs were obtained from CHPRC – Field Engineering Lead. 6-inch-diameter high-density polyethylene piping is assumed. The actual pipe diameter may be different and would be determined with hydraulic modeling during remedial design.
  - The influent flow rate is 189 L/min (50 gal/min).
  - The initial influent hexavalent chromium concentration is 7,500 μg/L and declines to 100 μg/L by the year 2015.
  - The ion exchange system regeneration occurs every 2 weeks.
  - Rock salt and hydrochloric acid quantities for regeneration are estimated at 208 L (55 gal).
  - Phosphoric acid and sodium hydroxide quantities are scaled based on estimated hexavalent chromium concentrations and mass.
  - The sodium dithionite quantity needed for regeneration is estimated at 3.1 times the estimated hexavalent chromium quantity removed.
  - The waste quantity is scaled based on hexavalent chromium mass.
  - Labor is approximately eight full-time equivalents based on current information.
  - The annual O&M cost of $1.6 million for the pump-and-treat system was estimated from the "100-DX Treatment Plant Pre-Conceptual Design and Cost Estimate Technical Memorandum" (working draft not released).

The 100-KR-4 and 100-KW pump-and-treat systems are configured and operated similar to the 100-D Hot Spot system described above, but are assumed to operate through the year 2018. The $2.71 million O&M cost for the 100-K Area pump-and-treat systems was estimated from actual costs incurred in 2007 (DOE/RL-2008-05, *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump and Treat Operations*, Rev. 0).

A periodic cost equal to 50 percent of the total capital installation cost was included to allow for decommissioning of the three pump-and-treat systems following the 5-year projected operating period at the 100-D Hot Spot and 8 years of operation of the two 100-K Area systems.

6.4 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

A detailed analysis of the components of Alternative 2 with respect to the seven NCP criteria evaluated is presented in Table 6-3 and summarized below.

6.4.1 Overall Protection of Human Health and the Environment

Alternative 2 would achieve overall protection of human health and the environment by addressing hexavalent chromium in the vadose zone and groundwater.

6.4.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 2 would comply with ARARs by addressing hexavalent chromium in the vadose zone and groundwater.

6.4.3 Long-Term Effectiveness and Permanence

Alternative 2 would be effective in the long term. If hexavalent chromium sources are removed, they would be removed permanently and contaminated materials disposed of in the ERDF. Groundwater treatment residuals also may need to be disposed of in the ERDF, depending on the specific ex situ treatment process employed. The conversion of hexavalent chromium to its less toxic, essentially immobile trivalent form is irreversible under typical environmental conditions such as those present on the Hanford Site. The technologies in Alternative 2 are adequate and reliable.

6.4.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Application of the ISR component of this remedial action alternative will convert hexavalent chromium in impacted soil and groundwater to the less soluble, essentially immobile, and less toxic trivalent form of chromium. This will substantially reduce the volume of these environmental media containing exceedances of hexavalent chromium. If other co-contaminants such as mercury, lead, organics, and radioisotopes are present, some component of RTD may be required for their removal.

The excavation of contaminated soils, as part of the RTD component of this remedial action alternative, will decrease the volume of hexavalent chromium-contaminated soil at the site. Those excavated soils, if any, with sufficiently high concentrations of hexavalent chromium will be pretreated before disposal at ERDF, to convert the hexavalent chromium to the less toxic and essentially immobile trivalent form.

Groundwater pump-and-treat implemented as part of this remedial action alternative will decrease the volume of hexavalent chromium-contaminated groundwater. The hexavalent chromium removed by the groundwater treatment process (for example, by ion exchange) will be properly treated and disposed of.

6.4.5 Short-Term Effectiveness

Risks to workers, the community, and the environment would be moderate for excavation and low for ISR and groundwater pump-and-treat. Mobilization of redox-sensitive or other currently immobile constituents is not anticipated to be an issue for ISR and will be evaluated as part of pre-design treatability studies. If, however, redox-sensitive metals such as iron, manganese, or arsenic are significantly mobilized during ISR, it is anticipated that these constituents will be (1) reoxidized and sequestered in the aquifer matrix as the ISR-impacted groundwater is reoxygenated before discharging to the river, or (2) captured before reaching the river by a pump-and-treat system. If non-redox sensitive (for example, certain radioactive) constituents are mobilized by the flushing action of these technologies, these constituents will be attenuated by aquifer adsorption processes or captured before reaching the river by the pump-and-treat system. Sustainability of Alternative 2 is considered higher for ISR because this technology is not energy intensive and results in lower greenhouse gas emissions, does not generate ex situ treatment residuals that must be managed, and is minimally disruptive of the site. Sustainability is considered moderate for RTD and groundwater pump-and-treat because of energy requirements and treatment residuals that must be managed indefinitely.

6.4.6 Implementability

ISR offers similar flexibility in implementation. In some cases there could be some advantage over RTD in areas of the Site that are relatively inaccessible (for example, culturally sensitive areas and near buildings and utilities). Sufficient areas are available for implementing the technologies such that RAOs can be achieved.

Table 6-3. Detailed Evaluation of Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

	Shallow Soil	Deep Soil	Source Area Groundwater	Groundwater Not Treated by ISR	Groundwater Adjacent to River
Description of remedy	Chromium-contaminated soils and/or debris would be excavated, treated as required, and disposed of at the ERDF. (It is anticipated that RTD will be employed for most shallow contaminated soil. There may be occasional situations in which shallow soils are more appropriately treated by ISR; for example, if subsurface utilities present an obstacle to excavation. In these situations, the information pertaining to deep soil would apply.)	Deep soil may be excavated with open-pit type of excavation or using caissons or other shoring methods. Alternatively, hexavalent chromium-contaminated soil would be treated using ISR in which water amended with a highly biodegradable organic material or chemical reductants is carefully metered through the soil to promote reduction of hexavalent chromium to trivalent chromium.	Groundwater in the vicinity of hexavalent chromium-contaminated source areas would be treated using ISR, potentially in conjunction with treatment of vadose zone soils. Amended water, after infiltrating downward through the vadose zone (and reacting with and entraining hexavalent chromium along the way), would encounter and mix with groundwater. Remaining amendment would promote reduction of hexavalent to trivalent chromium in groundwater. If groundwater exceeded chromium standards, it could be extracted and either amended with organic substrate and reinjected or treated ex situ.	Groundwater not treated by ISR would be remediated by groundwater extraction and ex situ treatment using ion exchange or other effective ex situ treatment technology.	Groundwater adjacent to the river would be extracted and treated ex situ. Alternatively, groundwater adjacent to the river could be treated by ISR. Before discharge to the river, groundwater may be oxygenated via air sparging or some other means.
1. Overall Protection of Human Health and the Environment					
	Excavation would remove contaminant mass leaching to groundwater and would minimize potential exposure to contaminated soils through direct contact and ingestion.	For excavated deep soil, same as for shallow soil. For treated soil, ISR would convert hexavalent chromium to the less toxic trivalent form that forms strong complexes with soil minerals, making it essentially immobile and less available for biological uptake.	ISR would convert hexavalent chromium to the much less toxic trivalent form that forms strong complexes with soil minerals, making it essentially immobile and less available for biological uptake.	Groundwater would be extracted from the subsurface and hexavalent chromium would be removed by ion exchange or some other process. Treated groundwater would be reinjected to the subsurface far enough upgradient of the river, and with sufficiently low chromium concentrations, that it would be safe for human health and the environment.	Groundwater extracted and treated ex situ would be reinjected to the subsurface far enough upgradient of the river, and with sufficiently low chromium concentrations, that it would be safe for human health and the environment. Alternatively, ISR would convert hexavalent chromium to the much less toxic trivalent form that forms strong complexes with soil minerals, making it essentially immobile and less available for biological uptake.
2. Compliance with ARARs					
	ARARs would be met because soil with chromium concentrations exceeding safe levels for human health and the environment would be removed, treated, and disposed in a secure facility (ERDF).	For excavated deep soil, same as for shallow soil. For treated soil, ARARs would be met because vadose zone soil with elevated hexavalent chromium concentrations would be treated such that hexavalent chromium would be converted to the less toxic and mobile trivalent form and resulting hexavalent and total chromium concentrations in soil would meet soil ARARs.	Would meet ARARs of 48 µg/L hexavalent chromium in inland groundwater, 20 µg/L hexavalent chromium in groundwater discharging to the river, and 100 µg/L total chromium in all Site groundwater. It is possible that redox-sensitive metals such as iron, manganese, or arsenic could be mobilized and temporarily exceed ARARs in groundwater. However, when the groundwater is sufficiently oxygenated, as it must be before discharge to the river (6 mg/L dissolved oxygen is required), the metals would be reimmobilized. If ISR flushes non-redox sensitive radiological constituents such that they exceed ARARs, groundwater pump-and-treat could be employed for their removal. It is not anticipated that these issues will occur, but treatability and/or pilot testing will be conducted to confirm this theory.	Same as for source area groundwater.	Same as for source area groundwater. In addition, would meet ARAR of 6 mg/L dissolved oxygen in groundwater discharging to the river.

Table 6-3. Detailed Evaluation of Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

	Shallow Soil	Deep Soil	Source Area Groundwater	Downgradient Groundwater	River Protection
3. Long-Term Effectiveness and Permanence					
(a) Magnitude of residual risks	Once excavation is completed, residual risks may remain in soils not excavated.	For excavated deep soil, same as for shallow soil. For treated soil, ISR of contaminated soils would irreversibly convert hexavalent to trivalent chromium. It is anticipated that resulting trivalent chromium concentrations in soil would be below acceptable levels. This would be confirmed by post-treatment soil sampling and analysis during pilot testing.	ISR would continue until standards for hexavalent chromium in groundwater were met. The residual from the process would be trivalent chromium, most of which would bind strongly and irreversibly to soil minerals in situ. Some trivalent chromium may remain in the dissolved phase. Post-treatment sampling of soil and groundwater would be undertaken to confirm that applicable standards for hexavalent and total chromium are met in groundwater and saturated soil.	Groundwater pump-and-treat would continue until standards for hexavalent and total chromium in groundwater were achieved. Ex situ treatment residuals, such as ion exchange resin and ion exchange brine, would be handled appropriately to minimize their residual risks.	Same as for source area groundwater and downgradient groundwater. In addition, groundwater would be oxygenated before discharge to the river.
(b) Adequacy and reliability of controls	Excavation is adequate and reliable.	For excavated deep soil, same as for shallow soil. For treated soil, ISR of hexavalent chromium in soil has been demonstrated to be adequate, reliable, and irreversible in numerous treatability studies and at several hexavalent chromium-contaminated field sites throughout the U.S.	ISR of hexavalent chromium in groundwater has been demonstrated to be adequate, reliable, and irreversible in numerous treatability studies and at several hexavalent chromium-contaminated field sites throughout the U.S.	Groundwater pump-and-treat has been proven to be adequate and reliable for hexavalent chromium at this Site and others.	Same as for source area groundwater and downgradient groundwater. Oxygenation of groundwater before discharge to the river may be required in order for the proposed remediation methods to be adequate.
4. Reduction of TMV through Treatment					
(a) Treatment process used	Excavated soils and/or debris may be treated before disposal in the ERDF, as necessary, to meet land-disposal requirements.	For excavated deep soil, same as for shallow soil. For treated soil, biological or chemical reduction of hexavalent to trivalent chromium.	Biological or chemical reduction of hexavalent to trivalent chromium.	Ion exchange or other appropriate ex situ treatment technology.	Same as for source area groundwater and downgradient groundwater. In addition, oxygenation of groundwater before discharge to the river.
(b) Degree and quantity of TMV reduction	TMV of hexavalent chromium in the 100 Area would be decreased by removal of impacted soils and/or debris. Soils and/or debris removed during excavation would be treated before disposal in the ERDF, as necessary, to meet land-disposal requirements.	For excavated deep soil, same as for shallow soil. For treated soil, toxicity and mobility would be greatly decreased by ISR of hexavalent to trivalent chromium. Volume would not be significantly decreased in soil except to the extent that hexavalent chromium is carefully metered from the vadose zone into groundwater.	Toxicity and mobility would be greatly decreased by ISR of hexavalent to trivalent chromium. Volume would not be significantly decreased in groundwater except to the extent that groundwater is subsequently pumped and treated.	TMV of hexavalent chromium in groundwater would be decreased by groundwater extraction. TMV of the hexavalent chromium extracted via groundwater may be decreased depending on details of the ex situ treatment system employed. Overall volume ultimately cannot be decreased because chromium is an element; however, the volume of hexavalent chromium in the 100 Area would be decreased via groundwater extraction.	Same as for source area groundwater and downgradient groundwater.
(c) Irreversibility of TMV reduction	Excavation of soils is irreversible.	For excavated deep soil, same as for shallow soil. For treated soil, ISR of hexavalent to trivalent chromium has been demonstrated to be irreversible under typical environmental conditions such as those that exist at the Site.	ISR of hexavalent to trivalent chromium has been demonstrated to be irreversible under typical environmental conditions such as those that exist at the Site.	Groundwater extraction is irreversible. Ex situ treatment may be reversible depending on the specific technology employed. For example, adsorption onto ion exchange resins is reversible, and resins often are regenerated by desorbing the adsorbed contaminants.	Same as for source area groundwater and downgradient groundwater.

Table 6-3. Detailed Evaluation of Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

	Shallow Soil	Deep Soil	Source Area Groundwater	Downgradient Groundwater	Downgradient Groundwater
(d) Type and quantity of treatment residuals	Treatment residuals would consist of excavated hexavalent chromium-contaminated soils and/or debris and any amendments needed to treat the soil before disposal in the ERDF to meet land-disposal requirements. The quantities of soil to be excavated and treated would be established by Washington Closure Hanford, LLC during RTD operations.	For excavated deep soil, same as for shallow soil. For treated soil, treatment residuals would consist of trivalent chromium in soil in situ and potentially hexavalent and trivalent chromium that is carefully metered to groundwater. (However, chromium in groundwater subsequently would be handled through groundwater ISR or pump-and-treat.)	Treatment residuals would consist of trivalent chromium, the majority of which would be adsorbed to soil in situ. Some trivalent chromium could be dissolved in groundwater. Sampling and analysis will be used to confirm that dissolved trivalent chromium concentrations are below standards. In the event that they are not, groundwater pump-and-treat would be employed.	Treatment residuals will depend on the specific ex situ treatment process employed and could consist of spent ion exchange resin, ion exchange brine, or other residuals if some other ex situ treatment process is used.	Same as for source area groundwater and downgradient groundwater.
(e) Statutory preference for treatment	Preference would be met for excavated soils that would be treated as necessary before disposal in the ERDF.	For excavated deep soil, same as for shallow soil. For treated soil, preference would be met because hexavalent chromium-contaminated soil that is the source of groundwater contamination would be irreversibly treated.	Preference would be met because hexavalent chromium would be irreversibly treated.	Preference would be met because hexavalent chromium would be removed from the aquifer and treated.	Preference would be met because hexavalent chromium would be irreversibly treated or removed from the aquifer, and groundwater would be oxygenated before discharge to the river.
5. Short-Term Effectiveness					
(a) Protection of workers during remedial action	Risk to workers during remedial construction would be mitigated by adherence to site-specific H&S plans and engineering controls (for example, dust suppression).	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.
(b) Protection of community during remedial action	Risks to the community during remedial construction include dust and safety risks from the presence of open excavations. These risks would be mitigated during implementation through use of engineering controls.	For excavated deep soil, same as for shallow soil. For treated soil, engineering controls would be used to protect the community from dust.	Engineering controls would be used to protect the community from dust.	Risks to the community would be mitigated by keeping community members away from work areas.	Same as for source area groundwater and downgradient groundwater.
(c) Environmental impacts of remedial action	Minimal risks to the environment will occur during excavation assuming implementation of adequate monitoring and engineering controls (for example, erosion controls).	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.
(d) Time until RAOs are achieved	Excavation will be used to assist in meeting the groundwater protection RAO by 2020.	For excavated deep soil, same as for shallow soil. For treated soil, vadose zone ISR will assist in meeting the groundwater protection RAO by 2020.	Groundwater ISR will assist in meeting the river protection RAO by 2012 and the groundwater protection RAO by 2020.	Groundwater pump-and-treat will assist in meeting the river protection RAO by 2012 and the groundwater protection RAO by 2020.	Same as for source area groundwater and downgradient groundwater.
(e) Sustainability	High-energy use and greenhouse gas emissions will occur from excavation equipment. Moderate energy use and greenhouse gas emission by transporting soil to nearby ERDF. Generates treatment residuals that must be managed indefinitely.	For excavated deep soil, same as for shallow soil. For treated soil, low-energy use and greenhouse gas emissions. Treatment residuals remain in situ and do not require management. Minimal site disruption.	Low-energy use and greenhouse gas emissions. Treatment residuals remain in situ and do not require management. Minimal site disruption.	High-energy use and greenhouse gas emissions from groundwater extraction. Treatment residuals require disposal. Minimal site disruption.	Same as for source area groundwater and downgradient groundwater. Water restored for ecological reuse in river.
6. Implementability					
(a) Technical feasibility	Feasible.	Feasible.	Feasible.	Feasible.	Feasible.
(b) Administrative feasibility	Administratively feasible; however, access is not possible in some areas, such as culturally sensitive areas and near buildings and utilities.	For excavated deep soil, same as for shallow soil. ISR may be administratively feasible in some areas where RTD is infeasible, for example, in areas with subsurface utilities.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.
(c) Availability of services and materials	Necessary engineering services and materials are readily available.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.	Same as for shallow soil.

Table 6-3. Detailed Evaluation of Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

	Shallow Soil		Deep Soil		Subsurface Groundwater	Demonstration Considerations	Other Factors
7. Present-Worth Cost to Remediate 100-D Area Southern Plume Hot Spot							
Present-worth cost*	100-D-12:	$670,000	100-D-12:	$2,440,000	100-D Hot Spot: $12.3 million		Not applicable.
	100-D-30 SW:	$780,000	100-D-30 SW:	$2,250,000	100-K Plume: $39.2 million		
	600-334:	$10,000	600-334:	$2,250,000			
	116-K-2:	$790,000	116-K-2:	$2,440,000			
	100-C-7:1	$710,000	100-C-7:1	$2,250,000			
	100-C-7:	$710,000	100-C-7:	$2,250,000			
	Future Site #1:	$710,000	Future Site #1:	$2,250,000			
	Future Site #2:	$710,000	Future Site #2:	$2,250,000			
	Future Site #3:	$710,000	Future Site #3:	$2,250,000			
	Future Site #4:	$710,000	Future Site #4:	$2,250,000			

NOTES: *The information in this preliminary cost estimate is based on the best available information regarding the anticipated scope of potential remedial action alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the feasibility study and/or during engineering design of the remedial action alternatives. The range presented is +50 to -30 percent of the order-of-magnitude cost estimate provided in Appendix B for the six known and four future sites selected for comparison. The cost for shallow soil remediation (depth presented in Appendix B) remains RTD, yet the deep soil is addressed by ISR. Deep soil also addresses groundwater hot spot where applicable.

ARAR = applicable or relevant and appropriate requirement.
ERDF = Environmental Restoration Disposal Facility.
H&S = health and safety.
ISR = in situ reduction.
RAO = remedial action objective.
RTD = removal, treatment, and disposal.
TMV = toxicity, mobility, or volume.

6.4.7 Cost

The combination of RTD, groundwater pump-and-treat, and ISR can be optimized to minimize overall cost. The ISR in particular is an extremely cost-effective way to address hexavalent chromium in the vadose zone and in groundwater hot spots.

To illustrate this, the southern plume groundwater hot spot and overlying vadose zone in the 100-D Area is used to demonstrate the cost of the ISR technology. For this example, costs are developed for ISR of the 9.1 by 9.1 m (30 by 30 ft) 100-D Area southern plume hot spot and overlying vadose zone are presented to compare (in Chapter 7) with the RTD and pump and treat costs presented in Section 6.3.7.

The total estimated net present value cost for Alternative 2 for application at the ten waste sites is $81.5 million. This includes RTD at nine waste sites, vadose zone ISR treatment at eight sites, vadose zone and groundwater hot spot ISR treatment at two sites, and continuing use of existing pump-and-treat systems for the durations established in Alternative 1.

The ISR cost estimate includes capital costs, O&M, and periodic costs.

- The capital cost includes purchase, delivery, and installation costs for all system components, plus allowances for scope/bid contingency, project management, remedial design and construction management.
- The annual O&M costs include costs for ISR reagent chemicals, a full-time system operator, and electricity ($0.034 per kWh) to operate the fluid transfer pumps. The O&M timeframe is estimated at 9 months.
- The periodic cost includes a 35 percent allowance, based on capital costs, to decommission the ISR system once treatment is complete, and move it to another waste site for reuse.

6.5 *National Environmental Policy Act of 1969* Values Evaluation

The 42 USC 432 *National Environmental Policy Act of 1969* (NEPA) process is intended to help federal agencies make decisions that are based on understanding environmental consequences and then to take actions that protect, restore, and enhance the environment. Secretarial policy (DOE, 1994, *Secretarial Policy Statement on the National Environmental Policy Act*) and DOE O 451.1B, *National Environmental Policy Act Compliance Program – Change 1*, require that CERCLA documents incorporate NEPA values such as analysis of cumulative, offsite, ecological and socioeconomic impacts to the extent practicable, in lieu of preparing separate NEPA documentation for CERCLA activities.

6.5.1 Description of *National Environmental Policy Act of 1969* Values

Several of the CERCLA evaluation criteria involve consideration of environmental resources, but the emphasis frequently is directed at the potential effects of chemical contaminants on living organisms. The NEPA regulations (40 CFR 1502.16, "Environmental Consequences") specify evaluation of the environmental consequences of proposed alternatives. These include potential effects on transportation resources, air quality, and cultural and historical resources; noise; visual and aesthetic effects; environmental justice; and the socioeconomic aspects of implementation. The NEPA process also involves consideration of several issues such as cumulative impacts (direct and indirect), mitigation of adversely affected resources, and the irreversible and irretrievable commitment of resources. The NEPA-related resources and values that DOE has considered in this evaluation include the following:

- Transportation Impacts. This value considers impacts of the proposed remedial action on local traffic (that is, traffic at the Hanford Site) and traffic in the surrounding region. Transportation impacts are considered in part under the CERCLA criteria of short-term effectiveness or implementability.
- Air Quality. This value considers potential air quality concerns associated with emissions generated during the proposed remedial actions.
- Natural, Cultural, and Historic Resources. This value considers impacts of the proposed remedial actions on wildlife, wildlife habitat, archaeological sites and artifacts, and historically significant properties in the Central Plateau.
- Noise, Visual, and Aesthetic Effects. This value considers increases in noise levels or impaired visual or aesthetic values in the Central Plateau during or following the proposed remedial actions.
- Socioeconomic Impacts. This value considers impacts pertaining to employment, income, other services (for example, water and power utilities), and the effect of implementation of the proposed remedial actions on the availability of services and materials.
- Environmental Justice. Environmental justice, as mandated by "Executive Order 12898 of February 11, 1994, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (59 FR 7629), refers to fair treatment of humans of all races, cultures, and income levels with respect to laws, policies, and government actions. This value considers whether the proposed remedial actions would have inappropriately or disproportionately high and adverse human health or environmental effects on minority or low-income populations.
- Cumulative Impacts (Direct and Indirect). This value considers whether the proposed remedial actions could have cumulative impacts on human health or the environment when considered together with other activities in the Central Plateau, at the Hanford Site, or in the region.
- Mitigation. If adverse impacts cannot be avoided, remedial action planning should minimize them to the extent practicable. This value identifies required mitigation activities.
- Irreversible and Irretrievable Commitment of Resources. This value evaluates the use of nonrenewable resources for the proposed remedial actions and the effects that resource consumption would have on future generations. When a resource (for example, energy, minerals, water, wetland) is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.

6.5.2 Detailed Evaluation of the *National Environmental Policy Act of 1969* Criteria

The no action alternative would have very limited if any impact relative to the NEPA criteria described above. Therefore, it is not discussed further in the following subsections.

6.5.2.1 Transportation Impacts

Implementation of Alternative 1 at hexavalent chromium waste sites will have short-term impacts on local traffic and traffic in the surrounding region. A majority of this impact is associated with the increased truck traffic as contaminated soil is moved from a waste site(s) to the ERDF. The magnitude of this impact grows in proportion to the number and size of sites that are remediated under Alternative 1.

Under Alternative 2, all soil and groundwater treatment is performed in situ, thus eliminating a majority of the transportation impacts. The ISR system operations will require routine operator visits to the site,

and periodic replenishment of ISR reagent. However, the total transportation impact from these activities is considerably smaller than that associated with haul-truck traffic under Alternative 1.

6.5.2.2 Air Quality

Air quality impacts from fugitive dust and RTD diesel equipment exhaust will be greatest under Alternative 1. These impacts are short-term and will occur while soil is being moved from the waste site(s) to ERDF. Fugitive dust emissions can be controlled with suppression measures. Alternative 2 will have very little, if any, measureable air quality impacts because a majority of the treatment is accomplished using electric pumps and gravity-fed chemical drip equipment.

6.5.2.3 Natural, Cultural, and Historic Resources

Alternative 1 and Alternative 2 are fairly intrusive, requiring disturbance of the ground surface and subsurface at each waste site. This activity could affect natural, cultural or historic resources, although the impacts could be mitigated. Adverse impacts to cultural resources could occur if such resources were encountered and appropriate mitigating actions were not taken. Adverse impacts would be minimized by avoiding known cultural resource and traditional-use areas whenever possible. Most of the waste sites in the 100 Area are located within areas previously disturbed by operations. Therefore, the potential for encountering resource sites during RTD excavation or emplacement of the chemical drip system is anticipated to be low. A cultural resource mitigation plan would be established before remediation begins. Known cultural resources and traditional-use areas would be avoided whenever possible. If cultural resources were encountered, the State Historic Preservation Office and Native American Tribes would be consulted about minimizing impacts and taking appropriate actions for resource documentation or recovery.

Some short-term adverse impacts to natural resources (for example, local wildlife) could occur during the construction and implementation phases of each alternative. Ecological surveys would be performed to identify the species present and the special precautions that should be taken to minimize adverse impacts. Revegetation of the waste sites following RTD and decommission of the groundwater treatment system and the ISR building would have positive impacts on natural resources

6.5.2.4 Noise, Visual, and Aesthetic Effects

Alternative 1 would pose the greatest noise, visual and aesthetic impact. These impacts would be highest while RTD work is being carried out, with some visual and aesthetic impacts from groundwater treatment extending for approximately 5 years. Alternative 2 would also have similar short-term impacts with a majority of these impacts resulting from RTD and pump-and-treat; it is anticipated that the RTD component of Alternative 2 is to be far less extensive and completed in a much shorter timeframe.

6.5.2.5 Socioeconomic Impacts

Alternative 1 would have greater positive socioeconomic impacts than Alternative 2 because of the employment opportunities that would arise during the life of the remedial action project. The labor force required to implement Alternative 1 would be drawn from current Hanford Site contractors and the local labor force, so adverse socioeconomic impacts would be minimal.

6.5.2.6 Environmental Justice

Because of the remote location of the 100 Area, environmental justice impacts from either alternative would be limited. Remedial action is expected to restore the 100 Area to an unrestricted use status.

6.5.2.7 Irreversible and Irretrievable Commitment of Resources

Alternative 1 and Alternative 2 would result in some temporary land-use loss during implementation. The RTD component under Alternative 1 would require fill material that would have to be obtained from borrow pits, and considerably more energy resources than required by Alternative 2. Both alternatives would require some short-term land-use loss until RAOs are achieved. However, the amount of land-use loss is small relative to the total amount of undisturbed land available in the 100 Area. Following completion of the remedial action, both alternatives would allow for unrestricted land use.

Alternative 1 would require some irreversible/irretrievable commitment of resources in the form of geologic materials (fill) and petroleum products (for example, diesel fuel, gasoline). Alternative 2 would rely primarily on electricity and gravity to deliver the ISR reagent to the waste site.

6.5.2.8 Cumulative Impacts

The remedial action activities associated with Alternative 1 and Alternative 2 are expected to have minor impacts when considered together with impacts from past and foreseeable future actions at and near the Hanford Site. Authorized current and future activities will include soil and groundwater remediation; demolition and decommissioning of inactive facilities, and site-related surveillance and maintenance activities.

6.5.2.9 Mitigation

Mitigation measures under the both alternatives would likely include surveillance, physical controls, and potential interim remedies. Mitigation measures under Alternative 1 and Alternative 2 would likely include dust suppression, stockpiling clean topsoil for reuse, minimizing the size of construction areas, and planning activities to avoid nesting and breeding cycles of birds and mammals.

6.5.2.10 Summary of National Environmental Policy Act of 1969 Evaluation

Hexavalent chromium contaminated soil and groundwater remedial actions in the 100 Area would result in some minor impacts. The long-term benefits from these remedial actions are within those normally experienced for similar type projects and are expected to offset the short-term impacts.

7. Comparative Analysis of Alternatives

This chapter presents a comparative analysis of the three remedial action alternatives developed for the 100 Area hexavalent chromium sources and groundwater plume hot spots. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the CERCLA evaluation criteria, and one another, so the key tradeoffs that have to be weighed to select a preferred remedial action alternative in the Proposed Plan are understood. The CERCLA modifying criteria of support regulatory agency and community acceptance are not discussed in the comparative analysis. The support regulatory agency concurrence criteria will be addressed through the development and issuance of the Proposed Plan. The community acceptance criteria will be addressed following the Proposed Plan public comment period through the amended interim action ROD responsiveness summary.

The remedial action alternatives discussed in the comparative analysis include:

- No Action
- Alternative 1 – Continue Current Actions
- Alternative 2 – Continue Current Actions with Selective Application of ISR.

7.1 Threshold Criteria

The threshold criteria for overall protection for human health and the environment and compliance with ARARs must be met by an alternative to be eligible for selection. An alternative that satisfies the criteria for overall protection of human health and the environment, but does not attains ARARs, may be selected if an ARAR's waiver is justified based on the circumstances described in the NCP under 40 CFR 300.430 (f)(1)(ii)(C), "*Selection of Remedy*."

7.1.1 Overall Protection of Human Health and the Environment

Because institutional controls were established in the prior interim action RODs, human health is currently protected under both alternatives. Alternative 2 provides a higher degree of protection for the environment because it includes additional technology to address hexavalent chromium in shallow and deep soil, and groundwater. Waste sites with shallow soil contamination will continue to be remediated through RTD, whereas deep soil will be addressed using ISR which converts hexavalent chromium to a less toxic and essentially immobile form (trivalent). Treatment of deep soil is accomplished in nine months using ISR versus up to 2 years for RTD under Alternative 1. Similarly, treatment of hot spot groundwater is accomplished in less than 1 year with ISR 5 years or longer using pump-and-treat under Alternative 1. The accelerated treatment of soil and groundwater is deemed to provide a higher degree of protection for the environment.

The no action alternative is not protective of human health and the environment because hexavalent chromium contaminated groundwater would continue to enter the Columbia River where it could pose a threat to aquatic receptors. Hexavalent chromium would also continue to leach from soil to groundwater, which in turn would result in long-term impacts to the environment. Therefore, the no action alternative is not protective of human health or the environment. The no action alternative was also rejected in previous 100 Area focused feasibility studies developed for the soil and groundwater OUs that were the basis for the existing interim action RODs.

7.1.2 Compliance with ARARs

The ARARs and point of compliance (monitoring wells near the river bank) as set forth in the identified interim RODs are unchanged. The primary ARAR for both alternatives is the Washington State and EPA ambient water quality criteria (AWQC) for hexavalent chromium. The AWQC for hexavalent chromium in river water has changed from the level identified in the groundwater OU interim RODs. The river water AWQC for hexavalent chromium has declined from 11 µg/L to 10 µg/L. Accordingly, the hexavalent chromium concentration in groundwater at the river bank has also declined from 22 µg/L to 20 µg/L based on the 1:1 mixing ratio.

The major ARARs for Alternative 1 also include the WAC 173-340 soil standards, and State of Washington standards for discharge of treated groundwater and management of hazardous waste (spent resin and brine). The major ARARs for Alternative 2 are the same as those identified for Alternative 1 with the addition of the Underground Injection Control Program.

Because both alternatives represent interim actions designed to reduce immediate ecological risks, they are not specifically intended to meet the ARARs that would be applicable to the final remedy. However, as indicated by the working objectives, both alternatives were developed with the expectation that they would become part of the final remedy. Therefore, both alternatives comply with the identified ARARs.

7.2 Balancing Criteria

The identification of a preferred remedial alternative, from those alternatives that satisfy the threshold criteria (unless an ARARs waiver is justified), is based primarily on how well the alternative performs relative to the balancing criteria. Because the no action alternative did not meet the threshold criteria for protection of human health and the environment it cannot be selected and is not evaluated further.

7.2.1 Long-Term Effectiveness and Permanence

This criterion relates primarily to the health risks that remain at the site once RAOs are met, and the extent and effectiveness of controls that may be required to manage the risk posed by untreated soil. Both alternatives provide long-term effectiveness and permanence but differ in how this is accomplished. Under Alternative 1, contaminated soil is excavated, treated if necessary, and transported to the ERDF. Similarly, contaminated groundwater is treated and the treatment residuals potentially disposed of at the ERDF. Alternative 2 also contains these elements, but with ISR some contaminated soil and groundwater would be treated in situ to convert hexavalent chromium to its less toxic trivalent form. This eliminates the need for management and disposal of hexavalent chromium contaminated soil and treatment residuals at the ERDF.

7.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion addresses the NCP statutory preference for treatment that yields a significant and permanent reduction in contaminant TMV. Alternative 1 reduces the mobility and volume of contaminated soil and groundwater by consolidating hexavalent chromium-contaminated media at the ERDF, and on ion exchange resin or within the resin brine which is also subsequently disposed at the ERDF. Alternative 2 also contains these elements, but the ISR component also reduces toxicity and mobility by converting hexavalent chromium to its trivalent form.

7.2.3 Short-Term Effectiveness

This criterion addresses the hazards to human health and the environment associated with the alternative's construction and implementation until RAOs are met. Both alternatives satisfy this criterion. However, under the ISR component of Alternative 2, the magnitude of risk to workers and the environment is reduced because the volume of contaminated soil and the volume of ion exchange resin and resin brine

that have to be handled are significantly reduced. The time required to achieve RAOs is also expected to be shorter under Alternative 2 because a large proportion of the contaminated media is treated in situ rather than brought to the surface for treatment and disposal.

7.2.4 Implementability

This criterion relates to the technical and administrative feasibility of implementing an alternative and the availability of resources necessary for implementation. Both alternatives are readily implemented and do not pose significant technical or administrative challenges. Under the ISR component of Alternative 2, bench-scale and/or field-scale testing may be required during remedial design to optimize the ISR reagent dose.

7.2.5 Cost

The total net present value of $81.5 million for Alternative 2 is considerably less than the $180 million for Alternative 1. The RTD component of Alternative 1 accounts for $127.4 million, groundwater pump-and-treat $51.5 million, and ICs the remainder of the total cost. The RTD component of Alternative 2 accounts for $6.5 million, groundwater pump-and-treat $51.5 million, ISR $22.9 million, and ICs the remainder of the total cost.

Remedial action alternative costs at the feasibility study level are generally presented as a -30 to + 50 percent cost range to reflect uncertainty in the project's overall scope. Accordingly, the expected net present value cost range for Alternative 1 is estimated to vary from $125.8 million (-30 percent) to $279.5 million (+50 percent) and that for Alternative 2 is $56.2 million (-30 percent) to $120.4 million. More detailed cost estimates will be developed during remedial design.

7.3 Key Tradeoffs

The national goal of the remedy selection process (40 CFR 300.430(a)(i), "*Remedial Investigation/ Feasibility Study and Selection of Remedy*") is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste.

Alternative 1 and Alternative 2 protect human health using institutional controls to prevent inadvertent exposure. Protection of human health over time is achieved by maintaining institutional controls until the RAOs are achieved. Protection of the environment under Alternative 1 is achieved by removing and consolidating source material at the ERDF, and treating groundwater to remove hexavalent chromium. Groundwater treatment residuals are also consolidated at the ERDF. Alternative 2 protects the environment by treating contaminated soil and groundwater in situ to convert hexavalent chromium to its less toxic, essentially immobile trivalent form. The treatment process has been demonstrated to be irreversible under typical environmental conditions such as those present on the Hanford Site, therefore, protection over time is maintained. Both alternatives minimize untreated waste.

The key tradeoff between the two alternatives is how and where treatment is performed. Under Alternative 1, final treatment is performed and the treatment residuals managed at the ERDF. Under Alternative 2, the treatment is performed in situ reducing or eliminating the need to bring contaminated soil and groundwater to the surface for treatment. In situ treatment can be performed within a shorter timeframe.

This page intentionally left blank.

8. References

10 CFR 1022, "Compliance with Floodplain and Wetland Environmental Review Requirements," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/10cfr1022_08.html

40 CFR 6, "Procedures for Implementing the National Environmental Policy Act and Assessing the Environmental Effects Abroad of EPA Actions," Appendix A, *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr6_08.html

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr61_08.html

40 CFR 61.01, "Lists of Pollutants and Applicability of Part 61," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr61.01.htm

40 CFR 61.05, "Prohibited Activities," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr61.05.htm

40 CFR 61.12, "Compliance with Standards and Maintenance Requirements," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr61.12.htm

40 CFR 61.14, "Monitoring Requirements," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr61_08.html

40 CFR 131, "Water Quality Standards," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr131_08.html

40 CFR 131.10, "Designation of Uses," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr131.10.htm

40 CFR 131.36, "Designation of Uses," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr131.36.htm

40 CFR 131.36(b)(1), "EPA's Section 304(a) Criteria for Priority Toxic Pollutants," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr131.36.htm

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr141_08.html

40 CFR 141.51, "Maximum Contaminant Level Goals for Inorganic Contaminants," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr141.51.htm

40 CFR 141.62, "Maximum Contaminant Levels for Inorganic Contaminants," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr141.50.htm

40 CFR 144, "Underground Injection Control Program," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr144_08.html

40 CFR 146, "Underground Injection Control Program: Criteria and Standards," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr146_08.html

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr268_08.html

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr300_08.html

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr141.50.htm

40 CFR 300.430(a)(i), "Remedial Investigation/Feasibility Study and Selection of Remedy," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr300.430.pdf

40 CFR 300.430(e), "Detailed Analysis of Alternatives," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr300.430.pdf

40 CFR 300.430(e)(6), "The No-Action Alternative," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2007/julqtr/pdf/40cfr300.430.pdf

40 CFR 300.430(e)(9), "Detailed Analysis of Alternatives," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr300.430.pdf

40 CFR 300.430(e)(9)(iii), "Nine Criteria for Evaluation," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr300.430.pdf

40 CFR 300.430 (f)(1)(ii)(C), "Selection of Remedy," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2004/julqtr/40cfr300.430.htm

40 CFR 300.440, "Procedures for Planning and Implementing Off-site Response Actions," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr141.50.htm

40 CFR 1502.16, "Environmental Consequences," *Code of Federal Regulations*. http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi

59 FR 7629, 1994, "Executive Order 12898 of February 11, 1994, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," Federal Register, Vol. 59, No. 32 (February 11). http://www.epa.gov/fedrgstr/eo/eo12898.htm

Archeological and Historic Preservation Act of 1960, 16 USC 469aa, et seq. http://www.law.cornell.edu/uscode/16/469.html

BHI-01185, 1998, *100-D Area Chromium Study Summary Report*, Bechtel Hanford, Inc., Richland, Washington.

BHI-01237, 1998, *Description of Work for Fiscal Year 1999 Drilling Within the Chromium Plume West of the 100-D/DR Reactors*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D8415370

BHI-01747, 2004, *Results of Hexavalent Chromium Sampling Near 100-D Area Sodium Dichromate Transfer Station Railroad Tracks*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=DA01162955

Clean Air Act of 1977, 42 USC 7401, et seq. http://www.epa.gov/air/caa/

Clean Water Act of 1977, 33 USC 1251, et seq. http://www.epa.gov/lawsregs/laws/cwa.html

65 FR 37253, 2000, "Establishment of the Hanford Reach National Monument," *Federal Register*, Vol. 65, No. 114, pp. 37253-37257 (June 13). http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000_register&docid=00-15111-filed

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq. http://www.epa.gov/oceaaget/lcla.html#Hazardous%20Substance%20Responses

DOE, 1994, *Secretarial Policy Statement on the National Environmental Policy Act*, DOE Memorandum, H. O'Leary, Secretary, U.S. Department of Energy, Washington, D.C. (June 13). http://gc.energy.gov/NEPA/nepa_documents/TOOLS/GUIDANCE/Volume2/1-6b-secpolicy.html

DOE O 451.1B, Chg 1, *National Environmental Policy Act Compliance Program – Change 1*, U.S. Department of Energy, Washington, D.C. www.directives.doe.gov/pdfs/doe/doetext/neword/451/o4511bc1.pdf

DOE/RL-93-64, 1995, *Sodium Dichromate Expedited Response Action Assessment*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D196084645

DOE/RL-94-61, 1995, *100 Area Source Operable Unit Focused Feasibility Study*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D196006751

DOE/RL-95-108, 1996, *Approach and Plan for Cleanup Actions in the 100-IU-2 and 100-IU-6 Operable Units of the Hanford Site*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D197142718

DOE/RL-95-60, 1995, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D196015041

DOE/RL-96-17, 2004, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D6542354

DOE/RL-2001-41, 2007, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www2.hanford.gov/arpir/?content=findpage&AKey=00099819

DOE/RL-2005-93, 2005, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=DA04193451

DOE/RL-2006-17, 2006, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www2.hanford.gov/arpir/?content=detail&AKey=DA02107064

DOE/RL-2006-20, 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. www5.hanford.gov/pdw/fsd/ar/fsd0001/fsd0003/da05317392/da05317392_39171_1.pdf

DOE/RL-2006-74, 2007, *Field Investigation Plan for the Source of the Southwestern Chromium Plume in the 100-D Area*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-01, 2008, *Hanford Site Groundwater Monitoring for Fiscal Year 2007,* Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www.hanford.gov/cp/gpp/library/gwrep07/html/start07.htm

DOE/RL-2008-05, 2008, *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump and Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. http://www2.hanford.gov/arpir/?content=findpage&AKey=0807090160

DOE/RL-2008-46, 2009, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-66, 2009, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Endangered Species Act of 1973, 16 USC 1531, et seq. http://www4.law.cornell.edu/uscode/16/ch35.html

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. http://www.hanford.gov/?page=91&parent=0

EPA, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision,* U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. April 2004.

EPA, 2005, *Interim Remedial Action Record of Decision Amendment: 100 K Area K Basins,* U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. June 2005.

EPA, 1980, *Comprehensive Environmental Response, Compensation, and Liability Act, Title I—Hazardous Substances Releases, Liability, Compensation, Section 121—Cleanup Standards.*

EPA/540/G-89/004, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*, OSWER 9355.3-01, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

EPA/540/G-89/006, 1988, *CERCLA Compliance with Other Laws Manual: Interim Final*, U.S. Environmental Protection Agency, Washington, D.C.

EPA/540/G-89/009, 1989, *CERCLA Compliance with Other Laws Manual: Part I,* U.S. Environmental Protection Agency, Washington, D.C.

EPA/ROD/R10-95/126, 1995, *Declaration of the Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington,* U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. September 1995. http://www.epa.gov/superfund/sites/rods/fulltext/r1095126.pdf

EPA/ROD/R10-96/134, 1996, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington,* U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. March 1996. http://www.epa.gov/superfund/sites/rods/fulltext/r1096134.pdf

EPA/541/R-00/122, 1999, *Interim Remedial Action Record of Decision Amendment: 100-HR-3 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. October 1999. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-08/044, 1997, *Amended Record of Decision for the 100-BC-1, 100-DR-1 and 100-HR-1 Operable Units*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. April 1997.

EPA/541/R-99/039, 1999, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6 and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. July 1999. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-99/059, 1999, *Declaration of the Record of Decision for the 100-KR-2 Operable Unit, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. September 1999. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. September 1999. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-00/045, 2000, *Explanation of Significant Differences for the 100 Area Remaining Sites Record of Decision: 100-IU-6 Operable Unit,* U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. June 2000. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-00/120, 2000, *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. January 2000. http://www.epa.gov/superfund/sites/rods/

EPA/541/R-00/121, 2000, *Declaration of the Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. September 2000. http://www.epa.gov/superfund/sites/rods/

Geomatrix Consultants, Inc., 2008, *Chromium Treatment Technology Information Exchange for Remediation of Chromium in Groundwater at the Department of Energy Hanford Site,* prepared for Fluor Hanford, Inc., Richland, Washington.

National Environmental Policy Act of 1969, 42 USC 4321, et seq. http://www.epa.gov/oecaerth/basics/nepa.html

National Historic Preservation Act of 1966, 16 USC 470, et seq. http://www.law.cornell.edu/uscode/16/470.html

Native American Graves Protection and Repatriation Act, 25 USC 3001, et seq. http://www4.law.cornell.edu/uscode/25/ch32.html

PNNL-13107, 2000, *Identification of a Hanford Waste Site for Initial Deployment of the In Situ Gaseous Reduction Approach*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13486, 2001, *Characterization Activities Conducted at the 183-DR Site in Support of an In Situ Gaseous Reduction Demonstration*, Pacific Northwest National Laboratory, Richland, Washington.

RCW 70.105, "Hazardous Waste Management Act of 1976," *Revised Code of Washington*, Olympia, Washington. http://apps.leg.wa.gov/RCW/default.aspx?cite=70.105

RCW 70.105D, "Hazardous Waste Cleanup – Model Toxics Control Act," *Revised Code of Washington*, Olympia, Washington. http://apps.leg.wa.gov/RCW/default.aspx?cite=70.105D

RCW 90.48, "Water Pollution Control Act," *Revised Code of Washington*, Olympia, Washington. http://apps.leg.wa.gov/RCW/default.aspx?cite=90.48

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. http://www.epa.gov/epawaste/inforesources/online/index.htm

Safe Drinking Water Act of 1974, 42 USC 300, et seq. http://www.epa.gov/ogwdw/sdwa/

SGW-38338, 2008, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A

WAC 173-201A-240, "Toxic Substances," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-240

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303

WAC 173-303-070(3), "Designation Procedures," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-070

WAC 173-303-140, "Land Disposal Restrictions," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-140

WAC 173-303-140(2)(a), "Applicability," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-140

WAC 173-303-645(3), "Ground Water Protection Standard," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-645

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

WAC 173-340-720(4), "Method B Cleanup Levels for Potable Ground Water," *Washington Administrative Code,* Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720

WAC 173-340-730(3), "Surface Water Cleanup Standards," *Washington Administrative Code,* Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-730

WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-740

WAC 173-340-740(1), "General Considerations," *Washington Administrative Code,* Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-740

WAC 173-340-740(2), "Method A Soil Cleanup Levels for Unrestricted Land Use," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-740

WAC 173-340-740(3), "Method B Soil Cleanup Levels for Unrestricted Land Use," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-740

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/wac/default.aspx?cite=173-340-747

WAC 173-340-750, "Cleanup Standards to Protect Air Quality," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-750

WAC 173-340-900, "Tables," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-900

WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-7490

WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures," *Washington* Administrative *Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-7493

WAC 173-340-7494, "Priority Contaminants of Ecological Concern," *Washington Administrative Code*, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-7494

WCH-191, 2008, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*, Washington Closure Hanford, LLC, Richland, Washington. (http://www.wch-rcc.com/pgs/readroom/WCH/wch191.pdf

This page intentionally left blank.

APPENDIX A

SUMMARY OF NOVEMBER 12-13, 2008 WORKSHOP ON THE EVALUATION OF HEXAVALENT CHROMIUM REMEDIATION TECHNOLOGIES FOR THE 100-B/C AREA

This page intentionally left blank.

Terms

Cr(VI)	hexavalent chromium
H&S	health and safety
O&M	operations and maintenance
RAO	remedial action objective

This page intentionally left blank.

Appendix A

Summary of November 12-13, 2008 Workshop on the Evaluation of Hexavalent Chromium Remedial Technologies for the 100-B/C Area

The evaluation of available chromium treatment technologies performed for the 100-D Area was used as a starting point for a similar evaluation performed for chromium contamination at the 100-B/C Area at a workshop held November 12-13, 2008. At this workshop, technologies that were evaluated and concluded to be non-viable methodologies at the 100-D Area were also assumed to be not applicable for use at the 100-B/C Area. The only exception to this were vadose zone-only technologies that for the 100-D Area were determined to be unsuitable because the hexavalent chromium may be too deep in the vadose zone and because of undesirable subsurface conditions such as cobbles and boulders that may be present in the 100-D Area. Some of these technologies, such as deep soil mixing, were carried forward for further evaluation at the 100-B/C Area, which does not have evidence of significant chromium contamination in the groundwater.

In addition to the evaluation performed for 100-D Area, a document prepared by Pacific Northwest National Laboratory, PNNL-16760, *Review of Techniques to Characterize the Distribution of Chromate Contamination in the Vadose Zone of the 100 Areas at the Hanford Site,* was also used as guidance in identifying technologies that would be most applicable to the 100-B/C Area vadose zone chromium contamination.

The purpose of the November 12-13, 2008 workshop was to bring subject matter experts, clients, regulators, and other interested parties (for example, groundwater specialists) together to discuss and evaluate treatment options for deep vadose zone chromium contamination at the 100-C-7 Waste Site (Harrington, 2008) located in the 100-B/C Area. Several subject matter experts were invited to participate and present various technologies to the panel for review and discussion. As noted above, technologies that were rejected in the 100-D Area evaluation were assumed to be inapplicable to the 100-B/C Area chromium as well; therefore, these were not addressed at the workshop. The technologies deemed potentially applicable and carried forward for discussion at the November 12-13, 2008 workshop are summarized in Table A-1 and included:

1. In Situ Chemical Reduction with Calcium Polysulfide.
2. In Situ Solidification/Stabilization – Deep soil mixing with cement/reducing agents.
3. In Situ Chemical Reduction with Zero Valent Iron.
4. In Situ Biological Reduction with Organic Substrates.

These technologies were further evaluated and ranked against the 100-C-7 baseline removal, treatment, and disposal option based on their effectiveness, ability to mitigate risk, cost, ease of implementation, and time to complete full-scale treatment. Based on these criteria, a combination of biological and chemical reduction of hexavalent chromium via infiltration was selected as the preferred technology.

References

PNNL-16760, 2007, *Review of Techniques to Characterize the Distribution of Chromate Contamination in the Vadose Zone of the 100 Areas at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

Harrington, R. A., 2008, *100 B/C Chromium Path Forward Project Workshop*, Working Draft, November 12-13, 2008, Washington Closure Hanford, Richland, Washington.

Table A-1. Retained Technologies from 100-D Area Focused Feasibility Study Evaluated for Applicability to the 100-B/C Area

Remedial Technology	Process Option	Descriptions	Effectiveness	Implementability	Relative Cost
(1) In Situ Chemical Reduction with Calcium Polysulfide	Chemical Infiltration	Liquid with chemical reductant (calcium polysulfide) is applied to ground surface at an application rate substantially below what would create saturation, to treat Cr(VI) within vadose zone prior to reaching groundwater.	MODERATE Chemical reductant follows source release pathways. Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth. Assuming adequate coverage of the source zone and sufficient dosage to maintain adequate reductant strength along the entire soil column, this technology can be established in a timely manner and can likely achieve RAOs by 2020.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize chromium (in first pore volume) toward groundwater. Handling chemical reductants (calcium polysulfide) is a H&S concern.	LOW to MODERATE capital cost, MODERATE O&M costs.
(2) In Situ Solidification/Stabilization – Deep soil mixing with cement/reducing agents	Deep Soil Mixingh	Large mixing augers (1.5 to 3 meters [5 to 10 feet] diameter) or horizontally rotating heads are used to blend and homogenize chemical reductants (e.g., EHC®*) with soil.	HIGH Chemical reductants are uniformly mixed with soil column, providing good contact and reaction between chromium and chemical. Cement can also be mixed with the chemical slurry to reduce the hydraulic conductivity and leachability of the soil. Given adequate coverage of the source area, this technology would be immediately effective in treating / immobilizing Cr(VI) in the vadose zone.	LOW Implementation will be more challenging in gravelly/cobbly lithologies. Level ground surfaces are needed to provide a stable base for mixing. Although deep soil mixing has been performed to depths of 30 meters (100 feet), most field applications have been limited to approximately 15 meters (50 feet) below ground surface.	HIGH capital costs, LOW O&M costs.

Table A-1. Retained Technologies from 100-D Area Focused Feasibility Study Evaluated for Applicability to the 100-B/C Area

Remedial Technology	Process Option	Descriptions	Effectiveness	Implementability	Relative Cost
(3) In Situ Chemical Reduction with Zero Valent Iron	This technology was not specifically evaluated in the 100-D Area, but was presented as a potential technology during the November 2008 workshop.				
(4) In Situ Biological Reduction with Organic Substrates	Biological Infiltration	Liquid with biological carbon source is applied to ground surface at an application rate substantially below what would create saturation, to treat Cr(VI) within vadose zone prior to reaching groundwater.	HIGH Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reactive strength is maintained over relatively longer distances. Assuming adequate coverage of the source zone and sufficient dosage to maintain adequate reductive capacity along the entire soil column, this technology can be established in a timely manner and can likely achieve RAOs by 2020.	HIGH Drip irrigation system used for surface application is simple to install and accessible for O&M. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize chromium (in first pore volume) toward groundwater.	LOW to MODERATE capital cost, MODERATE O&M costs.

NOTES: *EHC is a registered trademark of Adventus Americas, Inc. and is a solid material consisting of microscale zero-valent iron and a controlled-release fibrous organic carbon, as well as major, minor, and micro-nutrients.

Cr(VI) = hexavalent chromium
H&S = health and safety
O&M = operations and maintenance
RAO = remedial action objective

APPENDIX B

SUPPORTING COST INFORMATION
HEXAVALENT CHROMIUM FOCUSED FEASIBILITY STUDY
FOR THE 100 AREA

This page intentionally left blank.

Contents

B.1. Introduction **1**
B.2. Remedial Alternative Summary Descriptions **3**
B2.1 Alternative 0 – No Action 3
B2.2 Alternative 1 – Continue Current Actions 3
B2.2.1 Institutional Controls 3
B2.2.2 Remove, Treatment, and Disposal 3
B2.2.3 Pump-and-Treat Contaminated Groundwater 4
B2.3 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction 7
B2.3.1 In Situ Reduction System Design 7
B.3. Basis of Estimates **9**
B3.1 Global Assumptions 9
B3.1.1 Labor 9
B3.2 Remedial Alternative Overall Cost Summary 10
B3.3 Alternative 0 – No Action 10
B3.4 Alternative 1 – Continue Current Actions 10
B3.4.1 General Assumptions 10
B3.4.2 Special Conditions 12
B3.4.3 Cost Estimate and Breakdown 13
B3.5 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction 13
B3.5.1 General Assumptions 13
B3.5.2 Special Conditions 13
B3.5.3 Cost Estimate and Breakdown 13
B.4. References **31**
Distribution **1**

Figures

Figure B2-1. 100-D Area Hot Spot Groundwater Extraction Well Layout. B-5
Figure B2-2. 100-D Area Hot Spot Projected Hexavalent Chromium Concentration Trends. B-5

Tables

Table B2-1 Waste Site Information B-6
Table B3-1 Cost Estimate Summary B-11
Table B3-2 Cost Estimate Alternative 1 – Continue Current Actions B-14
Table B3-3 Cost Estimate Alternative 2 – Continue Current Actions with Selective Application of ISR B-22

Terms

AFL-CIO	American Federation of Labor-Congress of Industrial Organizations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHPRC	CH2M HILL Plateau Remediation Company
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FFS	focused feasibility study
FICA	*Federal Insurance Contributions Act*
FS	feasibility study
ft	feet
gal	gallon
gal/min	gallons per minute
HDPE	high-density polyethylene
HSSA	Hanford Site Stabilization Agreement
IC	institutional control
ICP	Inductively coupled plasma
ISR	in situ reduction
L/min	liters per minute
m	meter
µg/L	micrograms per liter
min	minute
NPV	net present value
O&M	operations and maintenance
OMB	Office of Management and Budget
RAO	remedial action objective
ROD	record of decision
RTD	removal, treatment, and disposal
WCH	Washington Closure Hanford, LLC

This page intentionally left blank.

Appendix B

Supporting Cost Information
Hexavalent Chromium Focused Feasibility Study for the 100 Area

B.1. Introduction

Cost estimates for the remedial action alternatives described in the DOE/RL-2009-22, *Hexavalent Chromium Focused Feasibility Study (FFS) for the 100 Area* (working draft not released) were prepared to assist with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) detailed and comparative evaluation of alternatives as required under 40 CFR 300.430 (e). The cost estimates were generally prepared in accordance with EPA/540/R 00/002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, OSWER 9355.0 75*. The cost estimate is one of the five balancing criteria evaluated in the FFS to provide input into the identification of a preferred remedial alternative in the Proposed Plan. The cost estimate information is based on the interim remedial action alternative descriptions presented in Section B2.0.

The cost estimates were prepared using information from multiple sources. Washington Closure Hanford, LLC, provided a majority of the information used for estimating removal, treatment, and disposal (RTD) remedial action costs for the six identified (known) hexavalent chromium sites, and the four "yet-to-be discovered" (future) sites. The groundwater pump-and-treat cost estimate was derived from actual costs associated with construction and operation of the DR-5, 100-KR-4, and 100-KW ion exchange systems. In situ reduction (ISR) costs were prepared based on experience at similar sites, vendor quotes, and information obtained from Means, 2008, *Mechanical Cost Data*. Unless specified, the quantities associated with each RTD remedial action alternative were estimated based on an assumed length and width for each site. The excavation depth was set equal to the depth to groundwater. Quantities for the groundwater pump-and-treat alternatives were estimated using currently available information for the 100-D area southern plume (hot spot application) and the 100-K area plumes (source area and downgradient plume).

The remedial action cost estimates include capital costs, annual operations and maintenance (O&M) costs and periodic costs. Capital costs are those expenditures that are required to construct the remedial action alternative. They include all labor, equipment, and material costs, including contractor markups (such as overhead and profit) associated with activities such as mobilization/demobilization, monitoring, site work, installation of extraction, containment and treatment systems, and disposal. Capital costs also include the expenditures for professional/technical services necessary to support construction of the interim remedial action alternative.

Operations and maintenance costs are those post-construction costs necessary to ensure or verify the continued effectiveness of an interim remedial action alternative such as operation of a pump-and-treat system. Operations and maintenance costs were estimated on an annual basis. Periodic costs are those costs that occur once every few years or once during the entire remedial action timeframe. Examples of periodic costs include a one-time RTD soil cover maintenance event to repair erosion or subsidence, or decommissioning of pump-and-treat and ISR systems once the remedial action is complete.

All capital, O&M and periodic costs were estimated using constant dollars. Future O&M costs and periodic costs were discounted to net present value (NPV) dollars using the real discount rates published in *Appendix C of the Office of Management and Budget (OMB) Circular No. A-94, Guidelines and Discount Rates for Benefit Cost Analysis of Federal Programs,* effective through January 2009. A

1.6 percent discount rate was used for projects with a 3- to 7-year period of analysis. The real discount rate accounts for the effects of inflation. All capital costs are assumed to occur in year 0 and, therefore, were not discounted. The RTD component of each remedial action alternative is assumed to be completed in 1 year or less. Therefore, no discounting of capital costs was performed.

The interim remedial action alternative cost estimates presented in the FFS are shown in year 2009 dollars. The estimates were prepared from information available at the time the FFS was prepared. The actual cost associated with implementation of an interim remedial action alternative will depend on additional information gained during remedial design, the final scope and design of the interim remedial action alternative, implementation schedule, competitive market conditions, and other variables. Therefore, the interim remedial action alternative cost estimates are expected to have an accuracy of between -30 to +50 percent unless otherwise noted.

Chapter B.2 provides a general description of each remedial alternative. Major costing assumptions are discussed in Chapter B.3.

B.2. Remedial Alternative Summary Descriptions

The following three interim remedial action alternatives were developed for the 100 Area hexavalent chromium FFS:

- Alternative 0 – No Action
- Alternative 1 – Continue Current Actions
- Alternative 2 – Continue Current Actions with Selective Application of ISR.

The following subsections provide additional information on the elements comprising each alternative.

B2.1 Alternative 0 – No Action

The 42 USC 9601 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* regulations (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List") require that a no-action alternative be evaluated as a baseline for comparison with other remedial action alternatives under consideration. Alternative 0 would consist of taking no action to remediate hexavalent chromium source areas or groundwater plumes in the 100 Area. Alternative 0 presumes that the U.S. Department of Energy will relinquish control of the 100 Area to another governmental or private entity without easements and covenants, and without the maintenance or enforcement of access or institutional controls (IC) (DOE/RL-2001-41, 2007, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, Rev. 2).

B2.2 Alternative 1 – Continue Current Actions

Alternative 1 represents a continuation of the interim remedial actions currently underway within the 100 Area to address hexavalent chromium in accordance with the interim action record of decision (interim ROD) documents. The primary components of this interim remedial action alternative are summarized below.

B2.2.1 Institutional Controls

ICs consist of physical and legal barriers to restrict or prevent human access to contaminated soil, waste sites, and groundwater. Physical methods of controlling access typically include signs, entry controls, excavation permits, artificial or natural barriers, and active surveillance. For Alternative 1, ICs will remain in effect until the remedial goals for hexavalent chromium are achieved in soil and groundwater at the defined point of compliance. For the purposes of this cost estimate, ICs are maintained for a period of 10 years. This period includes a 1—year duration for remedial design, 5 to 9 years for remedial action, and 1 year for regulatory agency review and site closeout.

B2.2.2 Remove, Treatment, and Disposal

The hexavalent chromium waste sites in the 100 Area are typically associated with the structures used to store, transport, or handle sodium dichromate liquid and powder. Many of the 100 Area source operable unit interim action RODs selected RTD for remediation of source and contaminated soil waste sites. Alternative 1 provides for the continued use of RTD to address hexavalent chromium-contaminated soil to the depths needed to achieve the remedial action objectives (RAO) described in Chapter 3 of the FFS report.

Six hexavalent chromium waste sites were identified in the 100 Area as candidates for remedial action under the FFS. These sites include 100-D-12, 100-D-30 SW, 600-334, 116-K-2, 100-C-7:1, and 100-C-7.

An allowance for four future sites was also added to this list for a total of 10 sites. The four future sites are expected to have characteristics similar to those of the six known waste sites.

Removal, treatment, and disposal was evaluated using characteristic information for the six known and four future waste sites. All of the waste sites, except the 100-C-7:1 site, are assumed to have dimensions of 9.1 by 9.1 meter (m) (30 by 30 feet [ft]) with depths of either 12.2 m (40 ft), 24.4 m (80 ft), or 25.9 m (85 ft). Table B2-1 summarizes the information used for estimating excavation quantities for RTD at each of the six known and four future waste sites.

The excavation of source and contaminated soil waste sites uses an observational approach. This allows waste sampling, characterization, and treatment to occur as excavation proceeds. Although a majority of the excavated waste material and soil may meet the Environmental Remediation Disposal Facility (ERDF) waste acceptance criteria without treatment (Washington Closure Hanford, LLC [WCH]-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*), the RTD cost estimates include a significant allowance for treatment. This allowance is based on WCH's experience with ERDF treatment and disposal costs in the 100 Area. All treatment is performed at the ERDF prior to final disposal.

Verification sampling is performed during (pre-verification) and after excavation is completed (verification) to confirm that interim action ROD remediation goals for hexavalent chromium have been met. It is anticipated that excavation to depths equal to the depth to groundwater will be required to meet remediation goals at each waste site. Once cleanup has been verified, clean soil from the onsite stockpile, along with material from approved borrow pits, would be transported to the waste site for use in backfilling each excavation. Recontouring and revegetation of the waste site would occur after remediation to ensure that infiltration is minimized. An allowance for a one-time maintenance event has also been included for each of the RTD options. This maintenance event consists of placing supplemental fill material over portions of the excavation footprint that may have settled.

B2.2.3 Pump-and-Treat Contaminated Groundwater

Hexavalent chromium present in the 100 Area groundwater operable units is associated with several source and contaminated soil waste sites. Remediation of groundwater is necessary to meet the RAOs for groundwater restoration and river protection. The 100 Area interim ROD for the 100-HR-3 and 100-KR-4 groundwater operable units selected pump-and-treat for remediation of contaminated groundwater. Alternative 1 provides for the continued use of pump-and-treat to address hexavalent chromium-contaminated groundwater to achieve the RAOs and the working objectives described in Chapter 4 of the FFS report.

In this FFS, remediation of the hot spot area (southern plume) in the 100-D Area and the two downgradient plumes in the 100-K Area was used to estimate capital, O&M, and periodic costs for the pump-and-treat component. The portion of the 100-D Area southern plume with hexavalent chromium concentrations greater than about 5,000 micrograms per liter (μg/L) was defined as the hot spot area. It is assumed that a pump-and-treat system similar to the DR-5 ion exchange pump-and-treat system will be used for remediation of the hot spot. Numerical modeling of the hot spot area assuming a well configuration consisting of four extraction wells and two injection wells (Figure B2-1), with a combined pumping rate of 189 liters per minute (L/min) (50 gallons per minute [gal/min]), estimates that hexavalent chromium concentrations will be reduced to 100 μg/L by approximately 2015 (Figure B2-2).

The pump-and-treat system to address the hot spot area is assumed to require four extraction wells to withdraw the groundwater at rates of approximately 47.5 L/min (12.5 gal/min) each and two injection

wells to dispose of the treated water. Four existing 10.2 centimeter (4-inch) diameter monitoring wells will be converted for this purpose (Figure B2-1).

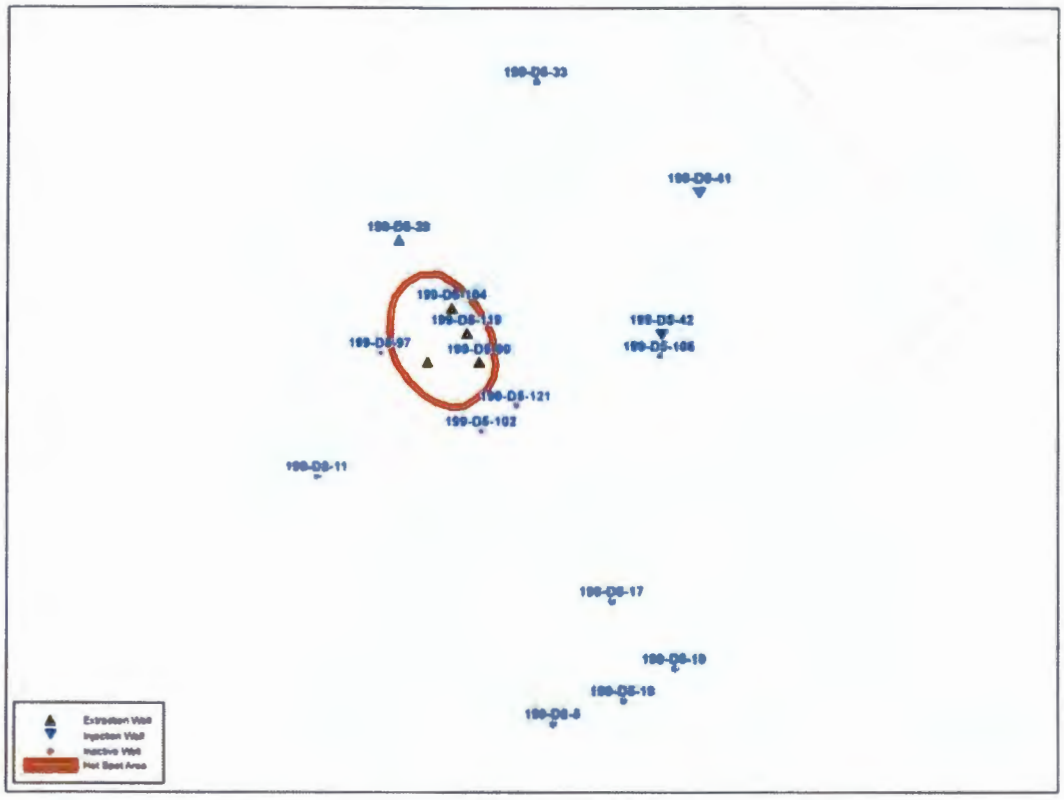

Figure B2-1. 100-D Area Hot Spot Groundwater Extraction Well Layout.

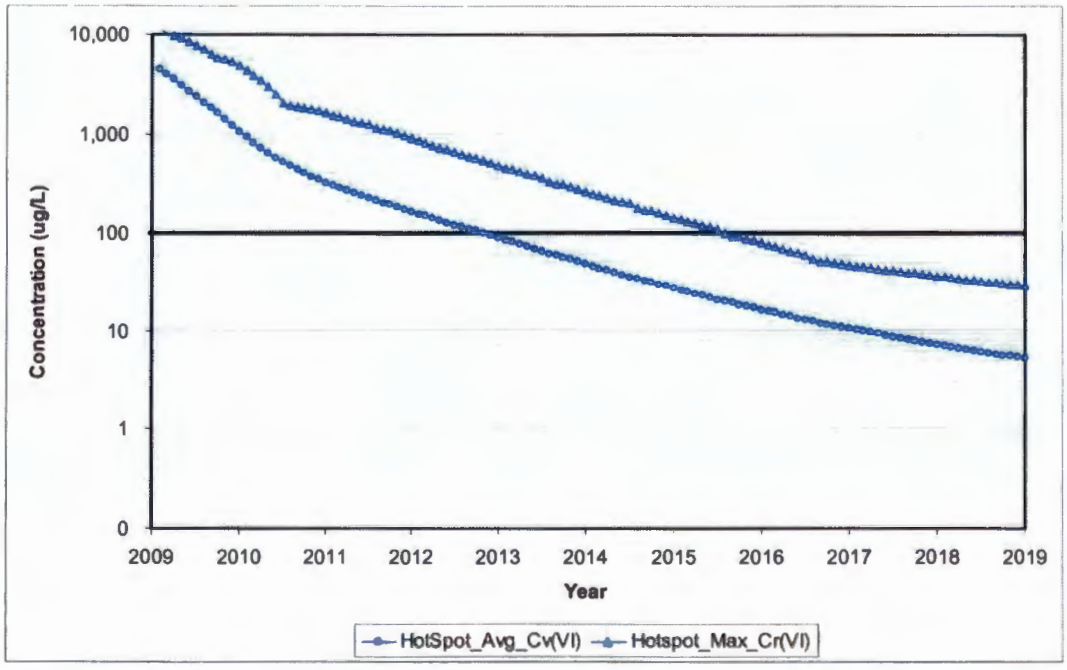

Figure B2-2. 100-D Area Hot Spot Projected Hexavalent Chromium Concentration Trends.

Table B2-1. Waste Site Information
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Description	Units	RTD (30 ft x 30 ft at bottom) x Depth (unless specified)									
		100-D-12	100-D-30 SW	600-334	116-K-2	100-C-7-1	100-C-7	Undiscovered Site #1	Undiscovered Site #2	Undiscovered Site #3	Undiscovered Site #4
		WCH	WCH	WCH	WCH	WCH	WCH	WCH	WCH	WCH	WCH
Soil Excavation Footprint (bottom)	square feet	900	900	900	900	30,000	900	900	900	900	900
Soil Excavation Footprint (top)	square feet	90,000	97,000	27,980	97,000	242,550	113,150	90,000	90,000	27,980	113,150
Alternative 1 Depth (Alternative 2 Depth)	feet	80 (8)	80 (18)	40 (0)	80 (20)	80 (15)	85 (15)	80 (15)	80 (15)	40 (15)	85 (15)
Total volume	bank cubic yards	106,718	106,020	16,130	106,718	341,697	126,725	106,718	106,718	16,130	126,725
ACL volume (soil)	bank cubic yards	2,400	2,000	1,333	2,000	77,778	2,167	2,400	2,400	1,333	2,167
ACL volume (concrete):	bank cubic yards	0	0	0	0	2,608	1,528	0	0	0	1,528
BCL volume (soil)	bank cubic yards	104,318	104,020	14,796	104,718	259,510	123,031	104,318	104,318	14,796	123,031
Tons ACL (soil)	U. S. Tons	4,560	3,800	2,533	3,800	147,778	4,117	4,560	4,560	2,533	4,117
Tons ACL (concrete):	U. S. Tons	0	0	0	0	5,293	3,101	0	0	0	3,101
Tons BCL (soil)	U. S. Tons	198,205	197,639	28,113	198,965	493,068	233,758	198,205	198,205	28,113	233,758
Tons BCL (concrete):	U. S. Tons	0	0	0	0	3,424	0	0	0	0	0
Backfill from borrow source	tons	4,560	5,126	2,533	3,800	184,399	7,019	4,560	4,560	2,533	7,019
Backfill from local stockpile	tons	198,205	197,639	28,113	198,965	493,068	233,758	198,205	198,205	28,113	233,758
Revegetation	Acres	5.6	5.6	1.6	5.6	13.9	6.5	5.6	5.6	1.6	6.5
		100-D Area (Southern Plume) Hot Spot									
Plume Length	feet	600									
Plume Width	feet	250									
Unconfined Aquifer Thickness	feet	25									
Porosity	dimensionless	0.3									
Volume	bank cubic yards	139,000									
	gallons	8,415,000									
		ISR Treatment									
Area	acre	1									
Depth	feet	80									
Total Volume	bank cubic yards	129,100									

Notes:
ACL = above cleanup levels
BCL = below cleanup levels

Extracted groundwater is transferred by pipeline to a centrally located facility for treatment using ion exchange.

The 100-K Area pump-and-treat system includes the 100-KR-4 and 100-KW systems. The 100-KR-4 system consists of nine extraction wells, five injection wells, and an ion exchange treatment system. The 100-KW system includes four extraction wells, two injection wells, and an ion exchange treatment system. Both of these systems are assumed to operate until the year 2018. This duration is based on the current baseline schedule.

The actual costs associated with construction and operation of the 100-KR-4 and 100-KW pump-and-treat systems were used as a basis for estimating the costs for the Alternative 1 pump-and-treat system for the 100-K Area.

B2.3 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

Alternative 2 contains all of the components of Alternative 1 with selective application of ISR in accordance with the site selection criteria described in Chapter 5 of the FFS.

The ISR component of this interim remedial action alternative consists of treating deep contaminated soil and groundwater (in proximity to the contaminated soil) in situ by delivering a dilute chemical reagent that converts hexavalent chromium to its less toxic and essentially immobile trivalent form. This conversion process has been demonstrated to be an irreversible process under typical environmental conditions, such as those found at the Hanford Site, and at many other hexavalent chromium-contaminated sites across the U.S. Table B2-1 provides an overview of the site information used for estimating the size of the ISR treatment area.

It is anticipated that large-scale groundwater contamination and primary source areas of hexavalent chromium contamination (for example, pipelines, storage tanks), as well as surface and subsurface soil, will continue to be remediated by pump-and-treat and by RTD, respectively. However, ISR may be applied to treat hexavalent chromium in settings where RTD or pump-and-treat would be more expensive, less effective, or difficult to implement. One example would be suspected vadose zone sources of hexavalent chromium that may be too deep for cost-effective application of RTD. Groundwater plume hot spots containing high concentrations of hexavalent chromium are another potential site for remediation by ISR.

For the purposes of the FFS, it is assumed that RTD would be used to address contaminated soil present in the zero to 6.1 m (20 ft) depth range, while ISR would be used to address contaminated soil present at depths between 6.1 m (20 ft) and the water table. At one (600-334) of the six known waste sites, it is assumed that no RTD would be performed and ISR used to treat the full vadose zone. The cost estimate also assumes that ISR would be used to treat localized areas of hexavalent chromium-contaminated groundwater underlying the soil treatment zone at two (116-D-2 and 116-K-2) of the six known waste sites. Pump-and-treat would be used to address the remaining areas of groundwater contamination at these two sites.

B2.3.1 In Situ Reduction System Design

The ISR treatment system for remediation of a typical vadose zone waste site consists of a tank system for storage and blending of the ISR reagent and delivery to the target area where it is introduced to the subsurface soil using a chemical drip system. The drip system would be installed over each of the ten waste sites with each system covering a 0.4-hectare (1-acre) area. The area covered by the drip system is

approximately 50 times greater than the size of the waste site. The drip system would consist of an array of 0.6- to 1.2-centimeter (0.25- to 0.5-inch) diameter, flexible drip lines spaced 0.6 to 1 m (2 to 3 ft) apart. The drip system is manifolded to a header that conveys the ISR reagent from the mixing tank. As the reagent solution infiltrates through the vadose zone, residual hexavalent chromium present in soil is converted to trivalent chromium following direct contact with the ISR reagent. Sufficient ISR reagent would be added to ensure that the treatment process would fully penetrate the vadose zone.

If hexavalent chromium was also present in groundwater underlying the vadose zone waste site, the system would be expanded to include injection of the ISR reagent. To ensure adequate remediation of the underlying groundwater, an existing monitoring well would be converted to an injection well and the ISR reagent introduced through the injection well. Four existing monitoring wells located upgradient, downgradient, and cross-gradient of the target area would be converted to extraction wells and pumped at an estimated rate of 47 L/min (12.5 gal/min) each. Pumping from the four wells promotes the vertical and lateral distribution of the ISR reagent throughout the treatment zone. Existing extraction wells located upgradient or cross-gradient of the treatment zone would be used to supply makeup water for the ISR system. If site-specific conditions prevent groundwater from being used as makeup, the ISR system will be supplied from an optional freshwater source.

The ISR component of this alternative is expected to remediate a deep vadose zone, or a deep vadose zone and groundwater target area, within 9 months of system startup.

B.3. Basis of Estimates

This chapter presents the information and assumptions used in developing cost estimates for each of the interim remedial action alternatives described in Chapter B.2.

B3.1 Global Assumptions

B3.1.1 Labor

All labor and material costs associated with RTD were estimated by WCH. It is assumed that the basis for these estimates is the fixed-price construction craft labor rates specified in the *Site Stabilization Agreement for All Construction Work for the U.S. Department of Energy at the Hanford Site*, Appendix A (commonly known as the Hanford Site Stabilization Agreement [HSSA]). The HSSA rates include base wage, fringe benefits, and other compensation as negotiated between Fluor Hanford and the National Building and Construction Trades Department American Federation of Labor-Congress of Industrial Organizations (AFL-CIO). It is assumed that the costs (workman's compensation, 26 USC 21, *Federal Insurance Contributions Act* [FICA] [*Social Security Act of 1935*], and state and federal unemployment insurance) are included within the fixed-price rate structure. It is assumed that labor and material rates for 2009 were used.

Labor and material costs associated with project management, remedial design engineering, and services during construction were estimated as a percentage of the interim remedial action alternatives' capital construction cost.

B3.1.1.1 Direct Cost Factors

The cost estimates include the following direct cost factors:

- Washington State sales tax at 8.3 percent was applied to all ISR purchased equipment.
- An allowance for scope contingency was added to the RTD, pump and treat, and ISR components of the remedial action alternatives. The scope contingency varies between 15 and 55 percent in accordance with Exhibit 5-6, EPA/540/R 00/002. For RTD, a scope contingency of 20 percent was used. Although this amount is toward the low end of the 15-55 percent range recommended in Exhibit 5-6, it is reasonable given the level of experience WCH has with the RTD technology at the Hanford Site. A 20 percent scope contingency was used for the pump-and-treat component because it is based on actual experience with the DR-5, 100-KR-4 and 100-KW systems. A scope contingency of 35 percent was used for ISR.
- A bid contingency of 10 percent was used for the ISR component. Bid contingency was not included for RTD since WCH self-performs the work. Bid contingency was not included with pump-and-treat because the total capital construction cost was derived from an actual construction cost.
- Project management and remedial design costs were estimated as a percentage of the total capital cost in accordance with the graded scale presented in Exhibit 5-8 of EPA/540/R 00/002.
- Construction management was estimated as a percentage of the total construction cost in accordance with the graded scale presented in Exhibit 5-8 of EPA/540/R 00/002. A construction management allowance was not included for the RTD component because WCH indicated that this factor was included within their unit pricing.

B3.1.1.2 Indirect Cost Factors

- Factors to account for indirect costs were not applied to the estimates. The RTD, and the pump and treat capital and O&M components already include indirect costs within the total or unit prices supplied by WCH and CH2M HILL Plateau Remediation Company (CHPRC). The cost for installation of the ISR chemical drip system is based on a vendor quote. The pricing for the remaining ISR components (tank installation, building and conveyance) was obtained from several different sources that may or may not include indirect costs. Potential indirect costs that may not have been captured are expected to fall with the contingency allowance.

B3.2 Remedial Alternative Overall Cost Summary

The estimates of capital, O&M, and periodic costs for both interim remedial action alternatives are summarized in Table B3-1. Additional cost information is presented in Sections B3.3, B3.4, and B3.5.

B3.3 Alternative 0 – No Action

Alternative 0 assumes no further action will be taken at a waste site. Therefore, the estimated cost is $0.

B3.4 Alternative 1 – Continue Current Actions

The primary components for Alternative 1 include institutional controls, RTD of soil and waste, and groundwater pump-and-treat. The general assumptions, special conditions, and cost estimate breakdown for Alternative 1 are presented in the following subsections.

B3.4.1 General Assumptions

The general assumptions for institutional controls are as follows.

- IC costs were estimated using IC cost information supplied by CHPRC from another operable unit feasibility study. The cost estimate includes both a capital and an O&M component.

The general assumptions for RTD include:

- RTD excavation costs by WCH include all labor, equipment and material to excavate soil and debris; size-reduce concrete from the adjacent facility; load out materials; backfill; perform revegetation activities; and prepare waste-site closeout documentation.
- RTD treatment and disposal costs include all labor, equipment, and material to transport containers to ERDF; treatment of hexavalent chromium-contaminated soil to meet land-disposal restrictions; and disposal at ERDF. ERDF treatment and disposal costs are estimated at 120 percent of the total excavation, sampling, backfill and site restoration cost.
- Costs for RTD are well known after years of experience applying this technology at the Hanford Site. They include the following:
  - Density of soil is 1.9 tons per bank cubic yard
  - Excavation cost is $15.00 per ton
  - Offsite backfill material cost is $8.00 per ton. Onsite stockpile material is handled at $2.50 per ton.
  - Soil excavation rates are 90 trucks per day total (15 trucks per day at 6 cycles each)
  - Each truck carries 32 tons per cycle (truck-and-pup operation)

Table B3-1. Cost Estimate Summary
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Site:	100 Area		
Location:	Hanford, Washington	**Base Year:**	2009
Phase:	Feasibility Study (-30% to +50%)	**Date:**	May 28, 2009

Alternative - Site Name	Total Project Duration (years)	Total Capital Cost	Annual O&M Cost	Total Periodic Cost	Total Net Present Value Cost	Total Non-Discounted Cost
Alternative 1						
1. ICs Component (cost per site)	9	$ 28,000	$ 3,400	$ 30,000	$ 80,900	$ 88,500
Subtotal					**$ 809,000**	**$ 885,000**
2. RTD Component						
2a - 100-D-12 (to 80 ft)	1.0	$ 11,740,000	$ -	$ 7,900	$ 11,750,000	$ 11,750,000
2b - 100-D-30 SW (to 80 ft)	1.0	$ 11,690,000	$ -	$ 7,900	$ 11,700,000	$ 11,700,000
2c - 600-334 (to 40 ft)	1.0	$ 2,260,000	$ -	$ 7,900	$ 2,270,000	$ 2,270,000
2d - 116-K-2 (to 80 ft)	1.0	$ 11,230,000	$ -	$ 7,900	$ 11,240,000	$ 11,240,000
2e - 100-C-7-1 (to 85 ft)	1.1	$ 37,960,000	$ -	$ 7,900	$ 37,970,000	$ 37,970,000
2f - 100-C-7 (to 80 ft)	1.0	$ 13,330,000		$ 7,900	$ 13,340,000	$ 13,340,000
2g - Future Site #1 (to 80 ft)	1.0	$ 11,740,000	$ -	$ 7,900	$ 11,750,000	$ 11,750,000
2h - Future Site #2 (to 80 ft)	1.0	$ 11,740,000	$ -	$ 7,900	$ 11,750,000	$ 11,750,000
2i - Future Site #3 (to 40 ft)	1.0	$ 2,260,000	$ -	$ 7,900	$ 2,270,000	$ 2,270,000
2j - Future Site #4 (to 85 ft)	1.0	$ 13,330,000		$ 7,900	$ 13,340,000	$ 13,340,000
Subtotal					**$ 127,380,000**	**$ 127,380,000**
3. Pump and Treat Component						
3a - 100-D Hot Spot	5	$ 3,140,000	$ 1,600,000	$ 1,570,000	$ 12,320,000	$ 12,690,000
3b - 100-K Plume	8	$ 12,910,000	$ 2,710,000	$ 6,450,000	$ 39,180,000	$ 41,070,000
Subtotal					**$ 51,500,000**	**$ 53,760,000**
4. Total by Site						
4a - 100-D-12 (soil and groundwater)		$ 14,908,000	$ 1,603,400		$ 24,150,900	$ 24,530,000
4b - 100-D-30 SW (soil)					$ 11,780,900	$ 11,790,000
4c - 600-334 (soil)					$ 2,350,900	$ 2,360,000
4d - 116-K-2 (soil and groundwater)					$ 50,500,900	$ 52,400,000
4e - 100-C-7-1 (soil)					$ 38,050,900	$ 38,060,000
4f - 100-C-7 (soil)					$ 13,420,900	$ 13,430,000
4g-4j - Future Sites #1 to #4 (soil)					$ 39,433,600	$ 39,460,000
Total Alternative 1		**$ 143,358,000**	**$ 4,313,400**		**$ 179,689,000**	**$ 182,030,000**
Alternative 2						
1. ICs Component (cost per site)	9	$ 28,000	$ 3,400	$ 30,000	$ 80,900	$ 88,500
Subtotal					**$ 809,000**	**$ 885,000**
2. RTD Component						
2a - 100-D-12 (to 8 ft)	1.0	$ 660,000	$ -	$ 7,900	$ 670,000	$ 670,000
2b - 100-D-30 SW (to 18 ft)	1.0	$ 770,000	$ -	$ 7,900	$ 780,000	$ 780,000
2c - 600-334 (no RTD)	0.0	$ -	$ -	$ 7,900	$ 10,000	$ 10,000
2d - 116-K-2 (to 20 ft)	1.0	$ 780,000	$ -	$ 7,900	$ 790,000	$ 790,000
2e - 100-C-7-1 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
2f - 100-C-7 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
2g - Future Site #1 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
2h - Future Site #2 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
2i - Future Site #3 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
2j - Future Site #4 (to 15 ft)	1.0	$ 700,000	$ -	$ 7,900	$ 710,000	$ 710,000
Subtotal					**$ 6,510,000**	**$ 6,510,000**
3. Pump and Treat Component						
3a - 100-D Hot Spot	5	$ 3,140,000	$ 1,600,000	$ 1,570,000	$ 12,320,000	$ 12,690,000
3b - 100-K Plume	8	$ 12,910,000	$ 2,710,000	$ 6,450,000	$ 39,180,000	$ 41,070,000
Subtotal					**$ 51,500,000**	**$ 53,760,000**
4. ISR Component						
4a - 100-D-12 (15 to 80 ft + groundwater)	1.0	$ 1,650,000	$ 210,000	$ 580,000	$ 2,440,000	$ 2,440,000
4b - 100-D-30 SW (15 to 80 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4c - 600-334 (15 to 40 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4d - 116-K-2 (15 to 80 ft + groundwater)	1.0	$ 1,650,000	$ 210,000	$ 580,000	$ 2,440,000	$ 2,440,000
4e - 100-C-7-1 (15 to 85 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4f - 100-C-7 (15 to 80 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4g - Future Site #1 (15 to 80 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4h - Future Site #2 (15 to 80 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4i - Future Site #3 (15 to 40 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
4j - Future Site #4 (15 to 85 ft)	1.0	$ 1,460,000	$ 210,000	$ 580,000	$ 2,250,000	$ 2,250,000
Subtotal					**$ 22,880,000**	**$ 22,880,000**
5. Total by Site						
4a - 100-D-12 (soil and groundwater)		$ 5,478,000	$ 1,813,400	$ 2,187,900	$ 15,510,900	$ 15,888,500
4b - 100-D-30 SW (soil)		$ 15,168,000	$ 2,923,400	$ 7,067,900	$ 42,290,900	$ 44,188,500
4c - 600-334 (soil)		$ 1,488,000	$ 213,400	$ 617,900	$ 2,340,900	$ 2,348,500
4d - 116-K-2 (soil and groundwater)		$ 2,458,000	$ 213,400	$ 617,900	$ 3,310,900	$ 3,318,500
4e - 100-C-7-1 (soil)		$ 2,188,000	$ 213,400	$ 617,900	$ 3,040,900	$ 3,048,500
4f - 100-C-7 (soil)		$ 2,188,000	$ 213,400	$ 617,900	$ 3,040,900	$ 3,048,500
4g-4j - Future Sites #1 to #4 (soil)		$ 8,668,000	$ 843,400	$ 2,381,600	$ 11,920,900	$ 12,190,000
Total Alternative 2					**$ 81,456,300**	**$ 84,031,000**

- Revegetation costs are $5,000 per acre
- Sampling costs are $700 per sample and assume 22 samples for each of the RTD depth options. Laboratory analysis includes inductively coupled plasma (ICP) metals and hexavalent chromium. Assumes quick turn (7 day preliminary and 30 day final).

A one-time allowance (periodic cost) for spot backfilling a RTD site to offset settlement is included.

The general assumptions for the 100 D Area southern plume hot spot pump-and-treat include:

- The extraction, injection, and treatment system configuration includes the following:
  - Three existing monitoring wells are converted to extraction wells and two are converted to an injection well. One existing extraction well would be reconfigured. Well conversion costs were obtained from CHPRC – Field Engineering Lead.
  - Conveyance piping and installation costs were obtained from CHPRC – Field Engineering Lead. 6-inch-diameter high-density polyethylene (HDPE) piping is assumed. The actual pipe diameter may be different and would be determined with hydraulic modeling during remedial design.
  - The influent flowrate is 189 L/min (50 gal/min).
  - The initial influent hexavalent chromium concentration is 7,500 μg/L and declines to 100 μg/L by the year 2015.
  - The ion exchange system regeneration occurs every 2 weeks.
  - Rock salt and hydrochloric acid quantities for regeneration are estimated at 208 L (55 gal).
  - Phosphoric acid and sodium hydroxide quantities are scaled based on estimated hexavalent chromium concentrations and mass.
  - The sodium dithionite quantity needed for regeneration is estimated at 3.1 times the estimated hexavalent chromium quantity removed.
  - The waste quantity is scaled based on hexavalent chromium mass.
  - Labor is approximately eight full-time equivalents based on current information.
  - The annual O&M cost of $1.6 million for the pump-and-treat system was estimated from the "100-DX Treatment Plant Pre-Conceptual Design and Cost Estimate Technical Memorandum" (working draft not released).

The 100-KR-4 and 100-KW pump-and-treat systems are configured and operated similar to the 100-D Area Hot Spot system described above, but are assumed to operate through the year 2018. The $2.71 million O&M cost for the 100-K area pump-and-treat systems was estimated from actual costs incurred in 2007 (DOE/RL-2008-05, *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump and Treat Operations*, Rev. 0).

A periodic cost equal to 50 percent of the total capital installation cost was included to allow for decommissioning of the three pump-and-treat systems following the 5-year projected operating period at the 100-D hot spot area, and 8 years of operation at the two 100-K Area systems.

B3.4.2 Special Conditions

No special conditions apply to this alternative.

B3.4.3 Cost Estimate and Breakdown

Based on an allowance for ten waste sites, which are excavated to depths between 12.2 and 25.9 m (40 and 85 ft), and the construction and operation of multiple pump-and-treat systems, the total NPV cost for Alternative 1 is estimated at $180 million. The RTD component of Alternative 1 accounts for $127.4 million, groundwater pump-and-treat $51.5 million, and ICs the remainder of the total cost. A detailed itemization of Alternative 1 costs is presented in Table B3-2.

Remedial action alternative costs at the feasibility study level are generally presented as a -30 to + 50 percent cost range to reflect uncertainty in the project's overall scope. Accordingly, the expected NPV cost range for Alternative 1is estimated to vary from $125.8 million (-30 percent) to $279.5 million (+50 percent).

B3.5 Alternative 2 – Continue Current Actions with Selective Application of In Situ Reduction

The primary components for Alternative 2 are the same as those presented for Alternative 1 with the inclusion of selective application of ISR as described in Chapter 5 of the FFS. The general assumptions, special conditions, and cost estimate breakdown for Alternative 2 is summarized in the following subsections and detailed in Table B3-3. The cost estimate summary for this alternative only provides cost information for the ISR component.

B3.5.1 General Assumptions

The ISR cost estimate includes capital costs, O&M and periodic costs.

- The capital cost includes purchase, delivery and installation costs for all system components, plus allowances for scope/bid contingency, project management, remedial design, and construction management.
- The annual O&M costs include costs for ISR reagent chemicals, a full-time system operator and electricity ($0.034 per kWh) to operate the fluid transfer pumps. The O&M timeframe is estimated at 9 months.
- The periodic cost includes a 35 percent allowance, based on capital costs, to decommission the ISR system once treatment is complete and move it to another waste site for reuse.

B3.5.2 Special Conditions

No special conditions apply to this alternative.

B3.5.3 Cost Estimate and Breakdown

The total estimated NPV cost for Alternative 2 for application at the ten waste sites is $80.2 million (see Table B3-1). This includes RTD at nine waste sites, vadose zone ISR treatment at eight sites, vadose zone and groundwater hot spot ISR treatment at two sites, and continuing use of existing pump-and-treat systems for the durations established in Alternative 1. A detailed itemization of Alternative 1 costs is presented in Table B3-3.

Remedial action alternative costs at the feasibility study level are generally presented as -30 to + 50 percent cost range to reflect uncertainty in the project's overall scope. Accordingly, the expected cost range for Alternative 2 is $56.2 million (-30 percent) to $120.4 million.

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
Capital Costs					
1. Institutional Controls					
a. Amend IC Plan and database	1	ea	$ 21,200	$ 21,200	from CHPRC 200-MW-1 OU IC worksheet
b. Project management	1	ea	$ 2,400	$ 2,400	from CHPRC 200-MW-1 OU IC worksheet
c. Remedial design	1	ea	$ 4,720	$ 4,720	from CHPRC 200-MW-1 OU IC worksheet
TOTAL IC COST				**$ 28,320**	
2a. RTD at 100-D-12					Excavation Depth is 80 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	202,765	ton	$ 15.00	$ 3,041,476	
d. Backfill (from borrow source)	4,560	ton	$ 8.00	$ 36,480	
e. Backfill (from local stockpiles)	198,205	ton	$ 2.50	$ 495,513	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
g. Revegetate	5.6	acres	$ 5,000	$ 27,835	
Subtotal				$ 3,768,704	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 4,522,444	
Subtotal				$ 8,291,148	
i. Scope contingency	1	ea	20%	$ 1,658,230	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 9,949,378	
j. Project management	1	ea	6%	$ 596,963	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 1,193,925	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 11,740,266**	
2b. 100-D-30 SW					Excavation Depth is 80 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	201,439	ton	$ 15.00	$ 3,021,579	
d. Backfill (from borrow source)	5,126	ton	$ 8.00	$ 41,012	
e. Backfill (from local stockpiles)	197,639	ton	$ 2.50	$ 494,097	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g. Revegetate	5.6	acres	$ 5,000	$ 27,835	
Subtotal				$ 3,751,922	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 4,502,307	
Subtotal				$ 8,254,229	
i. Scope contingency	1	ea	20%	$ 1,650,846	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 9,905,075	
j. Project management	1	ea	6%	$ 594,305	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 1,188,609	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 11,687,989**	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements.
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2c. RTD at 600-334					Excavation Depth is 40 feet
a Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c Excavation/remediation	30,646	ton	$ 15 00	$ 459,694	
d Backfill (from borrow source)	2,533	ton	$ 8.00	$ 20,267	
e Backfill (from local stockpiles)	28,113	ton	$ 2 50	$ 70,282	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g Revegetate	1.6	acres	$ 5,000	$ 8,029	
Subtotal				$ 725,672	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 870,806	
Subtotal				$ 1,596,477	
i Scope contingency	1	ea	20%	$ 319,295	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 1,915,773	
j Project management	1	ea	6%	$ 114,946	from Exhibit 5-8 EPA 540-R-00-002
k Remedial design	1	ea	12%	$ 229,893	from Exhibit 5-8 EPA 540-R-00-002
l Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 2,260,612**	
2d. RTD at 116-K-2					Excavation Depth is 80 feet
a Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	202,765	ton	$ 15.00	$ 3,041,476	
d Backfill (from borrow source)	3,800	ton	$ 8 00	$ 30,400	
e. Backfill (from local stockpiles)	198,965	ton	$ 2.50	$ 497,413	
f Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g Revegetate	5.6	acres	$ 5,000	$ 27,835	
Subtotal				$ 3,764,524	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 4,517,428	
Subtotal				$ 8,281,952	
i Scope contingency	1	ea	20%	$ 1,656,390	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 9,938,343	
j Project management	1	ea	5%	$ 496,917	from Exhibit 5-8 EPA 540-R-00-002
k Remedial design	1	ea	8%	$ 795,067	from Exhibit 5-8 EPA 540-R-00-002
l Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 11,230,327**	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements:
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2e. RTD at 100-C-7-1					Excavation Depth is 85 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 100 ft x 300 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation (soil)	640,846	ton	$ 15.00	$ 9,612,694	
d. Excavation/remediation (concrete)	8,718	ton	$ 19.00	$ 165,638	
e. Backfill (from borrow source)	184,399	ton	$ 8.00	$ 1,475,191	
f. Backfill (from local stockpiles)	493,068	ton	$ 2.50	$ 1,232,671	
g. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
h. Revegetate	13.9	acres	$ 5,000	$ 69,602	
Subtotal				$ 12,723,197	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 15,267,836	
Subtotal				$ 27,991,033	
i. Scope contingency	1	ea	20%	$ 5,598,207	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 33,589,240	
j. Project management	1	ea	5%	$ 1,679,462	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 2,687,139	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 37,956,841**	
2e. RTD at 100-C-7					Excavation Depth is 85 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	237,875	ton	$ 15.00	$ 3,568,126	
d. Excavation/remediation (concrete)	3,101	ton	$ 19.00	$ 58,926	
e. Backfill (from borrow source)	7,019	ton	$ 8.00	$ 56,156	
f. Backfill (from local stockpiles)	233,758	ton	$ 2.50	$ 584,396	
g. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
h. Revegetate	6.5	acres	$ 5,000	$ 32,470	
Subtotal				$ 4,467,474	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 5,360,969	
Subtotal				$ 9,828,443	
i. Scope contingency	1	ea	20%	$ 1,965,689	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 11,794,131	
j. Project management	1	ea	5%	$ 589,707	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 943,531	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 13,327,368**	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2f. RTD at Undiscovered Site #1 (to 80 ft)					Excavation Depth is 80 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	202,765	ton	$ 15.00	$ 3,041,476	
d. Backfill (from borrow source)	4,560	ton	$ 8.00	$ 36,480	
e. Backfill (from local stockpiles)	198,205	ton	$ 2.50	$ 495,513	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g. Revegetate	5.6	acres	$ 5,000	$ 27,835	
Subtotal				$ 3,768,704	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 4,522,444	
Subtotal				$ 8,291,148	
i. Scope contingency	1	ea	20%	$ 1,658,230	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 9,949,378	
j. Project management	1	ea	6%	$ 596,963	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 1,193,925	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 11,740,266**	
2g. RTD at Undiscovered Site #2 (to 80 ft)					Excavation Depth is 80 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	202,765	ton	$ 15.00	$ 3,041,476	
d. Backfill (from borrow source)	4,560	ton	$ 8.00	$ 36,480	
e. Backfill (from local stockpiles)	198,205	ton	$ 2.50	$ 495,513	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g. Revegetate	5.6	acres	$ 5,000	$ 27,835	
Subtotal				$ 3,768,704	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 4,522,444	
Subtotal				$ 8,291,148	
i. Scope contingency	1	ea	20%	$ 1,658,230	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 9,949,378	
j. Project management	1	ea	6%	$ 596,963	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 1,193,925	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 11,740,266**	
2h. RTD at Undiscovered Site #3 (to 40 ft)					Excavation Depth is 40 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	30,646	ton	$ 15.00	$ 459,694	
d. Backfill (from borrow source)	2,533	ton	$ 8.00	$ 20,267	
e. Backfill (from local stockpiles)	28,113	ton	$ 2.50	$ 70,282	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
g. Revegetate	1.6	acres	$ 5,000	$ 8,029	
Subtotal				$ 725,672	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 870,806	
Subtotal				$ 1,596,477	
i. Scope contingency	1	ea	20%	$ 319,295	From EPA 540-R-00-002 Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 1,915,773	
j. Project management	1	ea	6%	$ 114,946	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 229,893	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 2,260,612**	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements:
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2i. RTD at Undiscovered Site #4 (to 85 ft)					Excavation Depth is 85 feet
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	237,875	ton	$ 15.00	$ 3,568,126	
d. Excavation/remediation (concrete)	3,101	ton	$ 19.00	$ 58,926	
e. Backfill (from borrow source)	7,019	ton	$ 8.00	$ 56,156	
f. Backfill (from local stockpiles)	233,758	ton	$ 2.50	$ 584,396	
g. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
h. Revegetate	6.5	acres	$ 5,000	$ 32,470	
Subtotal				$ 4,467,474	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 5,360,969	
Subtotal				$ 9,828,443	
i. Scope contingency	1	ea	20%	$ 1,965,689	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 11,794,131	
j. Project management	1	ea	5%	$ 589,707	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 943,531	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 13,327,368**	
3. Pump and Treat - 100 D Area					
a. Extraction wells - convert from monitoring					CHPRC - Field Engineering Lead (costs include labor + materials unless noted)
-engineering, radiological review, work control	3	ea	$ 10,000	$ 30,000	
-misc. equipment (pump, wellhead, vault)	3	ea	$ 12,000	$ 38,988	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	3	ea	$ 2,000	$ 6,000	
-fabrication and installation of electrical rack	3	ea	$ 3,000	$ 9,000	
-misc. support	3	ea	$ 2,000	$ 6,000	
b. Extraction wells - existing					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	1	ea	$ 10,000	$ 10,000	
-misc. equipment (pump and other)	1	ea	$ 12,000	$ 12,996	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	1	ea	$ 3,000	$ 3,000	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	Assume this is not required for an existing extraction well.
-misc. support	1	ea	$ 2,000	$ 2,000	
c. Injection wells - convert from monitoring					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	2	ea	$ 10,000	$ 20,000	
-misc. equipment	2	ea	$ 6,000	$ 12,996	Assume misc equipment is 1/2 of that required for extraction well. Total cost includes WA State sales tax at 8.3%
-pump assembly and installation	0	ea	$ 3,000	$ -	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	
-misc. support	2	ea	$ 2,000	$ 4,000	
d. Conveyance piping	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost. Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
e. Treatment system	1	ea	$ 2,000,000	$ 2,000,000	$1,842,500 (2004 dollars) from Table 4-9, SGW-38494
Subtotal				$ 2,196,640	
i. Scope contingency	1	ea	20%	$ 439,328	
Subtotal				$ 2,635,968	
j. Project management	1	ea	5%	$ 131,798	
k. Remedial design	1	ea	8%	$ 210,877	
l. Construction management	1	ea	6%	$ 158,158	
TOTAL PUMP AND TREAT COST - 100 D AREA				**$ 3,136,802**	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
4. Pump and Treat - 100 K Area (includes KR-4 and KW)					
a. Extraction wells - convert from monitoring					CHPRC - Field Engineering Lead (costs include labor + materials unless noted)
-engineering, radiological review, work control	3	ea	$ 10,000	$ 30,000	
-misc. equipment (pump, wellhead, vault)	3	ea	$ 12,000	$ 38,988	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	3	ea	$ 2,000	$ 6,000	
-fabrication and installation of electrical rack	3	ea	$ 3,000	$ 9,000	
-misc. support	3	ea	$ 2,000	$ 6,000	
b. Extraction wells - existing					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	1	ea	$ 10,000	$ 10,000	
-misc. equipment (pump and other)	1	ea	$ 12,000	$ 12,996	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	1	ea	$ 3,000	$ 3,000	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	Assume this is not required for an existing extraction well.
-misc. support	1	ea	$ 2,000	$ 2,000	
c. Injection wells - convert from monitoring					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	2	ea	$ 10,000	$ 20,000	
-misc. equipment	2	ea	$ 6,000	$ 12,996	Assume misc equipment is 1/2 of that required for extraction well. Total cost includes WA State sales tax at 8.3%
-pump assembly and installation	0	ea	$ 3,000	$ -	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	
-misc. support	2	ea	$ 2,000	$ 4,000	
d. Conveyance piping	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost. Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
e. Treatment system					
-100-KR-4	1	ea	$ 7,215,876	$ 7,215,876	from Figure 5-3 DOE/RL-2008-05 Rev. 0
-100-KW	1	ea	$ 2,287,496	$ 2,287,496	from Figure 5-4 DOE/RL-2008-05 Rev. 0
Subtotal				$ 9,699,812	
i. Scope contingency	1	ea	20%	$ 1,939,962	
Subtotal				$ 11,639,775	
j. Project management	1	ea	Actual	$ 371,312	
k. Remedial design	1	ea	Actual	$ 200,000	
l. Construction management	1	ea	6%	$ 698,386	
TOTAL PUMP AND TREAT COST - 100 D/K AREA				**$ 12,909,473**	

Annual Operation and Maintenance Costs

1. Institutional Controls					
a. Weed and pest control	1	ea	$ 1,045.00	$ 1,045	
b. Waste site/fence maintenance	1	ea	$ 2,342.00	$ 2,342	
TOTAL IC COST				**$ 3,387**	
Year 2010				$ 3,387	NPV for Institutional Controls at 2.23% Real Discount Rate (9 yrs)
Year 2011				$ 3,387	
Year 2012				$ 3,387	
Year 2013				$ 3,387	
Year 2015				$ 3,387	
Year 2016				$ 3,387	
Year 2017				$ 3,387	
Year 2018				$ 3,387	
Year 2019				$ 3,387	$27,300
Subtotal				$ 30,483	

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2a. RTD at 100-D-12				$ -	
a Routine maintenance not required					
2b. 100-D-30 SW				$ -	
a Routine maintenance not required					
2c. RTD at 600-334				$ -	
a Routine maintenance not required					
2d. RTD at 116-K-2				$ -	
a Routine maintenance not required					
2e. RTD at 100-C-7-1				$ -	
a Routine maintenance not required					
2e. RTD at 100-C-7				$ -	
2f. RTD at Undiscovered Site #1				$ -	
2g. RTD at Undiscovered Site #2				$ -	
2h. RTD at Undiscovered Site #3				$ -	
2i. RTD at Undiscovered Site #4				$ -	
3. Pump and Treat - 100 D Area					
a Year 2010	1	ea	$ 1,595,165	$ 1,595,165	NPV for Pump and Treat O&M at 1.6% Real Discount Rate (5 yrs)
b Year 2011	1	ea	$ 1,595,165	$ 1,595,165	
c Year 2012	1	ea	$ 1,595,165	$ 1,595,165	
d Year 2013	1	ea	$ 1,595,165	$ 1,595,165	
e Year 2014	1	ea	$ 1,595,165	$ 1,595,165	
Subtotal				$ 7,975,825	$7,610,000.00

Notes - above costs based on following assumptions
- -Flow = 50 gpm; Cr(VI) Conc = 7500 ug/L
- -DR-5 system regeneration every two weeks
- -Quantities of rock salt, and hydrochloric acid remain 55 gallons/regeneration
- -Phosphoric acid and sodium hydroxide scaled based on chromium
- -Sodium dithionite quantity needed for regeneration estimated at 3 1 X estimated chromium quantity removed
- -Waste quantity scaled based on chromium quantity
- -Labor is approximately 7 FTE based on current costs.
- -Maintenance and electricity costs are estimated based on information from the 100-DX Treatment Plant Pre-Conceptual Design and Costs Estimate Technical memorandum

4. Pump and Treat - 100 K Area					
a Year 2010	1	ea	$ 2,713,788	$ 2,713,788	NPV for Pump and Treat O&M at 2.07% Real Discount Rate (8 yrs)
b Year 2011	1	ea	$ 2,713,788	$ 2,713,788	
c Year 2012	1	ea	$ 2,713,788	$ 2,713,788	
d Year 2013	1	ea	$ 2,713,788	$ 2,713,788	
e Year 2015	1	ea	$ 2,713,788	$ 2,713,788	
f Year 2016	1	ea	$ 2,713,788	$ 2,713,788	
g Year 2017	1	ea	$ 2,713,788	$ 2,713,788	
h Year 2018	1	ea	$ 2,713,788	$ 2,713,788	
				$ 21,710,304	$19,820,000.00

Note
O&M duration is based on baseline schedule (personal communication with 100-K Area Groundwater Lead)
Subtotal

Table B3-2. Cost Estimate Alternative 1 - Continue Current Actions
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
Periodic Costs - Occur Once in Year N		Date	9/30/2009	09/30/19	
1 Institutional Controls			0	30000	
a Prepare and issue sampling reports	1	ea	$ 10,000 0	$ 10,000	from CHPRC 200-MW-1 OU IC worksheet
b. Conduct site reviews (5-year)	1	ea	$ 20,000	$ 20,000	from CHPRC 200-MW-1 OU IC worksheet
Subtotal			$ -	$ 30,000	
Net Present Value				$ 25,594	Occur in Year 2015 (N=5) 1.6 percent discount rate
2 RTD - all depths	0	ea	$ -	0	
a Maintain soil cover	1	ea	$ 7,923	$ 7,923	from CHPRC - 200-MW-1 OU IC worksheet. One time allowance for subsidence
Subtotal			$ -	$ 7,923	
Net Present Value				$ 6,760	Occur in Year 2015 (N=5) 1.6 percent discount rate
3 Pump and Treat Operations	0	ea	$ -	$ -	Due to 5 to 8 yr O&M timeframe no capital equipment replacement required outside that included within annual O&M cost.
4 Pump and Treat Decommissiong					
	1	ea	50%	1,568,401	Assume decommissioning is percentage of installed cost
	1	ea	50%	6,454,737	
Subtotal			$ -	$ 8,023,138	
Net Present Value				$ 6,434,401	Occur in Year 2019 (N=9) 2.23 percent discount rate

Table B-3. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of BIR - Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
Capital Costs					
1. Institutional Controls					
a. Amend IC Plan and database	1	ea	$ 21,200	$ 21,200	from CHPRC 200-MW-1 OU IC worksheet
b. Project management	1	ea	$ 2,400	$ 2,400	from CHPRC 200-MW-1 OU IC worksheet
c. Remedial design	1	ea	$ 4,720	$ 4,720	from CHPRC 200-MW-1 OU IC worksheet
TOTAL IC COST				$ 28,320	
2a. RTD at 100-D-12 to 8 ft					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	1,951	ton	$ 15.00	$ 29,267	
d. Backfill (from borrow source)	1,951	ton	$ 8.00	$ 15,609	
e. Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
g. Revegetate	0.2	acres	$ 5,000	$ 1,015	
Subtotal				$ 213,290	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 255,948	
Subtotal				$ 469,239	
i. Scope contingency	1	ea	20%	$ 93,848	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 563,086	
j. Project management	1	ea	6%	$ 33,785	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 67,570	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 664,442	
2b. RTD at 100-D-30 SW to 18 ft					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	3,452	ton	$ 15.00	$ 51,787	
d. Backfill (from borrow source)	3,452	ton	$ 8.00	$ 27,620	
e. Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
g. Revegetate	0.4	acres	$ 5,000	$ 1,858	
Subtotal				$ 248,665	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 298,398	
Subtotal				$ 547,063	
i. Scope contingency	1	ea	20%	$ 109,413	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 656,476	
j. Project management	1	ea	6%	$ 39,389	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ 78,777	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 774,641	

Table B-9. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of ISR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements:
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2c. RTD at 600-334 (No Excavation at this Site Assumed)					
a. Sampling	-	sample	$ 700	$ -	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	-	ea	$ 45,000	$ -	
c. Excavation/remediation	-	ton	$ 15.00	$ -	
d. Backfill (from borrow source)	-	ton	$ 8.00	$ -	
e. Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f. Environmental assessment	-	ea	$ 100,000	$ -	Assume revision of current EA requirement.
g. Revegetate	-	acres	$ 5,000	$ -	
Subtotal				$ -	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ -	
Subtotal				$ -	
i. Scope contingency	1	ea	20%	$ -	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ -	
j. Project management	1	ea	6%	$ -	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	12%	$ -	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ -	
2d. RTD at 116-K-2 to 20 ft					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	3,986	ton	$ 15.00	$ 59,797	
d. Backfill (from borrow source)	3,986	ton	$ 8.00	$ 31,892	
e. Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g. Revegetate	0.4	acres	$ 5,000	$ 2,089	
Subtotal				$ 261,177	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 313,413	
Subtotal				$ 574,590	
i. Scope contingency	1	ea	20%	$ 114,918	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 689,508	
j. Project management	1	ea	5%	$ 34,475	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 55,161	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 779,146	

1

Table B-3. Cost Estimate Alternative 2 – Continue Current Actions with Selective Application of IRR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements:
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 10, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2e. RTD at 100-C-7-1 to 15 ft					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 100 ft x 300 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation (soil)	2,815	ton	$ 15.00	$ 42,224	
d. Excavation/remediation (concrete)	-	ton	$ 19.00	$ -	
e. Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
f. Backfill (from local stockpiles)	-	ton	$ 2.60	$ -	
g. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
h. Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i. Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j. Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 697,160	
2e. RTD at 100-C-7 to 15 ft					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	2,815	ton	$ 15.00	$ 42,224	
d. Excavation/remediation (concrete)	-	ton	$ 19.00	$ -	
e. Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
f. Backfill (from local stockpiles)	-	ton	$ 2.60	$ -	
g. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
h. Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i. Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j. Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 697,160	
2f. RTD at Future Site #1 (to 15 ft)					
a. Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c. Excavation/remediation	2,815	ton	$ 15.00	$ 42,224	
d. Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
e. Backfill (from local stockpiles)	-	ton	$ 2.60	$ -	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement
g. Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i. Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j. Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l. Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				$ 697,160	

Table B3-2. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of ISR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements:
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
2g. RTD at Future Site #2 (to 15 ft)					
a Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c Excavation/remediation	2,815	ton	$ 15.00	$ 42,224	
d Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
e Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 697,160**	
2h. RTD at Future Site #3 (to 15 ft)					
a Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c Excavation/remediation	2,815	ton	$ 15.00	$ 42,224	
d Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
e Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
f. Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
g Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 697,160**	
2i. RTD at Future Site #4 (to 15 ft)					
a Sampling	32	sample	$ 700	$ 22,400	Assumed number of samples for 30 ft x 30 ft area
b. Closeout documentation	1	ea	$ 45,000	$ 45,000	
c Excavation/remediation	2,815	ton	$ 15.00	$ 42,224	
d Excavation/remediation (concrete)	-	ton	$ 19.00	$ -	
e Backfill (from borrow source)	2,815	ton	$ 8.00	$ 22,520	
f Backfill (from local stockpiles)	-	ton	$ 2.50	$ -	
g Environmental assessment	1	ea	$ 100,000	$ 100,000	Assume revision of current EA requirement.
h Revegetate	0.3	acres	$ 5,000	$ 1,551	
Subtotal				$ 233,695	
Transportation/ERDF Treatment/Disposal	1	ea	120%	$ 280,434	
Subtotal				$ 514,130	
i Scope contingency	1	ea	20%	$ 102,826	From EPA 540-R-00-002. Assume bid contingency of 0% for WCH self-perform
Subtotal				$ 616,955	
j Project management	1	ea	5%	$ 30,848	from Exhibit 5-8 EPA 540-R-00-002
k. Remedial design	1	ea	8%	$ 49,356	from Exhibit 5-8 EPA 540-R-00-002
l Construction management	1	ea	0%	$ -	Included in costs above per WCH personal communication
TOTAL RTD COST				**$ 697,160**	

Table B-3. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of IBR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements:
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
3. Pump and Treat - 100 D Area					
a. Extraction wells - convert from monitoring					CHPRC - Field Engineering Lead (costs include labor + materials unless noted)
-engineering, radiological review, work control	3	ea	$ 10,000	$ 30,000	
-misc. equipment (pump, wellhead, vault)	3	ea	$ 12,000	$ 36,988	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	3	ea	$ 2,000	$ 6,000	
-fabrication and installation of electrical rack	3	ea	$ 3,000	$ 9,000	
-misc. support	3	ea	$ 2,000	$ 6,000	
b. Extraction wells - existing					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	1	ea	$ 10,000	$ 10,000	
-misc. equipment (pump and other)	1	ea	$ 12,000	$ 12,996	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	1	ea	$ 3,000	$ 3,000	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	Assume this is not required for an existing extraction well.
-misc. support	1	ea	$ 2,000	$ 2,000	
c. Injection wells - convert from monitoring					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	2	ea	$ 10,000	$ 20,000	
-misc. equipment	2	ea	$ 6,000	$ 12,996	Assume misc equipment is 1/2 of that required for extraction well. Total cost includes WA State sales tax at 8.3%
-pump assembly and installation	0	ea	$ 3,000	$ -	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	
-misc. support	2	ea	$ 2,000	$ 4,000	
d. Conveyance piping	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost. Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
e. Treatment system	1	ea	$ 2,000,000	$ 2,000,000	$1,642,500 (2004 dollars) from Table 4-9, SGW-36494
Subtotal				$ 2,196,640	
i Scope contingency	1	ea	20%	$ 439,328	
Subtotal				$ 2,635,968	
j Project management	1	ea	5%	$ 131,798	
k Remedial design	1	ea	8%	$ 210,877	
l Construction management	1	ea	6%	$ 158,158	
TOTAL PUMP AND TREAT COST - 100 D AREA				**$ 3,136,802**	
4. Pump and Treat - 100 K Area (includes KR-4 and KW)					
a. Extraction wells - convert from monitoring					CHPRC - Field Engineering Lead (costs include labor + materials unless noted)
-engineering, radiological review, work control	3	ea	$ 10,000	$ 30,000	
-misc. equipment (pump, wellhead, vault)	3	ea	$ 12,000	$ 36,988	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	3	ea	$ 2,000	$ 6,000	
-fabrication and installation of electrical rack	3	ea	$ 3,000	$ 9,000	
-misc. support	3	ea	$ 2,000	$ 6,000	
b. Extraction wells - existing					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	1	ea	$ 10,000	$ 10,000	
-misc. equipment (pump and other)	1	ea	$ 12,000	$ 12,996	15 GPM, 80 ft head pump. Total includes WA State sales tax at 8.3%
-pump assembly and installation	1	ea	$ 3,000	$ 3,000	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	Assume this is not required for an existing extraction well.
-misc. support	1	ea	$ 2,000	$ 2,000	
c. Injection wells - convert from monitoring					CHPRC - Field Engineering Lead
-engineering, radiological review, work control	2	ea	$ 10,000	$ 20,000	
-misc. equipment	2	ea	$ 6,000	$ 12,996	Assume misc equipment is 1/2 of that required for extraction well. Total cost includes WA State sales tax at 8.3%
-pump assembly and installation	0	ea	$ 3,000	$ -	
-fabrication and installation of electrical rack	0	ea	$ 2,000	$ -	
-misc. support	2	ea	$ 2,000	$ 4,000	
d. Conveyance piping	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost. Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
e. Treatment system					
-100-KR-4	1	ea	$ 7,215,876	$ 7,215,876	from Figure 5-3 DOE/RL-2008-05 Rev. 0
-100-KW	1	ea	$ 2,287,496	$ 2,287,496	from Figure 5-4 DOE/RL-2008-05 Rev. 0
Subtotal				$ 7,412,316	
i Scope contingency	1	ea	20%	$ 1,482,463	
Subtotal				$ 8,894,779	
j Project management	1	ea	Actual	$ 371,312	
k Remedial design	1	ea	Actual	$ 200,000	
l Construction management	1	ea	6%	$ 533,687	
TOTAL PUMP AND TREAT COST - 100 D AREA				**$ 9,999,778**	

Table B3-1. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of ISR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements:
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit		Unit Cost		Total	Notes and Cost Basis/Reference
4. ISR System (per individual waste site)							
a. Tank storage and mixing							
-groundwater equalization tank (5000 gallons)	1	ea	$	10,000	$	10,000	
-ISR reagent tank (5000 gallons)	1	ea	$	27,400	$	27,400	Rated for ethanol (RS Means 2008)
-building (400 square feet, includes concrete slab)	1	ea	$	40,000	$	40,000	
-chemical feed pump (50-100 mL/min)	1	ea	$	1,000	$	1,000	rate required ~ 50 ml/minute
-booster pump (150 gal min at 60 psi)	1	ea	$	3,000	$	3,000	
-cleanout system	1	ea	$	15,000	$	15,000	Assumed allowance cost
-electrical components	1	ea	$	50,000	$	50,000	Assumed allowance cost
-instrumentation and control	1	ea	$	50,000	$	50,000	Assumed allowance cost
Subtotal					$	196,400	
WA State Sales Tax at 8.3%	1					16,301	
-freight on equipment	2	lb	$	2,500	$	5,000	
Subtotal					$	217,701	
-labor for tank, building, equipment installation	1	ea		35%	$	68,740	Allowance estimated from information provided by designer
Subtotal					$	**286,441**	
b. Vadose zone - chemical drip system							
-chemical drip system	1	ea					
--GreMax Max-Emitter Emitterline, 4-lph, 20-mm, 32	36	1000 ft roll	$	179.00	$	6,444	OL42032MY Max-Emitter, 330 degree filter inlet and 330 degree flowpath, dual solution exit points 180 degrees apart, 4-lph (1-gph) x 20-mm x 32" spacing x 1000 ft roll
--Pressure Regulator Assembly, 15-psi, 20-mm fittin	400	ea	$	12.98	$	5,192	OLPRM1520
--Starter Fittings, 3/4" MPT x 20-mm Locking Cap	400	ea	$	1.06	$	424	Heavy Duty, O685S34MA
--Safety Lock Coupling, 20-mm, O685	200	ea	$	0.78	$	156	
--End Closures, 20-mm, Figure 8, OF8900	400	ea	$	0.38	$	152	
--Pressure Gauge, 0 to 100 psi, Stainless Steel	4	ea	$	70.00	$	280	OLFG0100
--4" Yelomine Pipe SDR21 (200 psi)	600	ft	$	9.76	$	5,855	
--4" Yelomine Pipe SDR21 (200 psi) couplers	36	ea	$	66.24	$	2,385	
--4" Yelomine Pipe SDR21 (200 psi) splines	72	ea	$	5.54	$	399	
--site restoration (clean gravel placement)	43560	ft3	$	1.56	$	67,780	
Subtotal					$	89,046	
WA State Sales Tax at 8.3%	1	ea		8.30%	$	7,391	
Subtotal					$	96,437	
-- freight	1	ls	$	5,800.00	$	5,000	Vendor quote
Labor installation and System Startup/Shakedown	240	hr	$	135.00	$	32,400	Vendor quote
Professional Installation oversight	120	hr	$	175.00	$	21,000	Vendor quote
Subtotal					$	**154,837**	
c. Vadose Zone - monitoring							
-lysimeter porous cup (30 ft)	1	ea	$	52,000.00	$	52,000	Estimate from designer Installed cost
-lysimeter porous cup (60 ft)	2	ea	$	75,000.00	$	150,000	Estimate from designer Installed cost
Subtotal					$	**202,000**	
d. Hot spot delivery system							
- Extraction wells - convert from monitoring							CHPRC - Field Engineering Lead
--engineering, radiological review, work control	4	ea	$	10,000	$	40,000	
--misc. equipment	4	ea	$	12,000	$	51,984	15 GPM, 60 ft head pump. Total includes WA State sales tax at 8.3%
--pump assembly and installation	4	ea	$	2,000	$	8,000	
--fabrication and installation of electrical rack	4	ea	$	3,000	$	12,000	
--misc. support	4	ea	$	2,000	$	8,000	
- Injection wells - convert from monitoring							CHPRC - Field Engineering Lead
--engineering, radiological review, work control	1	ea	$	10,000	$	10,000	
--misc. equipment	0.5	ea	$	12,000	$	6,498	Assume misc equipment is 1/2 of that required for extraction well Total cost includes WA State sales tax at 8.3%
--pump assembly and installation	0	ea	$	3,000	$	-	
--fabrication and installation of electrical rack	0	ea	$	2,000	$	-	
--misc. support	1	ea	$	2,000	$	2,000	
Subtotal					$	**139,482**	

1

Table B3-3. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of ISR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site: 100-D Area
Location: Hanford, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2009
Date: May 18, 2009

Description: This alternative includes the following elements.
-Institutional controls
-Soil removal, treatment and disposal to various depths
-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)

Cost Distribution: Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
a. Conveyance piping and appurtenances					
-Makeup water from 100-D Area	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE to convey makeup water in lieu of groundwater. This is an installed cost Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
-vadose zone system	400	ft	$ 20.00	$ 8,932	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
-groundwater extraction system	2000	ft	$ 20.00	$ 41,660	Assume 6-inch diameter HDPE for 15 gpm flow each well This is an installed cost Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
-flow control/metering hardware	1	ea	21,250	$ 21,250	Estimated from designer information
-injection well system	400	ft	$ 20.00	$ 8,932	Assume 6-inch diameter HDPE for 15 gpm flow each well. This is an installed cost Total cost includes 8.3% WA sales tax on 1/2 of the unit cost
Subtotal				**$ 121,234**	
Subtotal all ISR Components				**$ 902,994**	
Contingency (35% scope and 10% bid)	1	ea	45%	$ 406,347	from Exhibit 5-6 and Exhibit 5-7 EPA 540-R-00-002
Subtotal				$ 1,309,342	
Project management	1	ea	6%	$ 78,561	from Exhibit 5-8 EPA 540-R-00-002
Remedial design	1	ea	12%	$ 157,121	from Exhibit 5-8 EPA 540-R-00-002
Construction management	1	ea	8%	$ 104,747	from Exhibit 5-8 EPA 540-R-00-002
TOTAL ISR COST (vadose zone + groundwater)				**$ 1,649,771**	
Vadose Zone Only				**$ 1,461,297**	
Annual Operation and Maintenance Costs					
1. Institutional Controls					
a. Weed and pest control	1	ea	$ 1,045.00	$ 1,045	
b. Waste site/fence maintenance	1	ea	$ 2,342.00	$ 2,342	
TOTAL IC COST				$ 3,387	
Year 2010				$ 3,387	NPV for Institutional Controls at 2.23% Real Discount Rate (9 yrs)
Year 2011				$ 3,387	
Year 2012				$ 3,387	
Year 2013				$ 3,387	
Year 2015				$ 3,387	
Year 2016				$ 3,387	
Year 2017				$ 3,387	
Year 2018				$ 3,387	
Year 2019				$ 3,387	$27,300
Subtotal				$ 30,483	
2a. RTD at 100-D-12				$ -	
a. Routine maintenance not required					
2b. 100-D-30 SW				$ -	
a. Routine maintenance not required					
2c. RTD at 600-334				$ -	
a. Routine maintenance not required					
2d. RTD at 116-K-2				$ -	
a. Routine maintenance not required					
2e. RTD at 100-C-7-1				$ -	
a. Routine maintenance not required					
2e. RTD at 100-C-7				$ -	
2f. RTD at Undiscovered Site #1				$ -	
2g. RTD at Undiscovered Site #2				$ -	
2h. RTD at Undiscovered Site #3				$ -	
2i. RTD at Undiscovered Site #4				$ -	

Table B3-2. Cost Estimate Alternative 2 - Continue Current Actions with Selective Application of ISR
Focused Feasibility Study for 100 Area Hexavalent Chromium Remediation

Typical Site:	100-D Area	**Description:**	This alternative includes the following elements
Location:	Hanford, Washington		-Institutional controls
Phase:	Feasibility Study (-30% to +50%)		-Soil removal, treatment and disposal to various depths
Base Year:	2009		-Groundwater pump and treat (4 extraction wells, 1 injection well, IX treatment)
Date:	May 18, 2009	**Cost Distribution:**	Capital costs incur in year 0, O&M costs in years 1 to 5, periodic costs in year 6

Description	QTY	Unit	Unit Cost	Total	Notes and Cost Basis/Reference
3. Pump and Treat - 100 D Area					
a Year 2010	1	ea	$ 1,595,165	$ 1,595,165	
b Year 2011	1	ea	$ 1,595,165	$ 1,595,165	
c Year 2012	1	ea	$ 1,595,165	$ 1,595,165	
d Year 2013	1	ea	$ 1,595,165	$ 1,595,165	
e Year 2014	1	ea	$ 1,595,165	$ 1,595,165	NPV for Pump and Treat O&M at 1.6% Real Discount Rate (5 yrs)
Subtotal				$ 7,975,825	$7,810,000.00
Notes - above costs based on following assumptions					
-Flow = 50 gpm; Cr(VI) Conc. = 7500 ug/L					
-DR-5 system regeneration every two weeks					
-Quantities of rock salt, and hydrochloric acid remain 55 gallons/regeneration					
-Phosphoric acid and sodium hydroxide scaled based on chromium					
-Sodium dithionite quantity needed for regeneration estimated at 3.1 X estimated chromium quantity removed					
-Waste quantity scaled based on chromium quantity					
-Labor is approximately 7 FTE based on current costs					
-Maintenance and electricity costs are estimated based on information from the 100-DX Treatment Plant Pre-Conceptual Design and Costs Estimate Technical memorandum					
4. Pump and Treat - 100 K Area (both KR-4 and KW)					
a Year 2010	1	ea	$ 2,713,788	$ 2,713,788	
b Year 2011	1	ea	$ 2,713,788	$ 2,713,788	
c Year 2012	1	ea	$ 2,713,788	$ 2,713,788	
d Year 2013	1	ea	$ 2,713,788	$ 2,713,788	
e Year 2015	1	ea	$ 2,713,788	$ 2,713,788	
f Year 2016	1	ea	$ 2,713,788	$ 2,713,788	
g Year 2017	1	ea	$ 2,713,788	$ 2,713,788	
h Year 2018	1	ea	$ 2,713,788	$ 2,713,788	NPV for Pump and Treat O&M at 2.07% Real Discount Rate (6 yrs)
Subtotal				$ 21,710,304	$19,820,000.00
5. ISR Costs					
a Ethanol	1	ea	$ 100,000	$ 100,000	Purchase and delivered cost
b Citric acid	1	ea	$ 15,000	$ 15,000	Purchase and delivered cost
c Calcium Polysulfide	18000	gallon	$ 1	$ 24,480	$255/ton delivered quote from TKI. 24 tons per delivery. Assume four deliveries.
d Labor	1	ea	$ 70,000	$ 70,000	estimate from designer
e Electricity	50,000	kwh	$ 0.034	$ 1,700	Hanford rate of $0.034 per kwh
Subtotal				$ 211,180	
Periodic Costs - Occur Once in Year N		Date:	9/30/2009	09/30/19	
1 Institutional Controls			0	30000	
a Prepare and issue sampling reports	1	ea	$ 10,000.0	$ 10,000	from CHPRC 200-MW-1 OU IC worksheet
b Conduct site reviews (5-year)	1	ea	$ 20,000	$ 20,000	from CHPRC 200-MW-1 OU IC worksheet
Subtotal			$ -	$ 30,000	
Net Present Value				$ 25,594	Occur in Year 2015 (N=5) 1.6 percent discount rate
2 RTD - all depths	0	ea	$ -	0	
a. Maintain soil cover	1	ea	$ 7,923	$ 7,923	from CHPRC - 200-MW-1 OU IC worksheet. One time allowance for subsidence.
Subtotal			$ -	$ 7,923	
Net Present Value				$ 6,760	Occur in Year 2015 (N=5) 1.6 percent discount rate
3 Pump and Treat Operations	0	ea	$ -	$ -	Due to 5 yr O&M timeframe no capital equipment replacement required outside that included within annual O&M cost.
4 Pump and Treat Decommissiong	1	ea	50%	6,568,290	Assume decommissioning is percentage of installed cost
Subtotal			$ -	$ 6,568,290	
Net Present Value				$ 5,267,842	Occur in Year 2019 (N=6) 2.23 percent discount rate
5 ISR decommissioning costs	1	ea	35%	$ 577,420	Assume 35% of install cost. Most components moved to new site for reuse.

This page intentionally left blank.

B.4. References

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List," *Code of Federal Regulations*. http://edocket.access.gpo.gov/cfr_2008/julqtr/40cfr141.50.htm

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq. http://www.epa.gov/oecaagct/lcla.html#Hazardous%20Substance%20Responses

DOE/RL-2001-41, 2007, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-05, 2008, *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump and Treat Operations*, Rev. 0. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

EPA/540/R-00/002, 2000, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, OSWER 9355.0-75, U.S. Environmental Protection Agency, Washington, D.C.

Means, R. S., 2008, *Mechanical Cost Data,* 67th annual ed., Robert S. Means Company, Kingston, Massachusetts.

OMB Circular No. A-94, 2008, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* Appendix C, Office of Management and Budget, Washington, D.C., as revised.

Site Stabilization Agreement for All Construction Work for the U.S. Department of Energy at the Hanford Site, 1984, as amended, commonly known as the Hanford Site Stabilization Agreement (original title, *Site Stabilization Agreement, Hanford Site, between J. A. Jones Construction Services Company and Morrison-Knudsen Company, Inc., and the Building and Construction Trades Department of the AFL-CIO and its affiliated international unions, and the International Brotherhood of Teamsters, Chauffeurs, Warehousemen, and Helpers of America*).

Social Security Act of 1935, 26 USC 21, et seq. (*Federal Insurance Contributions Act*).

WCH-191, 2008, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*, Washington Closure Hanford, LLC, Richland, Washington. (http://www.wch-rcc.com/pgs/readroom/WCH/wch191.pdf

This page intentionally left blank.