SECTION

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Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
		(e.g., Slurry Wall or Grout Wall)		barrier perpendicular to the groundwater flow direction, partially filled with bentonite slurry, grout, or other low permeability material. The barrier is typically keyed into a lower-permeability zone. The slurry/grout could be jet injected, mixed with the soil using large augers or excavated.	Effectiveness is dependent on the continuity of the wall and the ability to key into the RUM, 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.	Installation of wall through cobbles and boulders to key into the RUM is very difficult and cost-prohibitive. Driven sheet piles near the river have been attempted but failed because of the presence of cobbles.			installation, waste from trench spoils.		implemented due to the depth to groundwater at 100-BC.
Containment (cont.)	Chemical/ Biological	Reactive Chemical Barrier (Apatite, ZVI, Zeolite, Polyphosphate, etc.)	trichloroethene, strontium-90	Subsurface injection or trenching in of reducing or sequestering chemicals along cross-gradient rows transecting plume. Chemicals are retained in the aquifer matrix so that contaminates are passively removed as groundwater moves through the treatment zone barriers.	Moderate Effective if barrier treatment zone conditions are maintained. High flows of highly aerobic groundwater, and changing water levels are likely to necessitate more frequent amendments and/or reduce permeability of barrier (for ZVI). Not effective in treating the bulk of the plume.	Moderate Can be implemented with injection wells or trenching. However, both may be very challenging at this site due to the presence of cobbles/ boulders.	High Dependant on number and type of wells.	Moderate	GHG and energy for installation	Retained	
		Reactive Chemical Barrier (ISRM)	Cr(VI)	Subsurface delivery and/or recirculation of chemical reductants along cross-gradient rows transecting plume. Residual reducing chemicals are retained in the aquifer matrix so Cr(VI) is passively removed as groundwater moves through the treatment zone barriers. Sodium dithionite or zero-valent iron maybe used as reductants. ISRM is currently in use at 100-D.	Moderate/High Effective if barrier treatment zone conditions are maintained. High flows of concentrated contaminants in groundwater, and changing water levels may reduce effectiveness and require more frequent amendments. The ISRM at 100-D has experienced some breakthrough. Not effective in treating the bulk of the plume.	Moderate/High Can be implemented with injection wells or recirculation dipole wells. Broad zones of secondary byproduct generation within treatment area may occur.	Moderate/High Dependant on number and type of wells.	Moderate	GHG and energy for installation	Retained	
	Chemical/ Biological (cont.)	Reactive Biological Barrier	Cr(VI), nitrate, and trichloroethene	Subsurface delivery and recirculation of electron donors along cross-gradient rows transecting plume. Residual reducing byproducts and biomass are retained in the aquifer matrix so that contaminants are passively removed as groundwater moves through the treatment zone barriers.	Low/Moderate Effective if barrier treatment zone conditions are maintained. The aerobic groundwater conditions may require frequent amendment of the barrier. Not effective in treating the bulk of the plume.	Moderate/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 reoxygenation of groundwater before discharge to the river.	Moderate/High Dependant on number and type of wells.	Moderate	GHG and energy for installation	Retained	
	Hydraulic Control	Hydraulic Containment via Extraction	All	Install extraction wells along downgradient edge of plumes to control migration of COPCs to the river.	Moderate Extraction should 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.	Low Facilities in place.	Moderate	GHG and energy for operations	Retained	
		Hydraulic Containment via Injection	All	Injection of river water or groundwater parallel to the river. Manages hydraulic gradients to create conditions (e.g., an inward gradient) 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.	Low/Moderate Should rapidly control plume migration to the river. However, some flushing and dilution of the contamination already close to the river may occur,	Moderate Can be accomplished using practically achievable injection rates. Injection only required two to three seasons (6 to 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	Moderate	GHG and energy for operations	Retained	

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment

Source: 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan."

Note: Other COPCs include: strontium-90, tritium, chloroform, TCE, and nitrate.

a. Additional details on technologies not retained are provided in Appendix I.

b. Sustainability includes potential impacts to the environment that could arise from implementing this technology (e.g., GHG emissions, waste generation, water use and resource impacts, energy use). Alternative design will dictate sustainability of an approach.

c. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC Applicability of "All" indicates implementation of a technology is not dependent on the nature of a chemical.

Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions (hereinafter called the Site-Wide IC Plan [DOE/RL-2001-41]) describes how DOE-RL will implement and maintain OU-specific ICs specified in CERCLA decision documents. The Site-Wide IC Plan (DOE/RL-2001-41) is updated based on final CERCLA decision documents within 180 days after issuance of the final decision document. The Site-Wide IC Plan (DOE/RL-2001-41) addresses the elements of *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA 540-F-00-005). In addition, ICs are reviewed during the CERCLA five-year review process.

Table 8-10 identifies DOE categories of ICs and the examples of ICs currently in use at the Hanford Site, including whether the institutional control will be retained in the FS.

Monitored Natural Attenuation. MNA is different from the no action response in that natural attenuation assumes that naturally occurring physical, chemical, and biological processes reduce contaminant concentrations. Under MNA, unaugmented, natural, intrinsic processes occur, and a monitoring program tracks remedial progress. MNA is also different from no action in that implementation of this action involves evaluating the nature and extent of the natural attenuation processes and verifying and monitoring that these processes reduce the mass, toxicity, and mobility of the contaminants to achieve compliance with RAOs. Implementation of MNA includes, as appropriate, elements of source control, exposure mitigation through implementation of ICs, definition of specific attenuating mechanisms involved, and specification of effective monitoring. Implementation of MNA may also include specification of contingent responses if specific conditions are not met during the monitoring stage.

MNA leaves contaminants in the vadose zone to attenuate over time from natural biological, radioactive decay, chemical reductive processes, and flushing from surface water infiltration. Natural attenuation is most effective on sites with readily degradable nonradionuclides or radionuclides with short half-lives. Attenuation changes the physical character and composition of a waste, making it less hazardous or nonhazardous. This general response action is different from no action in that it incorporates monitoring of the contaminated area to track progress toward compliance with RAOs.

To demonstrate effectiveness and protectiveness of MNA, the existence and irreversibility of mechanisms responsible for reductions in contaminant toxicity or mobility must be determined. For radionuclides with short half-lives, natural radiological decay can achieve substantial reductions in contaminant mass in a relatively short period. At 100-BC, these include cesium-137 (half-life of 30 years), europium-152 (half-life of 13 years), europium-154 (half-life of 8.8 years), strontium-90 (half-life of 29.1 years) and tritium (half-life of 12.4 years). Although radiological decay is well understood, MNA would be employed at waste sites to verify that vadose zone contamination has remained immobile while decay is reducing concentrations.

MNA relies on natural attenuation processes such as biological and chemical reduction, adsorption, dilution, dispersion, and radioactive decay to manage the contamination onsite. MNA includes an evaluation of the natural attenuation mechanisms and implements source control and long-term monitoring to track progress toward complying with RAOs. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (*Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 1 – Technical Basis for Assessment* [EPA/600/R-07/139]). Therefore, MNA can be an important component of the overall remedy, especially when contaminants are short-lived radionuclides.

As presented in *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P), MNA is an appropriate remedial response only where its use will be protective of HHE. In addition, MNA is appropriate when it will be capable of achieving site-specific RAOs within a time frame that is reasonable compared with other alternatives. Largely because of the uncertainty associated with the potential effectiveness of MNA to

meet remediation objectives that are protective of HHE, EPA expects that source control and long-term performance monitoring will be fundamental components of any MNA remedy. If used, an MNA remedy could contain a contingency plan to trigger active remediation in case the monitoring data did not show expected remedial progress.

Evaluation of MNA as an appropriate response action for contaminated waste sites will be completed in accordance with *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999a) and *Technical Guidance for the Long-Term Monitoring of Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999b).

Removal. Removal technologies include excavation of contaminated materials. The engineering design is based on existing information. Existing information, including operational process knowledge, vadose zone data, groundwater data, and waste site remediation of similar sites, is used in determining the area for remediation. Excavation of sites with contaminated soil follows the observational approach, allowing waste characterization, designation, and treatment to occur as excavation proceeds. The observational approach uses a variety of techniques including field screening, confirmation sampling, and soil borings or test pits as appropriate to determine the extent of contaminant removal required until cleanup goals have been met. Excavation is coupled with analytical assessment, dust control, efficient transportation, treatment as required, and disposal. Excavated soil is segregated to determine disposal or treatment requirements.

Excavation can use conventional equipment and methods, including excavators, bulldozers, and wheeled loaders. Earthmoving equipment removes clean overburden, which can be staged for later use in backfilling, and contaminated media to stage for appropriate waste management activities. Contaminated media are typically removed in lifts (layers of uniform thickness) to allow screening for contamination. Field screening supports waste designation and helps determine achievement of remedial goals.

Process options under the removal GRA include standard excavation (depths up to 6 m [20 ft]) and deep excavation (greater than 6 m [20 ft] depths). At excavations exceeding 6 m (20 ft) bgs, implementation requires technologies that are more complex, such a large layback or open-pit-type excavation or use of shoring. Given the increased complexity, deep excavations have an increased cost compared to standard excavation.

None of the contamination in 100-BC is expected to be in high enough concentration that the excavation efforts are considered nuclear activities. Consequently, standard excavating and personal protection practices are acceptable.

Ex Situ Treatment. Following excavation, soil can be treated with ex situ methods to reduce contaminant concentrations or toxicity, remove contaminants (transfer to different media), or reduce volume, and allow for less costly disposal. Treatment can be achieved by applying physical, chemical, biological, or thermal processes.

Additional treatment that may be required to meet waste acceptance criteria at ERDF is not included in the costs for this process. This ex situ treatment option only covers technologies that could be used to treat the soil so that part or all of the soil volume could be backfilled at the location from which it was removed..

Table 8-10. Categories and Types of Current Hanford Site Institutional Controls

DOE Categories of Institutional Controls[a]	DOE Categorical Description	Types of Current Hanford Site Institutional Controls	Examples of Institutional Controls
Active/Passive Controls	These controls have long been understood to apply to the long-term management of radioactive waste. Active controls require clear institutional and human responsibilities and the active performance of responsibilities such as controlling access to a disposal site by means such as guards, performing maintenance operations or remedial actions at a site, controlling or cleaning up releases from a site, or monitoring parameters related to disposal system performance. Passive controls are defined by their dependence on the design of controls and structures such as permanent markers placed at a disposal site, public records and archives, government ownership and regulations regarding land or resource use, and other methods of preserving knowledge about the location design and contents of a disposal system.	**Warning Notices:** Provide visual identification and warning of hazardous or sensitive areas. A mechanism of warning notices includes signs that provide visual identification and warning of hazardous or sensitive areas.	**Warning Notices:** • Requirement for placement of permanent signs and/or markers at specific areas of the site. • Applies to all COPCs. • *Effectiveness:* Good. Reduces or eliminates the potential for direct contact with radiological contamination for the duration of elevated risk period, and for preserving knowledge about a specific area or design. • *Implementability:* Very Good. Readily implemented, requires periodic surveillance and maintenance. • *Cost:* Low. *Retained*
Proprietary/Government Controls	This type of control is based on the legal authority of landowners to control the use of their land. Proprietary controls, such as easements, are based on the rights associated with ownership of an interest in land. Government controls rely on the powers of governments to protect the public health and safety through zoning, legislation, land ownership, or permit programs.	**Land Use Management:** Ensures that use of the land is compatible with any hazards that exist. As presented in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), "DOE will restrict the use of land on waste sites and prohibit activities that would interfere with the remedial activity in accordance with the ICs requirements of the CERCLA decision documents and as described in applicable work plans." Implementation of land use management controls can ensure that any changes in use of the land are assessed before being allowed, and that ICs are maintained beyond change of ownership, as appropriate. Mechanisms include land use and real property controls (e.g., proprietary controls including easements and covenants) and excavation permits. Land use and real property controls ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. Site evaluations are required before any land disturbance activity, and excavation permits are required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. **Groundwater Use Management:** Ensures proper use of groundwater through groundwater controls. As described in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), groundwater use on the Hanford Site is generally restricted, except for limited research purposes and for monitoring and treatment, as approved by EPA or Ecology, or as authorized in EPA- or Ecology-approved documents. Excavation permits and the land use process also control groundwater use.	**Land Use Management:** • Land use and real property controls (e.g., proprietary controls including easements and covenants). • Applies to all COPCs. • *Effectiveness:* Good. Reduces or eliminates the potential for direct contact with contaminated groundwater when well implemented and maintained for the duration of elevated risk period. Ensures compatible land use. • *Implementability:* Very Good. Readily implemented, must identify and comply with all necessary legal requirements. • *Cost:* Low. *Retained* **Groundwater Use Management:** • Groundwater controls. • Applies to all COPCs. • *Effectiveness:* Good. Ensures no improper use of groundwater. • *Implementability:* Very Good. Readily implemented, but will likely require ongoing oversight and coordination with state water resource managers. • *Cost:* Low. *Retained*

Table 8-10. Categories and Types of Current Hanford Site Institutional Controls

DOE Categories of Institutional Controls[a]	DOE Categorical Description	Types of Current Hanford Site Institutional Controls	Examples of Institutional Controls
Structural/Nonstructural Controls	Structural controls include physical barriers (e.g., gates, fences, and natural barriers) to keep trespassers away from a site and signs to warn people of dangers and restrict disturbance to engineered barriers in place to restrict or contain actual or potential contaminant migration. Nonstructural controls are all other limitations on the use of land that do not require physical means of exposure prevention.	**Entry Restrictions:** Prevent or limit the access of humans to particular hazardous or sensitive areas. They can also be used to avoid disturbance and exposure to remedies such as excavation areas, engineered barriers, or an effective vegetative soil layer, and serve to ensure adequate training for those who enter these areas. Procedural requirements for access, warning signs, and fencing can be implemented to provide entry restrictions.	**Entry Restrictions:** • Procedural requirements for access excavation/drilling permits. • Applies to all COPCs. • *Effectiveness:* Good. Reduces or eliminates the potential for direct contact with contaminated groundwater when well implemented and maintained for the duration of elevated risk period. Protects integrity of active remedies. • *Implementability:* Very Good. Readily implemented, requires periodic surveillance and maintenance. • *Cost:* Low. *Retained*
Informational Tools[b]	Provide information or notification about whether a remedy is operating as designed and/or that residual or contained contamination may remain onsite. Information devices include state registries, deed notices, and advisories.	**Waste Site Information Management:** This is an administrative mechanism implemented to maintain and provide access to information on the location and nature of contamination. The WIDS database identifies waste management units on the Hanford Site, their location, waste type, and status. Other descriptive information contained in WIDS includes size, extent, and appearance; testing or sampling efforts; regulatory information; bibliographic references; images; change history; and data validation. RL maintains the system in accordance with the WIDS change control system, which documents and traces additions, deletions, and/or other changes dealing with the status of waste management units.	**Waste Site Information Management:** • Administrative • Applies to all COPCs. • *Effectiveness:* Good. Ensures access to information on the location and nature of contamination. • *Implementability:* Very Good. Readily implemented, but requires maintenance of the information management system. • *Cost:* Low. *Retained*

a. DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions.*

b. An "Informational Tool" is an EPA category of an IC that is used at the Hanford Site as discussed in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).

Ex situ treatment options include the following:

- Ex situ solidification/stabilization
- Soil washing
- Ex situ vitrification
- Ex situ thermal desorption

Disposal. Following excavation, contaminated soil needs to be properly disposed, either at the onsite or an offsite landfill, or by backfilling treated soil. Before implementation of a disposal option, waste acceptance criteria must be evaluated. Treatment required to meet ERDF waste acceptance criteria is evaluated under the disposal GRA.

Backfilling treated soil involves excavation and ex situ treatment, followed by onsite disposal. Before implementation of this disposal option, treated soil will need to be compared to PRG criteria to verify backfilling is appropriate.

Disposal at the onsite landfill includes transport of excavated soil to EDRF. The waste acceptance criteria for ERDF are based on regulatory requirements (e.g., RCRA Land Disposal Requirements) and risk-based considerations for long-term protection of HHE. If waste cannot be accepted at ERDF, a suitable EPA-approved disposal facility will be used. Part of this process option is treatment required to meet ERDF waste acceptance criteria. Therefore, an ex situ treatment process option does not need to be evaluated if excavation and disposal at ERDF are selected as remedial options.

In Situ Treatment. In situ treatment consists of actions that treat contamination in place using physical, chemical, or biological treatment techniques. The main advantage of in situ treatment is that it allows soil to be treated without being excavated and transported, resulting in significantly reduced exposure to site workers relative to removal of contaminated media for disposal or ex situ treatment. Other advantages include reduced disturbances to vegetation and cultural resources relative to excavation. In situ treatment may also provide larger areal zone of treatment, and there is typically little secondary waste generated. For this evaluation, in situ process options were subdivided by technologies that require delivery of a chemical or biological reagent to the subsurface for treatment, and those that do not. Within actions requiring delivery of a reagent, technologies can be further subdivided by the reagent approach (physical, chemical, or biological), and by the method for delivering the reagent to the subsurface. For treatment of contaminated soil in 100-BC, the following in situ remedial technologies and process options were evaluated:

- Reagent Approach:
  - Solidification
  - Stabilization/sequestration
  - Chemical reduction
  - Biological reduction
  - Combined chemical/biological reduction
  - Gaseous ammonia injection
  - In situ gaseous reduction (ISGR) with chemical reductant or biological substrate
- Delivery Method:
  - Mixing with conventional excavation equipment
  - Deep soil mixing (vertical/horizontal)
  - Foam delivery of reagents

- Gas delivery of reagents
- Horizontal injection wells
- Jet grouting
- Surface infiltration
- Void-fill grouting

In Situ Treatment—Other:

- Soil blending
- Desiccation
- In situ vitrification
- In situ flushing
- Phytoremediation

Containment. Containment actions consist of physical measures to restrict contaminant migration to groundwater. Containment remedial technologies include surface barriers, horizontal subsurface barriers, and compaction. Containment options were evaluated for soil impacted by mobile contaminants that have the potential to impact groundwater, including some radionuclides, Cr(VI), nitrate, and other metals. For treatment of contaminated soil in 100-BC, surface barriers, horizontal subsurface barriers, and dynamic compaction were evaluated.

Surface barrier technologies are constructed over contaminated waste sites to control the vertical entry of water into contaminated media, which in turn, reduces leaching of contamination to groundwater. In addition to their hydrological performance, barriers can function as physical obstructions to prevent intrusion by human and ecological receptors, limit wind and water erosion, and attenuate radioactivity. Surface barriers include maintaining existing soil cover (when applicable), modified RCRA Subtitle C or Subtitle D barrier, asphalt/concrete cap, and vegetative cap (evapotranspiration [ET] cap).

Emplaced horizontal subsurface barriers are set beneath existing in situ contaminants. These bottom barriers have features similar to those of vertical barriers in that they minimize movement of contaminants, restrict infiltration of groundwater, and contain similar materials with similar technologies. Horizontal barrier technologies can include jet grouting, soil freezing, and wire saw barriers.

Dynamic compaction can consolidate soil and buried waste, and minimize the potential subsidence for a subsequent barrier. The process involves dropping a weight from a predetermined height onto the area to be compacted.

8.3.1.2 Identification and Screening of Technologies for Groundwater

No Action. The no action response entails no further action to remove, remediate, monitor, or restrict access to contaminated groundwater. CERCLA RI/FS Guidance (EPA/540/G-89/004) and the NCP (40 CFR 300) guidance requires this response to remain in the FS process for comparative purposes, where it is used as a baseline against which all other alternatives will be compared.

Institutional Controls. Institutional controls are administrative controls and legal restrictions imposed on land use to prevent or reduce exposure to hazardous waste or hazardous constituents and/or to protect the integrity of a remedy. Section 8.3.1.1 and Table 8-10 describe ICs for the Hanford Site.

For groundwater, ICs include administrative controls, access, and drilling restrictions until achievement of RAOs. Groundwater use management controls are in place to ensure proper use of groundwater. Groundwater use on the Hanford Site is generally restricted, except for limited research purposes and for

monitoring and treatment, as approved by EPA or Ecology, or as authorized in EPA- or Ecology-approved documents. An evaluation of groundwater use management restrictions is presented in Table 8-7.

Monitored Natural Attenuation. MNA relies on natural attenuation processes such as biological and chemical transformations, adsorption, dilution, and dispersion to manage the contamination onsite. Section 8.3.1.1 describes this response action in detail. MNA includes an evaluation of the natural attenuation mechanisms and implements source control and long-term monitoring to track progress toward complying with RAOs. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (*Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment* [EPA/600/R-07/139]). Therefore, MNA can be an important component of the overall remedy, especially for waste sites with short-lived radionuclides.

As presented in *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P), MNA is an appropriate remedial response only where its use will be protective of HHE, and when it will be capable of achieving site-specific RAOs within a time frame that is reasonable compared with other alternatives. Largely because of the uncertainty associated with the potential effectiveness of MNA to meet remediation objectives that are protective of human health and the environment, EPA expects that source control and long-term performance monitoring will be fundamental components of any MNA remedy. If used, an MNA remedy could contain a contingency plan to trigger active remediation in case the monitoring data did not show expected remedial progress.

Evaluation of MNA as an appropriate response action for contaminated groundwater will be completed in accordance with the guidelines provided in the following documents:

- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P)
- *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999a)
- *Technical Guidance for the Long-Term Monitoring of Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999b)
- *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 3 – Assessment for Radionuclides Including Tritium, Radon, Strontium, Technetium, Uranium, Iodine, Radium, Thorium, Cesium, and Plutonium-Americium* (EPA/600/R-10/093)

Monitored natural attenuation may be selected as appropriate technology for remediation of contaminated groundwater under certain circumstances. MNA may be considered as an individual remedial alternative, or it may be combined with other technologies to develop a compound alternative (Figure 8-16 illustrates MNA of groundwater). Determining how MNA fits with other remediation technologies requires evaluation of the specific role that MNA will play in the alternative. Evaluation of an MNA technology application follows a logical sequence of assessment of the four essential functional requirements of MNA as listed below:

- **The contamination condition does not currently present an actual risk to human or ecological receptors**. There must be an expectation that exposure mitigation can and will be maintained throughout the MNA period. Site monitoring must be adequate to confirm exposure mitigation.

- **The source of the observed contamination is no longer contributing to the plume**. The source may have been previously controlled through an engineered remedy or naturally ceased to contribute to the problem. In some cases, a source control element (e.g., localized pump-and-treat or selected in situ remedy) may be combined with the MNA alternative to ensure adequate control of secondary sources (e.g., residual mobile contamination in the vadose zone, or high-concentration plume segments in groundwater).

- **The target plume is static or retreating, or existing monitoring data otherwise confirm that attenuating processes are present and operating at the site**.

- **Effective monitoring exists currently, or can be implemented**, that will provide confirmation that the attenuation is proceeding as expected and that remedial goals are achieved.

Development and evaluation of MNA either as a technology, or as a stand-alone alternative for groundwater contaminant plumes requires thorough understanding and description of current site conditions, knowledge of contaminant characteristics, in addition to representative historical monitoring results to form the basis for evaluation of MNA as an appropriate alternative. The following conditions will be considered in evaluating MNA for COCs at 100-BC:

- **Reduction of Cr(VI)** may also occur in reducing conditions within the aquifer, or through chemical reaction with reducing compounds. Chemical reduction of Cr(VI) produces chromium(III), which is subject to subsequent precipitation of chromium oxide and hydroxide compounds that exhibit extremely low water solubility. In groundwater at 100-BC, Cr(VI) reduction generally occurs only at locations where the aquifer has been modified to produce reducing conditions, either through application of some remedial process or through some pollution-related process (e.g., anaerobic conditions related to septic tank/leach field discharges, or historical releases of reducing constituents). Because the aquifer at 100-BC is generally aerobic and chemically oxidizing, chemical reduction of Cr(VI) is not generally considered to be a substantial attenuating process. At some localized areas, however, reduction may be taking place.

- **Diffusion and dispersion** within the aquifer are physical processes that reduce contaminant concentrations in groundwater over time and distance. Diffusion is a concentration-driven physical process that results in movement of dissolved constituents from areas of high concentration to adjacent areas of relatively low concentrations. Dispersion is a physical process that results in mixing of dissolved constituents within the aquifer water due to variations in groundwater flow velocity along varying flow paths within the aquifer. This mixing results in reduction in contaminant concentrations over distance. The 100-BC groundwater plumes cover a relatively large area and the distance along flow paths is relatively long between inland areas of elevated contaminant concentration and locations of potential exposure to receptors at the groundwater/river interface. This indicates that diffusion and dispersion may provide substantial concentration reduction prior to groundwater discharge to the river.

Pump-and-Treat. The pump-and-treat GRAs identify collection, ex situ treatment, and discharge as remedial technologies. The following text details these remedial technologies and applicable process options.

Collection. This process option involves collection of contaminated groundwater through the operation of groundwater extraction wells.

Ex Situ Treatment. Ex situ treatment uses an aboveground system to reduce the concentration of contaminants in groundwater. Ex situ treatment functions through collection, treatment, and discharge of

groundwater. Aboveground treatment may involve physical, biological, or chemical processes. Ex situ treatment process options include the following:

- Ion exchange
- Chemical reduction and precipitation
- Electrocoagulation
- Wetlands
- Subgrade bioreactors
- Ex situ bioreactors
- Phytoremediation
- Air stripping
- Granular activated carbon
- Membrane separation (reverse osmosis)

Onsite and Offsite Discharge:

  - Onsite discharge includes groundwater injection wells, surface infiltration, and beneficial reuse of treated water.
  - Offsite discharge includes surface water discharge (National Pollutant Discharge Elimination System [NPDES]).

In Situ Treatment. In situ treatment consists of actions that treat contamination in place. In situ treatment of contaminated groundwater generally includes methods to separate and remove contaminants or to degrade contaminants. Methods of in situ degradation generally involve adding agents to groundwater (via injection wells or permeable barriers) that facilitate chemical or biological changes that reduce mobility, toxicity, and/or concentration. For this evaluation, technologies are subdivided by the reagent approach (physical, chemical, or biological), and the method for delivering the reagent to the subsurface. For treatment of contaminated groundwater in 100-BC, the following in situ remedial technologies and process options were evaluated:

- Reagent Approach:
  - In situ chemical stabilization
  - In situ chemical treatment/reduction
  - In situ biological treatment (anaerobic)
  - In situ aerobic co-metabolism (biological treatment)
  - Hydrogen or other organic gas sparging
  - In situ treatment using combination of biological and chemical substrates
  - Water flushing
- Delivery Method:
  - Surface infiltration
  - Groundwater circulation wells (GCWs)

- Vertical wells
- Horizontal wells

Containment. Containment technologies assist in preventing or significantly reducing the migration of contaminants in groundwater through physical barriers or treatment barriers. For treatment of contaminated groundwater in 100-BC, the following containment process options were evaluated:

- Containment wall (such as slurry wall or grout wall)
- Reactive chemical barrier (such as apatite, ZVI, zeolite, polyphosphate)
- ISRM
- Reactive biological barrier
- Hydraulic containment via extraction
- Hydraulic containment via injection

8.3.2 Evaluation of Technologies and Selection of Representative Technologies

Tables 8-8 and 8-9 present the identification and screening of technologies and remedial process options for 100-BC. Table 8-8 presents technologies for vadose zone treatment for Cr(VI), radionuclides, and other metals. Table 8-9 presents GRAs and process options for groundwater impacted with Cr(VI) and other COPCs.

The various technologies screened in the tables include demonstrated and proven processes, innovative technologies, and potential processes that have undergone laboratory trials or bench scale testing. Factors considered in this evaluation include the state of technology development, site conditions, waste characteristics, nature and extent of contamination, and presence of constituents that could limit the effectiveness of the technology. A qualitative comparison of implementability, effectiveness, and cost provided additional evaluation of technologies. The screening tables present information pertaining to the sustainability of a process option. It is important to note, however, that sustainability was not considered as a criterion for the screening of process options.

Implementability refers to the relative degree of difficulty anticipated in implementing a particular process option under regulatory, technical, and schedule constraints posed by the site. As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), process options and entire technology types can be eliminated from further consideration if a technology or process option cannot be effectively implemented at the site. As discussed in Section 4.2.5 of the CERCLA RI/FS Guidance (EPA/540/G-89/004), "technical implementability is used as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site." Institutional or administrative implementability, which includes "the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology," is also considered in the initial screening.

Effectiveness refers to the ability of the process option to perform as part of a comprehensive remediation plan to meet RAOs under the conditions and limitations present onsite. Additionally, the NCP (40 CFR 300) defines effectiveness as the "degree to which an alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risk, affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection." This relative measure for comparison of process options performs the same or similar functions. Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that the evaluation of process options with respect to effectiveness should focus on: "(1) the potential effectiveness of process options in handling the estimated areas or volumes of media

and meeting the remediation goals identified in the remedial action objectives; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site."

For the initial screening of technology types and process options, the cost criterion is relative. It compares processes and technologies that perform similar functions and have similar effectiveness. Section 4.2.5 of the CERCLA RI/FS Guidance (EPA/540/G-89/004) states that "cost plays a limited role in the screening of process options. Relative capital and O&M costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type." For this evaluation, cost is used to screen out process options that have a high relative cost if other choices perform similar functions with similar effectiveness. The cost criterion includes a cursory consideration of the rough order of magnitude costs of construction and any long-term costs to operate and maintain the technologies.

Technologies that are not technically implementable or feasible based on implementability, effectiveness, and cost were screened out. Technical implementability is the first screening criteria evaluated as part of this process, per EPA guidance. However, for technologies with significant technical implementability challenges, an evaluation of effectiveness and cost was still completed to allow for a more complete evaluation. Technologies that were considered technically impracticable based on unsuccessful case studies at the site, challenges associated with existing site conditions (lithology), a potential increased risk to worker safety, or of increased complexity as compared to other technologies of comparable effectiveness were screened out. Technologies were also removed from further consideration if they were considered to have limited treatment effectiveness for the specified COPC or performance uncertainties. Appendix I provides a thorough discussion of the technologies not retained, including a detailed screening rationale. Remedial technology types and process options considered viable for remediating contamination at 100-BC are carried forward into the development (Chapter 9) and detailed analysis of alternatives (Chapter 10). The list of retained options should be considered dynamic, flexible, and subject to revision based on subsequent design investigation findings, results of treatability studies, or technological developments.

8.3.2.1 Evaluation of Technologies and Selection of Representative Technologies for Vadose Zone Contamination

For treatment of vadose zone soil (Table 8-8) at 100-BC, the following response actions were retained:

- No action
- ICs
- MNA
- Removal through standard excavation
- Removal through deep excavation
- Backfill of treated soil
- Onsite landfill (ERDF) disposal
- EPA approved offsite landfill disposal
- In situ biological reduction
- Void-fill grouting
- Modified RCRA C or D surface barrier containment
- Asphalt/concrete cap containment

8.3.2.2 Evaluation of Technologies and Selection of Representative Technologies for Groundwater Contamination

For treatment of contaminated groundwater (Table 8-9) at 100-BC, the following response actions and technologies were retained:

- No action
- ICs provide controls during remediation to interrupt the exposure pathway
- MNA provides treatment of contaminants through biological and chemical reduction, radioactive decay, adsorption, dilution, and dispersion
- Pump-and-treat provides for treatment of contaminants through:
  - Collection through groundwater extraction system
  - Ex situ ion exchange
  - Groundwater injection wells discharge
  - Discharge through surface infiltration
  - Discharge through beneficial reuse of treated water
- In situ biological treatment (anaerobic) through liquid substrate provides for treatment of contaminants
- Vertical wells provide treatment of contaminants as a component of pump-and-treat
- Reactive chemical barrier provides for treatment of contaminants
- Hydraulic containment via extraction provides engineered system to interrupt the exposure pathway

The "No Action" GRA does not provide capability to remove contaminants or interrupt the exposure pathway to receptors but is also retained per the NCP (40 CFR 300).

Figures 8-8 through 8-25 present technology-specific information on technologies that have been retained. Technologies are intended to interrupt pathways to receptors or eliminate the sources. For 100-BC, Chapter 9 selects technologies that are applicable for each waste site type group, which are developed into alternatives for each waste site group. Appendix I presents additional information on the screening of technologies that were not retained for treatment of contaminated media at 100-BC.

Standard Excavation

Key Components

- Completed using standard earthmoving equipment.
- Conventional open pit (standard) excavation limited to approximately 20 feet below ground surface based on equipment constraints.
- Extent of excavation required will be determined using an observational approach which combines characterization and remediation steps to maximize use of resources.
- The observational approach includes design of remediation based on available data. Specific site characterization will be performed during the removal of the waste. Remedial actions are guided by the observational approach where various methods, including in-situ and ex-situ sampling, process knowledge, and field measurements, guide day-to-day excavation.
- Clean overburden soil is removed and stockpiled.
- Contaminated soil is removed and segregated to determine disposal or treatment requirement, or direct-loaded into containers for disposal.
- Verification sampling can be performed to demonstrate cleanup levels are achieved.
- Excavations are backfilled and compacted using clean overburden and borrow soil.

Shallow excavation at 100-B-19.

Examples of Relevant Experience

- Removal, treatment, and disposal (RTD) has been selected as a remedial alternative in previous 100 Area decision documents. Full-scale remediation in the 100 Areas using RTD began in July 1996. Over one million tons of contaminated soil and debris have been disposed of. *(EPA/ROD/R10-99/039)*
- Excavations completed at Trenches 216-B-26 and 216-B-53A and at 216-B-14 Crib for Sr-90 and Cs-137 bearing soils. *(HNF-36881)*
- Uranium-contaminated sediments at Process Trench 316-5 were also excavated. *(WHC-SA-2062-FP)*

Risk Reduction Mechanism

- Contaminated materials removed, eliminating source of exposure.
- Mitigates further migration of contaminants to groundwater.

Screening Criteria *(dashed line indicates range)*

	Low	Moderate	High
Relative Effectiveness			
Relative Implementability			
Relative Capital Cost			
Relative O&M Cost	*No associated costs.*		

Figure 8-8. Standard Excavation

Deep Excavation

Key Components

- Excavation using standard equipment, requiring implementation of complex mechanisms such as shoring or lay backs to provide stability.
- Excavation complexity increases with greater depth.
- Extent of excavation required will be determined using an observational approach which combines characterization and remediation steps to maximize use of resources.
- The observational approach includes design of remediation based on available data from process knowledge and LFI. Specific site characterization will be performed during the removal of the waste. Remedial actions are guided by the observational approach where various methods, including in-situ and ex-situ sampling, process knowledge, and field measurements, guide day-to-day excavation.
- Extent of excavation required will be determined using an observational approach which combines characterization and remediation steps to maximize use of resources.
- The observational approach includes design of remediation based on available data from process knowledge and LFI. Specific site characterization will be performed during the removal of the waste. Remedial actions are guided by the observational approach where various methods, including in-situ and ex-situ sampling, process knowledge, and field measurements, guide day-to-day excavation.
- Requires careful evaluation of the side walls and anchoring systems selected to support the excavation, including stability calculations.
- Clean overburden soil is removed and stockpiled.
- Excavated soil is segregated to determine disposal or treatment requirements.
- A combination of in-process and verification sampling can be used to determine extent of excavation required and demonstrate cleanup levels are achieved.
- Excavations are backfilled and compacted using clean overburden and borrow soil.

Deep excavation at 100-B-27.

Examples of Relevant Experience

- Removal, treatment, and disposal (RTD) has been selected as a remedial alternative in previous 100 Area decision documents. Full-scale remediation in the 100 Areas using RTD began in July 1996. Over one million tons of contaminated soil and debris have been disposed of. *(EPA/ROD/R10-99/039)*
  - Excavation of contaminated soil was completed to groundwater (approximately 46 feet below ground surface) at waste site 100-B-27 at the Hanford 100-B Area with 10,190 cubic meters of contaminated soils removed. *(RSVP-2009-040)*
  - Waste site 100-C-7 at the Hanford 100-B/C Area has been excavated to greater than 70 feet below ground surface with over 700,000 cubic meters of soils removed. Excavtion is still on-going to remove contaminated soil.

Risk Reduction Mechanism

- Contaminant sources in deep vadose zone soils are physically removed.
- Mitigates further migration of contaminants to groundwater.

Screening Criteria *(dashed line indicates range)*

	Low	Moderate	High
Relative Effectiveness			
Relative Implementability			
Relative Capital Cost			
Relative O&M Cost	*No associated cost.*		

Figure 8-9. Deep Excavation

On-Site Disposal: Environmental Restoration Disposal Facility (ERDF)

Key Components

- Contaminated soil and waste material transported from waste site to on-site disposal facility at Hanford—Environmental Restoration Disposal Facility (ERDF).
- Treatment (*e.g.*, macro-encapsulation) performed at the facility as required to meet land disposal restrictions (LDR).
- Engineered to meet appropriate performance standards under 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," and meet minimum technical requirements for landfills under WAC 173-303-665, "Landfills."
- Facility can accept the majority of remediation waste streams. Liquid wastes that cannot be solidified and certain LDR wastes that cannot be accepted would need to be sent off-site for disposal.
- ERDF consists of a series of disposal areas (cells). Each pair of cells is 70 feet deep, 500 feet by 1,000 feet at the base, and over 1,400 feet wide at the top.
- Cell pairs have a disposal capacity of 3 million tons. As of June 2010, over 11 million tons of contaminated material have been deposited into ERDF. *(www.handford.gov/page.cfm/ERDF)*

Hanford's Environmental Restoration Disposal Facility

Examples of Relevant Experience

- Hanford's ERDF, in the 200 West Area, is a landfill regulated by USEPA and capable of receiving about 16,000,000 tons of waste.
- Accepts low-level radioactive, hazardous, and mixed wastes that are generated during the cleanup activities at the Hanford Site.
- First started operations in 1996. Over 11,000,000 tons of contaminated soil and debris have been disposed at the facility. *(RLI-D02-14)*

Risk Reduction Mechanism

- Waste material is placed in an engineered landfill with physical and regulatory controls to greatly restrict or eliminate environmental mobility.
- Waste material is consolidated at a single location. Risk reduction primarily achieved through excavation.

Screening Criteria *(dashed line indicates range)*

	Low	Moderate	High
Relative Effectiveness			
Relative Implementability			
Relative Capital Cost			
Relative O&M Cost	*No associated cost.*		

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Figure 8-10. Onsite Disposal: The Environmental Restoration Disposal Facility

Off-Site Disposal (Off-site Landfill and Off-Site Repository)

Key Components

- Disposal alternative for wastes not accepted at the Hanford ERDF.
- Includes disposal of waste at Toxic Substances Control Act (TSCA) Regulated Facilities and at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.
- Waste designated as Transuranic (TRU), spent nuclear fuel, and some PCB-containing wastes require off-site disposal.
- Hanford's TRU Waste Management Program coordinates and implements all post- generator aspects of TRU waste management, including receipt and interim storage of newly-generated TRU waste.
- TRU, mixed PCBs-containing, and low-level waste originated from Hanford remedial activities are inspected, characterized, and processed for permanent disposal at the Waste Receiving and Processing (WRAP) facility located in Hanford's 200 West Area.

A shipment of TRU waste leaves the Hanford Site, bound for the WIPP in Carlsbad, New Mexico. Each TRUPAC holds 14 55-gallon drums of waste.

Example of Relevant Experience

- In 2008, about 17,400 m^3 of Contact Handled-TRU waste and 2370 m^3 of Remote Handled-TRU waste from Hanford were listed in the inventory of the WIPP. *(DOE/TRU-09-3425)*

Risk Reduction Mechanism

- Waste material is placed in an engineered landfill with physical and regulatory controls to greatly restrict or eliminate environmental mobility.
- Waste material is consolidated at a single location. Risk reduction primarily achieved through excavation.

Screening Criteria *(dashed line indicates range)*

	Low	Moderate	High
Relative Effectiveness			
Relative Implementability			
Relative Capital Cost			
	High capital cost associated with disposal at WIPP facility.		
Relative O&M Cost	*No associated cost.*		

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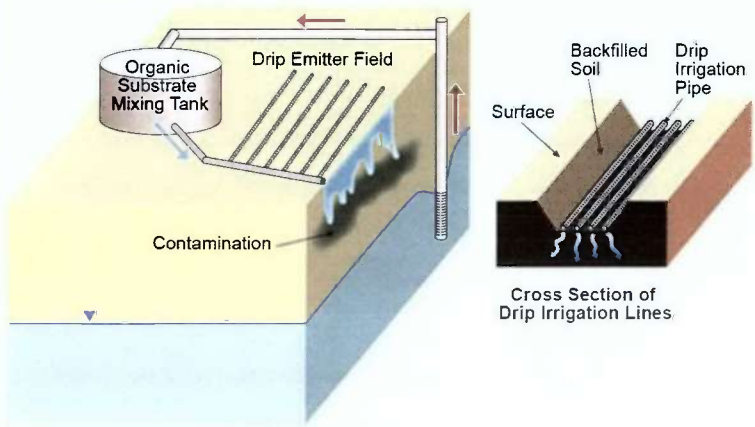
Figure 8-11. Offsite Disposal (Offsite Landfill and Offsite Repository)

In-Situ Biological Reduction (Vadose Zone)

Key Components

- Uses native microorganisms to reduce contaminants to less- or non-toxic compounds, either directly by the microbes through dissimilatory or enzymatic reduction, or indirectly by a reduced electron acceptor (*e.g.*, ferrous iron or sulfide).
- Natural process are enhanced by adding organic substrates (a carbon source) to stimulate microorganisms in the subsurface and change the geochemistry to anaerobic conditions.
- Localized temporary generation of secondary byproducts (reduced manganese, iron, and arsenic) should be expected.
- Organic substrate application methods include surface infiltration (shown in conceptual schematic), aqueous injection using wells, gas injection using wells, and soil mixing using solid reagents.
- Components for surface infiltration include:
  - Reagent tank
  - Subsurface drip irrigation system
  - Infiltration basin

Conceptual Schematic



Examples of Relevant Experience

Reports for examples of applications using bio-remediation to convert Cr(VI) to less toxic (Cr(III)) include:

- Hinkley Remediation Semiannual Status Report (July through December 2009), Pacific Gas and Electric Company (PG&E) Groundwater Remediation Program, Hinkley, California (CH2M HILL, 2010)
- PNNL-18784, Hanford 100-D Area Biostimulation Treatability Test Results

Pilot studies have demonstrated the processes can be used for applications in the vadose zone:

- A trailer-mounted 10-gpm In Situ Delivery (ISD™) system was used at a former agricultural facility (chrome plating) in Walla Walla, Washington to treat Cr+6-contaminated soil and groundwater that was a result of a leaking UST. (ETEC, Case Study, AGGRESSIVE HEXAVALENT CHROMIUM REMEDIATION USING A 10-GPM IN SITU DELIVERY (ISD™) SYSTEM)
- Laboratory studies have demonstrated the processes, showing that adding water and organic nutrients to columns packed with vadose zone materials contaminated with Cr(VI) cause the effective conversion of Cr(VI) to Cr(III) (Tokunaga et al., 2003, "In-situ reduction of Cr(VI) in heavily contaminated soils through organic carbon amendment," and Oliver, 2001, Microbial Reduction of Hexavalent Chromium Under Vadose Zone Conditions)

Risk Reduction Mechanism

- Biological treatment can reduce Cr(VI) to the less-toxic and less mobile Cr(III), and nitrate to nitrogen gas.
- Volume of Cr(III) will not change, but toxicity will be reduced.
- Can reduce contaminant volume by removing contaminants as they are completely degraded, and/or mobility and toxicity reduced by transforming contaminants to less-toxic and/or less soluble forms.

Screening Criteria *(dashed line indicates range)*

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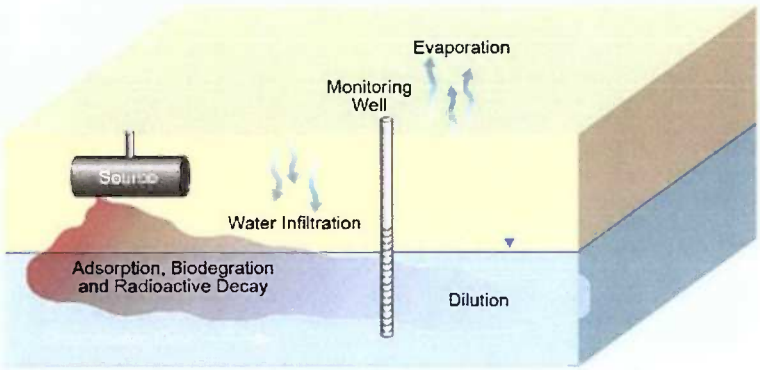
Figure 8-12. In Situ Biological Treatment (Vadose Zone)

Monitored Natural Attenuation (MNA)

Key Components

- Relies on unaugmented natural, intrinsic processes (dilution, volatilization, flushing from surface water infiltration, sorption, microbial degradation, radioactive decay, and chemical reactions) to reduce contaminant concentrations and migration.
- Transport modeling and evaluation of intrinsic processes may be required to evaluate potential groundwater migration and time required to achieve cleanup criteria.
- Incorporates long-term monitoring to track progress towards compliance with cleanup objectives. Typically combined with other technologies that manage source areas and mitigate exposure.

Conceptual Schematic



Examples of Relevant Experience

- ROD for 200-ZP-1 indicates additional 100-yr period of MNA needed to reach groundwater cleanup goals. Response action for 200-PO-1 OU may include MNA of existing iodine-129, tritium, and nitrate in groundwater plume. *(DOE-RL-2009-10)*

Risk Reduction Mechanism

- Contaminant concentrations reduced by dilution, volatilization, adsorption, microbial degradation, radioactive decay, chemical reactions.
- Biodegradation can transform contaminants into benign compounds. Partial degradation may result in formation of more toxic compounds.
- Plume is diluted or dispersed as it moves through groundwater, reducing toxicity but possibly increasing volume to be treated.

Screening Criteria *(dashed line indicates range)*

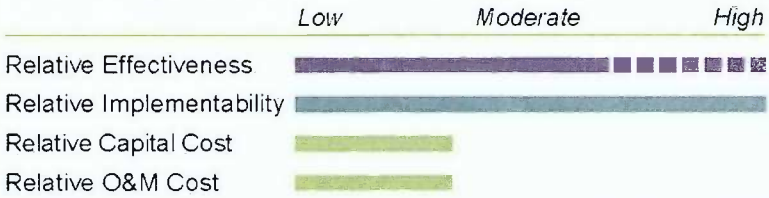


Figure 8-13. Monitored Natural Attenuation

Void Fill Grouting

Key Components

- In-situ treatment technology used to immobilize contaminants by solidification of wastes.
- Void grouting may be considered to fill large empty spaces (*e.g.*, pipelines, trenches, pits). Structure is then left in place.
- Grout can be cement-based (*e.g.*, Type I, II, III, IV, and V Portland cement) or chemical-based (*e.g.*, silicates, acrylics, lignosulfonates, phenoplasts, and aminoplasts).
- Portland cement-based grouts may offer an additional benefit to treat certain radionuclides and metals, since the increased pH from grouting may yield increasing precipitation and sorption of these compounds (*e.g.*, Sr-90).
- Grout can be mixed in batches or with a mobile continuous mixer, depending on the size of the grouting project.

Conceptual Schematic

Grouting of the 100-B-28 sodium dichromate supply line.

Examples of Relevant Experience

- In 2008, approximately 27,000 ft of pipeline were grouted at the DOE Melton Valley Site. *(www.bechteljacobs.com/pdf/factsheets/melton_valley.pdf)*

Risk Reduction Mechanism

- Immobilizes residual mobile contaminants that may be present within the structure.
- Reduces the potential of contaminant migration to groundwater.
- Immobilized contaminants left in place; however, volume of contaminated materials increases.

Screening Criteria *(dashed line indicates range)*

	Low	*Moderate*	*High*
Effectiveness			
Implementability			
Relative Capital Cost			
Relative O&M Cost		*No associated cost.*	

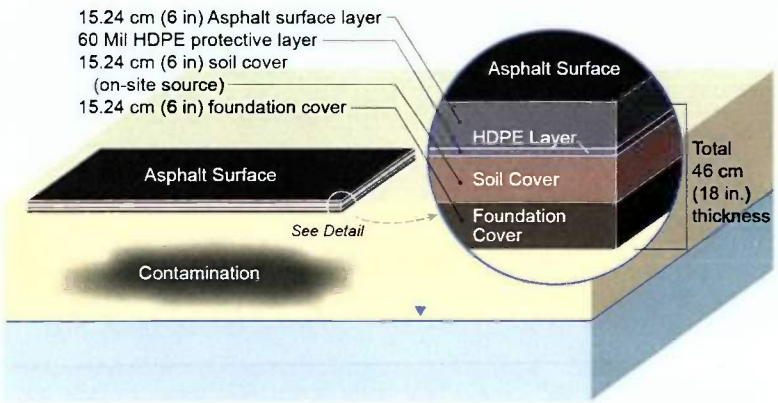
Figure 8-14. Void-Fill Grouting

Surface Barriers

Key Components

- Surface barriers are earthen and/or manufactured covers placed on the ground surface above contaminated media.
- Designed to be impermeable, to prevent surface water infiltration through the vadose zone, and to limit contaminant leaching to groundwater. May also prevent direct contact to contaminants.
- Types of surface barriers include: Modified RCRA Subtitle C and/or D, Asphalt/ Concrete, Vegetative and the Hanford Barrier.
- Asphalt/Concrete caps (shown in conceptual schematic) can be placed around structures to remain in place (e.g., reactors) in the short term to promote drainage, prevent infiltration into possible sources below the reactors, and prevent exposure to contaminated soil.
- Excavation, handling, and transport of contaminated soil are reduced.
- Can also be implemented at the bottom of an excavation to limit infiltration through contaminated soil left in place. Implementation may require soil characterization and soil compaction tests.
- Periodic inspection and repair required.

Conceptual Schematic



Examples of Relevant Experience

- In 2010, approximately 1.8 acres of modified asphalt was placed over the TY Tank Farm with approximately 5 USTs suspected of leaking radioactive and hazardous chemical waste. The asphalt barrier was installed to prevent rain water and snow melt from infiltrating into the ground surface. *(www.hanfordnews.com/2010/08/13/15712/asphalt-being-laid-over-underground.html)*

Risk Reduction Mechanism

- Prevents surface water infiltration and reduces contaminant migration through vadose zone, limiting potential leaching to groundwater.
- When coupled with Institutional Controls, may reduce direct contact and exposure to ecological receptors.
- Toxicity of contaminants is not reduced.

Screening Criteria *(dashed line indicates range)*

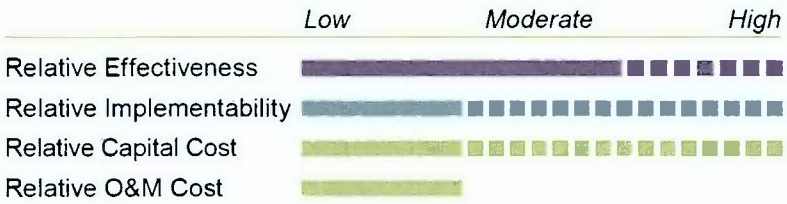


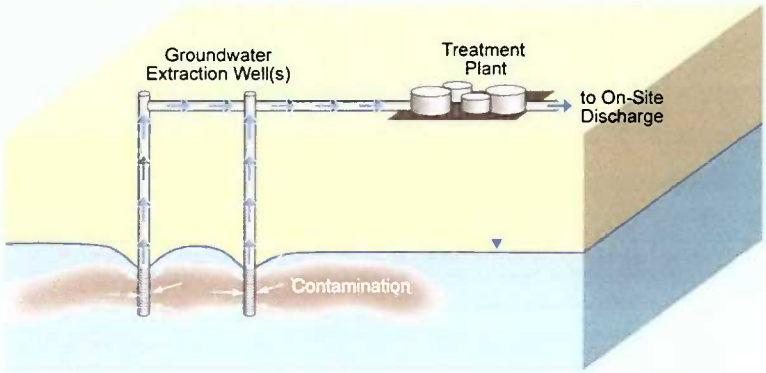
Figure 8-15. Surface Barriers

Groundwater Extraction System and On-Site Discharge

Key Components

- Involves continued operation of existing groundwater extraction systems with the potential to expand the system configuration based on remediation goals.
- Treated water is discharged on site.
- Groundwater extraction and injection well network provides for hydraulic containment of contamination.
- Groundwater extraction and on-site discharge are components of a pump-and-treat system, where ex-situ treatment of extracted groundwater can include bioreactors, ion exchange, air stripping, etc.
- Incorporates long-term groundwater monitoring to evaluate system performance, effectiveness, and compliance with remediation cleanup goals.

Conceptual Schematic



Examples of Relevant Experience

Summary of Groundwater Pump-and-Treat Systems Operating at Hanford

Pump and Treat System	Startup Date	Contaminant	Volume Treated (millions of liters)	Mass Removed (Kg)
100-DR-5[a]	2004	Cr(VI)	375	326
100-DX[a]	2010	Cr(VI)	55	18
100-HR-3[a]	1997	Cr(VI)	4040	393
100-HX[a]	2011	Cr(VI)	under construction	under construction
100-KR-4[a]	1997	Cr(VI)	5441	349
100-KW[a]	2007	Cr(VI)	1053	137
100-KX[a]	2009	Cr(VI)	1694	78
200-ZP-1[b]	1994	CCl4	5833	13503
200-UP-1[b]	1994	CCl4, Nitrate, Tc-99, and U	1022	56509

a) DOE/RL-2011-25, Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and the 100-NR-2 Groundwater Remediation
b) DOE/RL-2011-26, Calendar Year 2010 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations

Risk Reduction Mechanism

- Extraction of groundwater removes contaminants from the subsurface and contains plume to prevent further migration.
- Contaminant volume, toxicity, and mobility are reduced through pump-and-treat process.

Screening Criteria *(dashed line indicates range)*

Figure 8-16. Groundwater Extraction System and Onsite Discharge

Ion Exchange

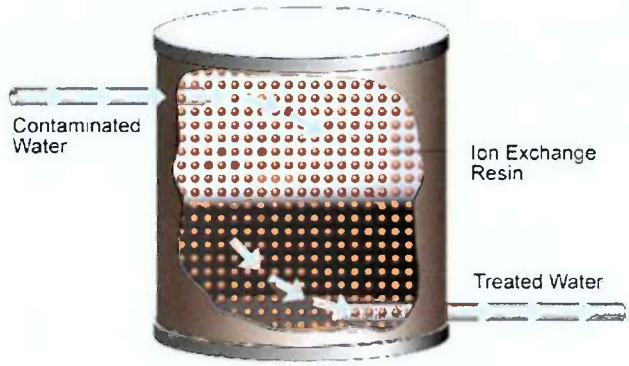
Key Components

- Ions are removed from an aqueous solution and replaced with innocuous ions from the exchange medium.
- Can remove dissolved metals and radionuclides from water.
- Exchange medium can be synthetic resins and inorganic or natural polymeric materials.
- Resins can be regenerated for reuse or disposed of.
- Ion exchange is a non-destructive technology (removal is achieved through mass transfer).

Risk Reduction Mechanism

- Contaminant is transferred to the ion exchange resin which ultimately requires disposal.
- Contaminant volume, toxicity, and migration are reduced through pump-and-treat process.

Conceptual Schematic



Examples of Relevant Experience

- Ion exchange (IX) is the current Hanford groundwater treatment for many pump-and-treat systems: *(DOE/RL-2010-11)*
  - 100-DR-5 system: Removed ~326 kg Cr(VI) since startup in 2004 through calendar year 2010 (CY10)
  - 100-HR-3 system: Removed ~393 kg Cr(VI) since startup in 1997 through CY10
  - 100-KR-4 system: Removed ~349 kg Cr(VI) since startup in 1997 through CY10
  - 100-KW system: Removed ~137 kg Cr(VI) since startup in 2007 through CY10
  - 100-KX system: Removed ~78 kg Cr(VI) since startup in 2009 through CY10
  - 100-DX system: Removed ~18 kg Cr(VI) since startup in December 2010
  - 100-HX system is under construction for startup in 2011 using ion exchnage treatment technology for removal of Cr(VI)

Screening Criteria *(dashed line indicates range)*

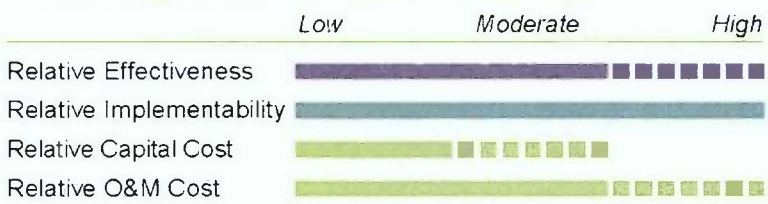


Figure 8-17. Ion Exchange

Vertical Wells

Key Components

- Vertical wells can be used to inject reagents into groundwater, to treat contaminant plumes, extract groundwater, and monitor groundwater.
- Three methods typically used for drilling injection wells are rotosonic, air rotary-casing hammer, and hollow-stem auger.
- Soil profiling during drilling of vertical wells may serve to characterize lithology and contaminant distribution within the aquifer.
- For injection applications, injection reagents must be compatible with the mechanical components of the injection well system and natural formation of the aquifer.
- Site assessment and aquifer characterization may be required to determine suitability of vertical injection.

Using Recovery Act funding, contractors are drilling more than 250 wells to support groundwater treatment and monitoring systems. In this photo, workers prepare to begin drilling operations for wells at the 100-NR-2 operable unit. www.hanford.gov

Examples of Relevant Experience

Summary of Groundwater Pump-and-Treat Systems Operating at Hanford (2008-2009)

Pump and Treat System	Number of Extraction/ Injection Wells
100-DR-5[a]	4 Extraction / 1 Injection
100-HR-3[a]	10 Extraction / 4 Injection
100-KR-4[a]	9 Extraction / 5 Injection
100-KW[a]	4 Extraction / 2 Injection
100-KX[a]	12 Extraction / 9 Injection
200-ZP-1[b]	14 Extraction / 5 Injection
200-UP-1[b]	2 Extraction / 5 Injection

a) DOE/RL 2009 15. *Calendar Year 2008 Annual Summary Report for the 100 HR 3, 100 KR 4, and 100 NR 2 Pump and Treat Operations.*
b) DOE/RL-2010-11 Revision 1. *Hanford Site Groundwater Monitoring and Performance Report for 2009.*

Risk Reduction Mechanism

- Does not reduce risk as a stand-alone technology. Reduction in toxicity, mobility, and volume of contaminants is achieved through the injection of reagents that treat groundwater contaminants.

Screening Criteria *(dashed line indicates range)*

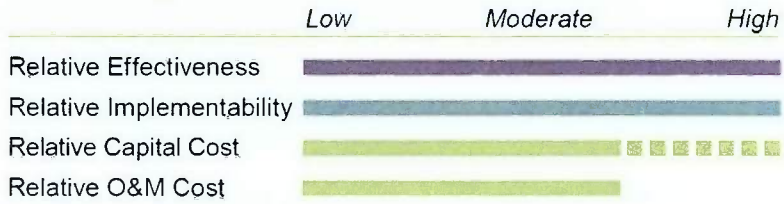


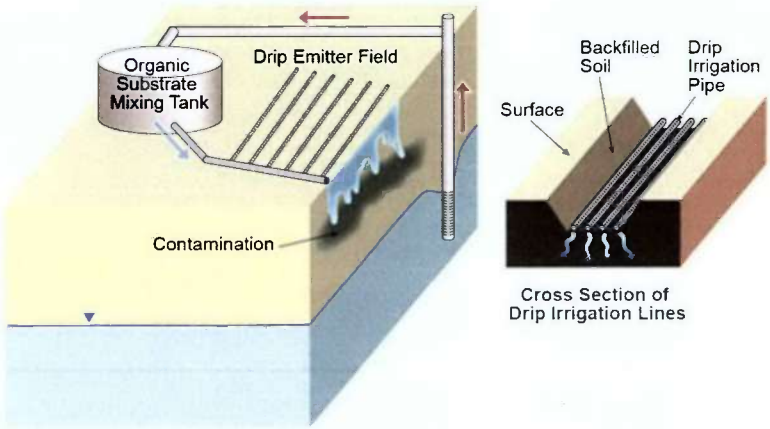
Figure 8-18. Vertical Wells

Surface Infiltration (Groundwater and Vadose Zone)

Key Components

- A delivery method that applies reagents (biological and chemical) to the ground surface to target remediation, primarily on the vadose zone.
- Surface infiltration can be done through drip irrigation (shown at right) and shallow-basin systems.
- Systems are generally designed to be 12 inches below the surface and covered for protection.

Conceptual Schematic



Examples of Relevant Experience

- An ongoing study in the 100-N area sequesters strontium-90 subsurface contamination using surface infiltration of an apatite solution. *(PNNL-18303)*
- PNNL conducted a surface infiltration application of phosphate at the 300 area for uranium. Results of the study are pending. *(PNNL Report Pending)*

Risk Reduction Mechanism

- Does not reduce risk as a stand-alone technology. Risk reduction is primarily achieved by reagent approach (chemical, biological, or physical reactions based on amendment delivered).

Screening Criteria Applies to Both Media

(dashed line indicates range)

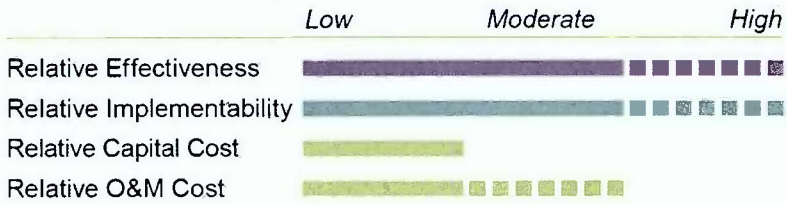


Figure 8-19. Surface Infiltration

Beneficial Reuse of Treated Water

Key Components

- Discharge component of a groundwater extraction-and-treatment system.
- Treated water is discharged through an on-site beneficial use, such as dust control, etc.
- Return of treated groundwater to the subsurface may help to conserve groundwater as a resource or can be used to augment hydraulic containment or flush a contaminant source.

Dust suppression being used at a demolition site in the Hanford 200 North Area. www.hanford.gov

Examples of Relevant Experience

- The treated effluent from the 200 Area Effluent Treatment Facility will be pumped to a state-approved land disposal site selected to maximize the migration time to the river and allow for the decay of untreated tritium present in the effluent. *(WHC-SA-2105-FP)*
- In the 300 Area, water supply well (399-4-12) supplies water for the research aquariums in the 331 Building. The well has been in operation since approximately 1982. *(DOE/RL-2008-36)*

Risk Reduction Mechanism

- Does not reduce risk as a standalone technology.
- Contaminant volume and toxicity is reduced through pump-and-treatment process.

Screening Criteria *(dashed line indicates range)*

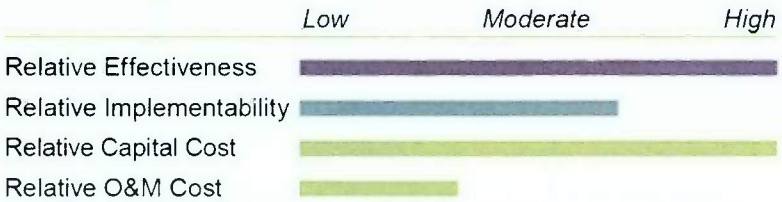


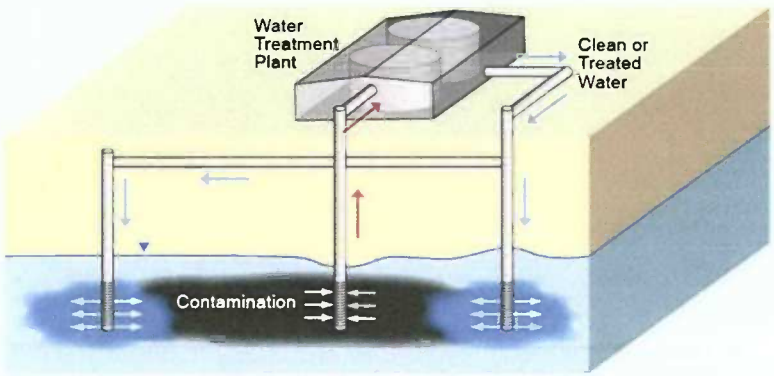
Figure 8-20. Beneficial Reuse

Flushing – Saturated Zone, Water

Key Components

- Involves the injection of clean or treated water into a zone of contaminated groundwater to expedite remediation of plume.
- Groundwater is captured and treated to meet discharge standards.
- Applicable for media impacted with contaminants with high to moderate solubility (*e.g.*, Cr(VI), Tc-99, uranium, nitrate, and possibly carbon-14).
- Effective groundwater capture is required to contain the plume.
- Groundwater flushing performance depends on residual contamination in lower-permeability layers, lenses, or sorbed to soil.

Conceptual Schematic



Examples of Relevant Experience

- At Topock Compressor Station, Needles, California, the U.S. Department of the Interior proposed water flushing as a preferred alternative for remediation of Cr(VI) in groundwater. This alternative involves injection of fresh and carbon-amended water to flush Cr(VI) and push the plume through in-situ biological treatment barriers located downgradient of the water injection wells. *(DOI060410A)*

Risk Reduction Mechanism

- Extraction of groundwater removes contaminants from the subsurface and contains plume to prevent further migration.
- Reduction in toxicity, mobility, and volume of contaminants is achieved through a groundwater capture and treatment system.

Screening Criteria *(dashed line indicates range)*

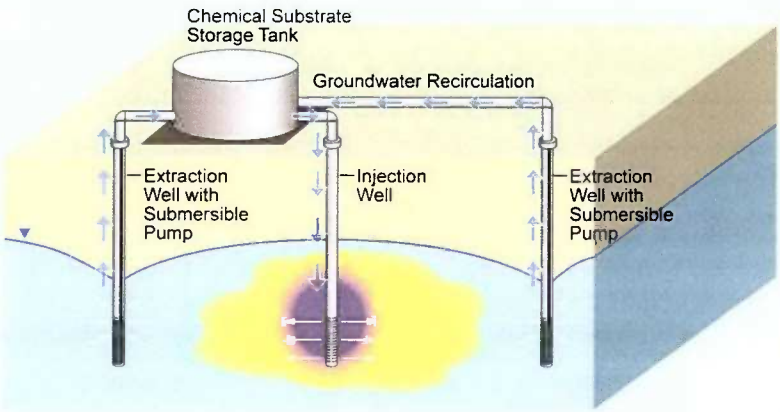
Figure 8-21. Water Flushing (Groundwater)

In-Situ Chemical Reduction (Groundwater)

Key Components

- A reducing agent (such as calcium polysulfide) is added to the groundwater to chemically convert the contaminants to less-mobile and/or less-toxic forms, *e.g.*, Cr(IV) to Cr(III).
- Adding groundwater recirculation can increase the zone of influence and decrease injection spacing.
- In-situ reduction of contaminants that are contained in the recycled groundwater reduces the need for more costly ex-situ treatment.
- Localized temporary generation of secondary byproducts (reduced manganese, iron, and arsenic) should be expected.

Conceptual Schematic



Examples of Relevant Experience

- 2005 treatability test injected calcium polysulfide in the Hanford 100-K Area: Results indicated significant decrease in Cr(VI) concentrations, with reduction persisting after 4 years. *(DOE/RL-2006-17)*

Risk Reduction Mechanism

- Chemical reagents cause chemical transformation (reduction) to non- or less-toxic compounds, reducing toxicity.
- Reduction of uranium and Tc-99 is potentially reversible.

Screening Criteria *(dashed line indicates range)*

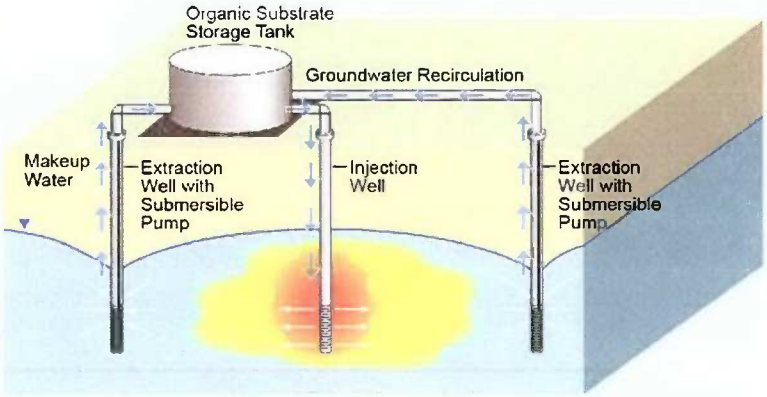
Figure 8-22. In Situ Chemical Reduction (Groundwater)

In Situ Biological Treatment – Anaerobic (Groundwater)

Key Components

- Uses native microorganisms to transform or break down contaminants into less- or non-toxic substances.
- Natural process enhanced by adding organic substrates to stimulate anaerobic micro-organisms in the subsurface.
- The addition of a recirculation system (extract and reinject groundwater) can enhance substrate delivery and increase the zone of influence.
- In-situ reduction of contaminants that are contained in the recycled groundwater reduces the need for more costly ex-situ treatment.
- Localized temporary generation of secondary byproducts (reduced manganese, iron, and arsenic) could be expected.

Conceptual Schematic



Examples of Relevant Experience

- Reports for examples of applications using bio-remediation to convert Cr(VI) to less toxic (Cr(III)) include:
  - Hinkley Remediation Semiannual Status Report (July through December 2009), Pacific Gas and Electric Company (PG&E) Groundwater Remediation Program, Hinkley, California (CH2M HILL, 2010)
  - PNNL-18784, Hanford 100-D Area Biostimulation Treatability Test Results.
  - Faybishenko, B., 2009, In Situ Long-Term Reductive Bioimmobilization of Cr(VI) in Groundwater Using Hydrogen Release Compound, Lawrence Berkeley National Laboratory, Berkeley, California
- PG&E implemented two pilot studies at the site: an Upland reductive zone in situ pilot test (ISPT) to evaluate how well recirculation wells can distribute reductant (ethanol) throughout the aquifer to achieve treatment across a transect of the plume, and a Floodplain ISPT to evaluate the efficacy of using lactate to enhance the existing reducing environment in the floodplain adjacent to the Colorado River. List of the reports referenced regarding the two pilot studies implemented by PG&E are available at the California Department of Toxic Substances Control (DTSC) Project Website: http://dtsc-topock.com/.

Risk-Reduction Mechanism

- Biological treatment can dechlorinate CVOCs to less toxic substances, and reduce nitrate to nitrogen gas.

Screening Criteria *(dashed line indicates range)*

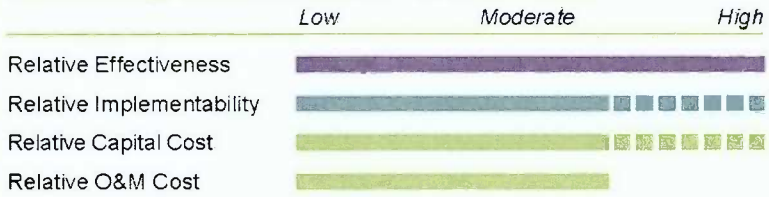
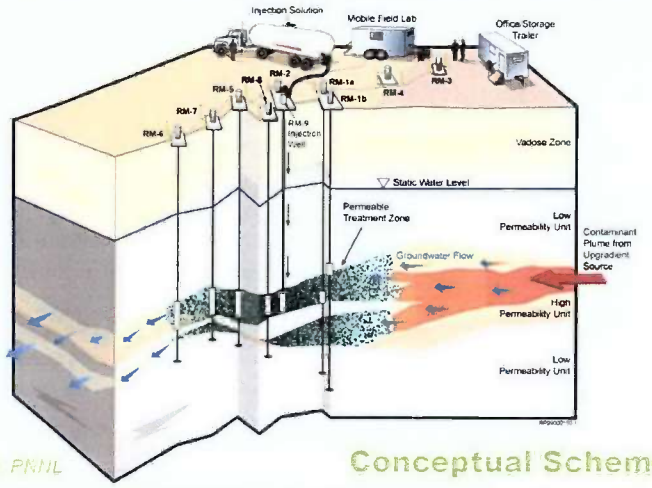


Figure 8-23. In Situ Biological Treatment Anaerobic (Groundwater)

Reactive Chemical Barrier (In-Situ Redox Manipulation) (Groundwater)

Key Components

- Zone of chemically reactive material that transforms (reduces) contaminants in groundwater as it flows through.
- Reactive zone can be generated by a series of injection/recirculation wells or a trench that transects the groundwater flow pathway.
- Reactive material is a reducing chemical (*e.g.*, sodium dithionite or zero valent iron).
- Generation of secondary byproducts and/or break-through may occur.
- Occasional amendments/ applications may be necessary.
- Used to control migration; not effective in treating the bulk of the plume.
- Dispersing reactive material into the aquifer can make implementation complex. Varying hydraulic gradients, and varying water levels can reduce the effectiveness.



Source: PNNL

Conceptual Schematic

Examples of Relevant Experience

- Currently in use in Hanford 100 D; geochemical parameters indicate success in producing the desired Cr-reducing conditions; concentration reductions have been noted, but concentrations in downgradient wells have been variable (*i.e.*, some breakthrough has occurred). *(DOE/RL-2010-11)*

Risk Reduction Mechanism

- Risk reduction achieved through treatment. Risk reduction limited to zone of active treatment and further migration. Does not adequately reduce risk throughout the bulk of the plume.
- Chemical reagents transform (reduce) contaminant to non-or less-toxic compound [*e.g.*, Cr(VI) to Cr(III)]; generation of secondary byproducts may occur .
- ISRM acts as a barrier; when effective, reduces contaminant plume migration/mobility.

Screening Criteria *(dashed line indicates range)*

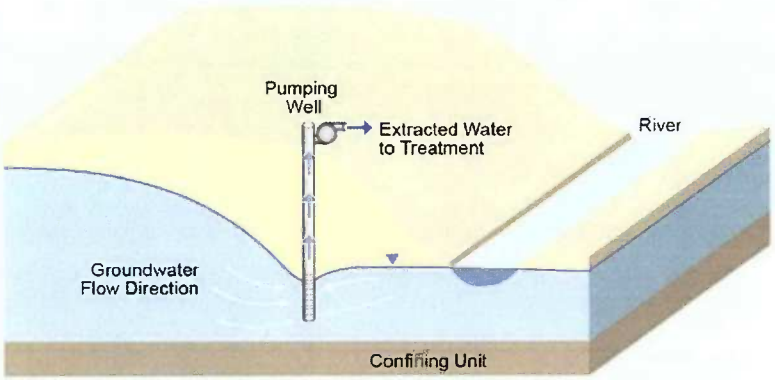
Figure 8-24. Reactive Chemical Barrier (In Situ Redox Manipulation Groundwater)

Hydraulic Containment via Extraction (Groundwater)

Key Components

- Extraction wells provide hydraulic containment by pumping groundwater from the plume edge to control contaminant migration.
- Changes groundwater flow characteristics and pulls contaminated groundwater towards the extraction wells.
- Removed groundwater will require treatment or proper disposal.

Conceptual Schematic



Examples of Relevant Experience

- At least eight pump-and-treat systems are successfully operating at Hanford to provide hydraulic containment in addition to removing contamination. Information regarding capture zone efficiency for each system can be found in *Hanford Site Groundwater Monitoring and Performance Report for 2009* (DOE/RL-2010-11)

Risk Reduction Mechanism

- Reduces mobility by providing a barrier between the contaminated groundwater and the Columbia River.
- Reduces volume by removing dissolved phase contaminant mass; toxicity reduced by subsequent treatment at a temporary or permanent facility.

Screening Criteria *(dashed line indicates range)*

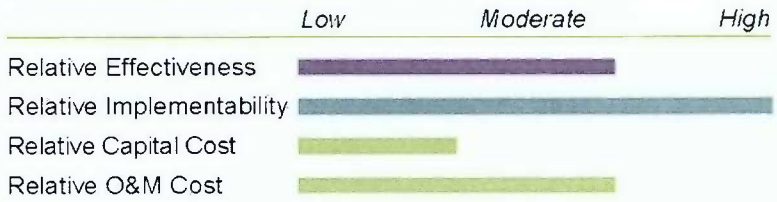


Figure 8-25. Hydraulic Containment via Extraction (Groundwater)

9 Development and Screening of Alternatives

This chapter discusses the development of remedial action alternatives for 100-BC. The primary inputs for this process were: the physical characteristics of the site (Chapter 3); waste site characterization information, contaminant transport mechanisms and CSM (Chapters 4 and 5); the identified risks (Chapters 6 and 7); and the RAOs, target remediation areas, and the remedial technology screening results (Chapter 8).

The remedial technologies retained from the screening described in Section 8.3 (Chapter 8) are combined into remedial alternatives for 100-BC that provide a range of technology groupings for waste site and groundwater remediation. Because of the significant amount of source removal activities conducted under interim actions, waste site and groundwater remediation alternatives are considered separately in this document. With the exception of the No Action Alternative, the remedial alternatives were developed to target achievement of the RAOs by considering the CERCLA program goals and expectations identified in the NCP (40 CFR 300). The remedial alternatives presented in this chapter are carried forward for a detailed and comparative evaluation in Chapter 10.

Highlights

- Remedial action alternatives were developed for 100-BC that provide a range of technology groupings for remediation. Separate alternatives were developed for waste site and groundwater remediation.
- Alternatives evaluated for waste remediation include:
  - Alternative HH-1: No Action
  - Alternative HH-2: MESC, MNA, and Institutional Controls
  - Alternative HH-3: RTD Optimized with Other Technologies
  - Alternative HH-4: Aggressive RTD
- Alternatives evaluated for groundwater remediation include:
  - Alternative GW-1: No Action
  - Alternative GW-2: MNA and Institutional Controls
  - Alternative GW-3: River Protection Pump-and-Treat
  - Alternative GW-4: Aggressive Pump-and-Treat

9.1 Development of Remedial Alternatives

The NCP, "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(a)(1)(iii)], sets the following expectations for remedial action alternatives development:

- To use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials. Principal threat wastes at 100-BC included spent nuclear fuel, fuel basin sludge, and reactor cores. These are being addressed through other CERCLA decisions.
- To use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.
- To use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of the principal threats posed by a site, with priority placed on treating waste that is liquid, highly toxic, or highly mobile, will be combined with engineering controls (such as containment) and institutional controls, as appropriate, for treatment residuals and untreated waste.
- To use institutional controls, such as water use and deed restrictions, to supplement engineering controls as appropriate for short- and long-term management in order to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Institutional controls may be used during the conduct of the RI/FS and implementation of the remedial action and, where necessary, as

a component of the completed remedy. The use of institutional controls will not substitute for active response measures (for example, treatment and/or containment of source material, restoration of groundwater to its beneficial uses) as the sole remedy unless such active measures are determined not to be practicable.

- To consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse effects than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.

- To return usable groundwater to its beneficial uses wherever practicable and within a timeframe that is reasonable, given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction.

- For groundwater response actions, a limited number of remedial alternatives should be developed to achieve site-specific remediation levels within different restoration periods using one or more different technologies.

- The No Action Alternative (no further action if some removal or remedial action has already occurred at a site) will also be developed.

The remedial alternatives for 100-BC were developed to encompass all waste sites carried forward into the FS and groundwater plumes within 100-BC. Remedial alternatives were developed separately for waste sites and groundwater plumes, to provide greater flexibility in selecting a comprehensive remedial alternative for both waste sites and groundwater.

The rationale for grouping and development of remedial alternatives for 100-BC waste sites and groundwater are provided in the following sections.

9.1.1 Waste Sites

As presented in Table 8-5 (Chapter 8), 10 waste sites have been included for evaluation in the FS. The waste site COCs and the COPCS for the Waste Sites Remaining for Remedial Action are listed in Table 8-1 (Chapter 8).

The evaluations of remedial actions for specific waste sites relies upon a comprehensive review of all available data for each site; including, field data, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and any other information identified during the development of the RI/FS. As a result of this comprehensive review the characteristics of each site are sufficiently defined for the purpose of alternative development and comparison in the FS. During implementation of remedial actions should field conditions vary from those presented in the FS and indicate a need to re-evaluate the efficacy of the selected remedial action, the appropriate remedy modification will be used consistent with CERCLA guidance.

Development of the alternative components for individual waste sites is based on the type of risk driver/ PRG exceedance identified for each site. As described in Section 8.2.1 (Chapter 8) remedial alternatives were developed to address the following target remediation areas:

- Waste sites remaining for remedial action. The two waste sites (100-B-34, 1607-B5) included in this group will have had no remedial action performed on them as of December 2012 and all actions will be completed after the ROD is signed. Two sites are located under active utilities (100-B-34 and 1607-B5). On the basis of process knowledge and analogous site data, the sites will need to be remediated to be protective under the CERCLA final remedy decision.

- Shallow Human Health Direct Contact Exposure Sites. Two waste sites (118-B-1 and 118-B-8:1) were interim closed or remediated but have PRG exceedances for human health direct contact in shallow soil (<4.6m [15 ft] bgs). Under a CERCLA final remedy decision, the sites will need to be remediated to be protective.

- Surface Water and/or Groundwater Protection Sites. Two waste sites (118-B-1 and 118-B-6) were interim closed or remediated but exceed the tritium PRG for the protection of surface water and/or groundwater. Under a CERCLA final remedy decision, the sites will need to be remediated to be protective.

- Special Case Sites. The two pipeline sites (100-B-22:1 and 100-C-9:4) do not pose an unacceptable risk in their current configuration but may in the future if the pipelines are exposed at the surface. Under a CERCLA final remedy decision, the sites will need to be remediated to remain protective.

- ARCL Sites. One ARCL site, 132-B-5, is included in the FS. Recent RESRAD dose rate modeling indicates that radionuclide contamination poses an unacceptable risk to human health from direct contact with demolition debris. Under a CERCLA final remedy decision, the site will need to be remediated to remain protective.

- B Reactor Museum Sites. Two B Reactor Museum sites are included in the FS (118-B-8:3 and 132-B-2) on the basis of analogous site data, but do not pose an unacceptable risk in their current configuration. Under a CERCLA final remedy decision, institutional ontrols will need to be established to prevent inadvertent waste site intrusion and remain protective.

No waste sites with COC concentrations greater than ecological protection PRGs were identified in 100-BC.

9.1.2 Groundwater

The groundwater COCs at 100-BC were identified in Section 8.2.1 (Chapter 8) and include Cr(VI), strontium-90, and tritium. Remedial action for these COCs is required to restore the unconfined aquifer groundwater beneficial use and to protect surface water quality.

As part of the development and evaluation of groundwater alternatives, a numerical groundwater flow and contaminant transport model was used as an evaluation and design concept tool. Groundwater flow and transport simulations and particle tracking were performed for each design concept to determine the feasibility of each design. The model was also used to perform a limited amount of optimization for well location and pumping scenarios. However, the design concepts developed for this FS are not final. Depending on which alternative is selected, the model simulations will be refined during the RD/RA work plan phase after the ROD is signed.

The groundwater flow model was constructed using the U.S. Geological Survey (USGS) modular groundwater flow model MODFLOW. Particle tracking was performed using the USGS program MODPATH. To simulate contaminant plume response to various remedial action alternatives, the contaminant transport model MT3DMS was used. Model development and calibration are documented in a comprehensive modeling report contained in Appendix F (*Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model* [SGW-46279]). The results of the groundwater alternative modeling are included in Appendix F (*Modeling of RI/FS Design Alternatives for 100-BC-5* [ECF-100BC5-11-0115)]. These supplemental documents also discuss uncertainty with the model results because of variability in subsurface conditions and other factors.

9.1.3 Common Elements

The remedial alternatives developed for the 100-BC waste sites and groundwater contain elements that are common to multiple alternatives. To limit redundancy in the discussion of these common elements, they are discussed in this section.

9.1.3.1 Institutional Controls

While remediation is underway, institutional controls will be put in place to control access, protect workers, and prevent exposure to contamination. Institutional controls for 100-BC are expected to be implemented independently for each waste site or groundwater plume. Existing institutional ontrols and other potential controls were described previously in Section 8.4.1. Institutional controls that are inplace to prevent exposure to contamination will remain in place until the waste site or groundwater plume is remediated.

Post remediation, institutional controls will be put in place to address waste site contamination using excavation and irrigation restrictions, as identified in Table 9-1. Additional waste sites may be added through closure reclassifications.

9.1.3.2 Monitored Natural Attenuation

As described in Section 8.1.4 MNA can reduce COC concentrations in vadose zone soil and groundwater because of various naturally occurring physical, chemical, and biological processes. The primary natural attenuation processes for 100-BC COCs in soil is radioactive decay. The primary natural attenuation processes in groundwater include dilution, dispersion, biodegradation, radioactive decay, and sorption. MNA may also include contingency actions in the event the natural processes do not reduce COC concentrations in accordance with expectations. MNA is rarely appropriate as a sole remedy without other active remedial measures (source control) or institutional ontrols (*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* [EPA/540/R-99/009]). When MNA is a component of a broader alternative, it builds off the other actions, including interim remedial actions.

A screening-level evaluation of applying MNA to groundwater at 100-BC indicates that it can play an important role in overall remediation of groundwater for strontium-90 (radioactive decay and sorption to aquifer materials), tritium (radioactive decay and dispersion), and Cr(VI) (dispersion and dilution).

The following discussion provides a preliminary analysis of groundwater plume conditions at 100-BC with respect to the requirements (bolded below) for application of MNA:

1. **The contamination condition does not currently present an actual risk to human or ecological receptors.** The groundwater contaminant plumes are generally well defined for 100-BC, and current institutional controls (for example, prohibitions against use of groundwater for a source of drinking water) prevent current exposure to human receptors. However, discharge of contaminated groundwater at concentrations above ecological risk-based standards into the Columbia River and may present an exposure hazard to ecological receptors.

2. **The source of the observed contamination is no longer contributing to the plume.** Extensive removal actions have already been implemented, at known source areas that have contributed to groundwater COC plumes at 100-BC. This is particularly important to supporting selection of MNA for groundwater remediation where unremediated source areas are still associated with persistent groundwater plumes. The expected efficacy of source area remedial alternatives at 100-BC is considered in the overall assessment of MNA for groundwater plume remediation.

3. **The target plume is static or retreating, or existing monitoring data confirm that attenuating processes are present and operating at the site.** The presence and activity of attenuating processes within the affected aquifer system can be demonstrated by either of two methods – 1) monitoring history of the plume indicates the plume is stable or shrinking; this indicates sources are no longer contributing and that attenuating processes are working within the plume, or 2) if the plume is not stable or shrinking, then empirical measurements and observations of aquifer/plume conditions confirm attenuating processes are present and operable within the aquifer. Source removal activities associated with Interim Actions at 100-BC have mobilized vadose zone contamination to groundwater. Therefore, historical monitoring for specific contaminants does not indicate static or shrinking plumes at all locations. Observations and measurements of aquifer conditions, however, do indicate some attenuating processes are at work within the system. Multiple attenuating processes may be effective on any one contaminant of concern. The following processes are identified as potentially applicable within 100-BC OU:

   a. Radioactive decay is confirmed for radioactive contaminants of concern. Strontium-90 and tritium both exhibit sufficiently short radioactive half lives (that is, 28.8 yr and 12.3 yr, respectively) that radioactive decay of these COCs is a major attenuating element of an MNA alternative.

   b. Sorption of constituents to aquifer matrix reduces the relative groundwater concentration of contaminants that interact substantially with the matrix. The tendency of a constituent to sorb, or bind, to the aquifer matrix is generally described by its relative distribution coefficient (K_d). Constituents with higher K_d exhibit a stronger tendency to bind to the aquifer solid matrix and reduce the relative groundwater concentration. Alternatively, constituents that exhibit lower K_d exhibit reduced tendency to bind to aquifer solids and, therefore, do not exhibit concentration reduction through sorption to the aquifer matrix. Some constituents exhibit no tendency to sorb to aquifer solids and, therefore, sorption does not provide any meaningful attenuation for those constituents. Strontium-90 in groundwater that exhibits meaningful attenuation because of sorption effects.

   c. Dispersion of groundwater contaminant plumes. Spreading of contaminants from the main direction of groundwater flow takes place as the groundwater moves, altering concentrations from those that would occur if advection were the only transport mechanism. The mechanisms causing dispersion within the plume include molecular diffusion, different water velocities within individual pores, and different water velocities between adjacent pores, and tortuosity of the subsurface flow path. Because of the relatively low concentrations of Cr(VI) in groundwater at 100-BC, dispersion is a meaningful attenuation mechanism along the flow paths from upland source areas to the groundwater discharge locations in the Columbia River.

4. **Effective monitoring either exists currently or can be implemented.** Groundwater monitoring at 100-BC is currently sufficient to define COC plumes in groundwater and to evaluate and select remedial technologies. Implementation of an MNA technology at 100-BC will require evaluation of groundwater monitoring systems to include establishment of specific monitoring points as well as selected points of compliance for remediation performance assessment. Current understanding of conditions within the affected portions of the shallow unconfined aquifer system indicates there are not technological limitations to establishing an effective monitoring system at 100-BC to support remedial action performance monitoring. A site-specific DQO and SAP will identify specific data

needs, in terms of location and timing of monitoring activities to support implementation of MNA as a remedial technology. Monitoring activities are expected to include sampling of monitoring wells, aquifer tubes, and pore water beneath the river bottom. Additionally, MNA performance monitoring should include an assessment and response plan (or contingency) that will be implemented to adjust the alternative if the findings are not as expected.

Table 9-1. Institutional Controls Implemented at Waste Sites Post Remediation*

Risk Driver	Waste Sites/Area	Alternative S-2 Institutional Controls	Alternative S-3 Institutional Controls	Alternative S-4 Institutional Controls
Waste sites with groundwater/surface water protection risk if irrigation were applied (Vadose Soil Contaminant Concentrations Exceed SSL but are Less Than-PRG)	100-B-1, 100-B-14:2, 100-B-18, 116-B-14, 116-B-4, and 118-C-1. An institutional control to prohibit irrigation will be applied to sites that meet this condition.	Prohibit irrigation	Prohibit irrigation	Prohibit irrigation
Waste sites with deep (greater than 4.6 m [15 ft] bgs) radiological contamination exceeding HH direct contact PRG-levels	100-B-14:1, 100-B-21:4, 100-B-5, 100-B-8:1, 100-B-8:2, 100-C-6:1, 100-C-6:2, 100-C-6:3, 100-C-6:4, 116-B-1, 116-B-11, 116-B-16, 116-B-2, 116-B-3, 116-B-4, 116-B-5, 116-B-6A, 116-C-1, 116-C-2A, 116-C-2B, 116-C-2C, 116-C-3, 116-C-5, 118-C-1, and 118-C-3:2. An institutional control to restrict excavation will be applied to sites that meet this condition.	Excavation restrictions	Excavation restrictions	Excavation restrictions
Pipeline sites with shallow contamination (less than 4.6m [15 ft] bgs) that may pose an unacceptable level of risk if excavated	100-B-22:1, 100-B-34, 100-C-9:4, and 118-B-8:3.	Excavation restrictions for 100-B-22:1 100-B-34 100-C-9:4 118-B-8:3	Excavation restrictions for 118-B-8:3	None

* Additional waste sites may be added through closure reclassifications.

9.1.3.3 Operations & Maintenance

O&M of each remedial alternative (except the No Action Alternative) is required to ensure that the remedy is operated and maintained in a manner that ensures long-term effectiveness and permanence. O&M requirements of the selected remedy will be described in a separate O&M plan prepared during the RD/RA phase. The O&M Plan will describe performance monitoring data needs and monitoring requirements, monitoring methods, analytes and sampling frequencies, routine maintenance activities and frequencies, and reporting.

The nature and scope of O&M activities varies by alternative. For example, O&M activities for a MNA-based remedy would include inspection, maintenance, and periodic replacement of monitor wells, whereas a groundwater pump-and-treat based remedy would include routine and preventive maintenance programs as well as replacement of pump-and-treat system components at the end of their design life (typically 25 years). Alternatives with longer durations would include multiple replacements of system components on a 25-year frequency.

9.1.3.4 Remedy Performance Monitoring

Remedy performance monitoring will be conducted to evaluate the effectiveness of the selected alternative, with the exception of the No Action Alternative, to attain the final remedial goals specified in the 100-BC ROD. The nature and scope of the performance monitoring program will vary by alternative, will be developed during remedial design and would be included in a performance monitoring plan. Remedy performance monitoring applies to MNA actions, as well as active engineered remedies.

The largest component of remedy performance monitoring is expected to be associated with groundwater remedial components. Performance monitoring of a pump-and-treat system would be designed to evaluate contaminant mass removal from 100-BC groundwater. The design would include both hydraulic and chemical/radionuclide concentration monitoring of extracted groundwater. Hydraulic monitoring would consist of measuring flow rates and total flow, as well as a distribution of water levels within and in adjacent monitoring wells within the zone of influence. The injection well network would also be monitored for hydraulic performance. Water-level measurements would be used to evaluate whether extraction and injection wells are operating within their design criteria to capture the plume. Results of the evaluation would be used to optimize the remedy by altering extraction and injection flow rates, adding new wells if necessary, or shifting to a pulsed pumping strategy. Chemical/radionuclide monitoring would consist of sampling monitoring wells, aquifer tubes, and pore water below the river bottom for COCs, potential degradation byproducts, and geochemical parameters to support the evaluation of overall remedy performance.

The geochemical groundwater parameters used in the natural attenuation evaluation of Cr(VI) typically include pH, dissolved organic carbon, sulfide, dissolved oxygen, iron (II), and chromium isotope ratios (Cr^{53}/Cr^{52}) (*Monitored Natural Attenuation of Inorganics in Ground Water, Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium* [EPA/600/R-07/140]). In addition to these parameters, site-specific parameters may be identified to better understand the ability of natural attenuation processes for the aquifer conditions present at 100-BC to reduce Cr(VI) concentrations. Sampling and analysis of strontium-90 and tritium will also be included in the groundwater monitoring program to track decay rates. CERCLA 5-year reviews will be used to assess whether MNA is achieving the protectiveness requirements inherent in the RAOs. If MNA is not achieving the protectiveness requirements, contingent remedies may be implemented to achieve more timely remediation.

A series of groundwater monitoring plans has been developed under many of the interim action RODs as described in the 100 Area RDR/RAWP (DOE/RL-96-17); (*Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* [DOE/RL-96-90]); and *Sampling and Analysis Plan for Soil and Groundwater at the In Situ Bioremediation Design Test Wells at the Hanford 100-D Area* (DOE/RL-2010-56), as described in the *Central Plateau Industrial Building D4 Project Waste DQO and Sampling and Analysis Plan* (DOE/RL-2010-57). The number of wells monitored and the frequency of remedy performance monitoring is anticipated to vary, depending on the phase of remediation. A geostatistical analysis will be conducted to determine the optimum spatial distribution for the performance monitoring network. For alternatives where active remediation is occurring, the frequency of monitoring typically varies depending on site-specific conditions. Frequencies may include quarterly

(for new wells during the first year following installation), semiannually, annually, biennially, or every 5 years. Sampling frequencies are typically reduced once contaminant concentration trends are established.

9.2 Description of Waste Site Alternatives

As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), alternatives were developed that incorporate process options and technologies retained in Chapter 8 and include an appropriate range of waste management options to ensure the protection of human health and the environment. Because of the significant source removal actions conducted under the interim actions, separate alternatives were developed for the waste sites and groundwater.

Four waste site alternatives are evaluated:

- **S-1:** No Action. This alternative is required by the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy"[40 CFR 300.430(e)(6)]).
- **S-2:** Maintain Existing Soil Cover (MESC), MNA, and Institutional Controls. This alternative uses the existing soil cover to prevent direct exposure to contaminated material in conjunction with natural attenuation by radioactive decay to achieve PRGs at sites 118-B-1, 118-B-6, 118-B-8:1 and 132-B-5. Institutional controls are used to eliminate the potential exposure pathway at pipeline sites 100-B-22:1, 100-B-34, 100-C-9:4, the septic tank site 1607-B5, and the B Reactor Museum sites 118-B-8:3 and 132-B-2.
- **S-3:** RTD Optimized with Other Technologies. This alternative uses shallow RTD at the pipeline sites 100-B-22:1, 100-B-34, 100-C-9:4, ARCL site 132-B-5, and the septic tank site 1607-B5 to remove shallow contamination and achieve PRGs. Surface caps are used for sites 118-B-1 and 118-B-6 that exceed surface and/or groundwater protection PRGs and site 118-B-8:1 where excavation is not feasible because of its proximity to the 105-B reactor. Institutional controls are used to prevent direct exposure to contaminated material at the B Reactor Museum sites 118-B-8:3 and the 132-B-2 where removal is not practicable because of the National Historic Landmark status.
- **S-4:** Aggressive RTD. This alternative uses RTD to the total depth of contamination above PRGs at 9 of the 10 waste sites. A surface cap is used for site 118-B-8:1 where excavation is not feasible because of its proximity to the 105-B reactor.

Table 9-2 summarizes the retained technologies identified in Chapter 8 as they apply to the waste site remedial alternatives. Table 9-3 identifies the technologies applied for each alternative to each of the 10 waste sites that are carried into the FS.

Table 9-2. Retained Technologies Applied to Waste Site Remedial Action Alternatives

Remedial Technology	Process Option	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Vadose Zone					
No Action	No Action	X			
Shielding	Maintain Existing Soil Cover		X		
Monitored Natural Attenuation	Monitored Natural Attenuation		X	X	X
Excavation	Standard Excavation			X	X
	Deep Excavation				X
Disposal	Disposal to ERDF or other EPA approved location			X	X
Void Fill Grouting	Grouting of Pipelines				
Surface Barriers	Asphalt and Evapotranspiration Barriers			X	X

Table 9-3. Remedial Components for Waste Site Remedial Action Alternatives

Waste Site	Alternative 1	Alternative 2	Alternative 3	Alternative 4
100-B-22:1	No Action	MNA and Institutional Controls	RTD of Pipelines using Standard Excavation and Disposal at ERDF	RTD of Pipelines using Standard Excavation and Disposal at ERDF
100-B-34	No Action	MNA and Institutional Controls	RTD of Pipelines using Standard Excavation and Disposal at ERDF	RTD of Pipelines using Standard Excavation and Disposal at ERDF
100-C-9:4	No Action	MNA and Institutional Controls	RTD of Pipelines using Standard Excavation and Disposal at ERDF	RTD of Pipelines using Standard Excavation and Disposal at ERDF
118-B-1	No Action	MNA and Institutional Controls	Surface Barrier - Evapotranspiration Cap	RTD to the Total Depth of Soil Contamination above Surface Water and Groundwater Protection PRGs, 22 m (72 ft) bgs, using Deep Excavation and Disposal at ERDF
118-B-6	No Action	MNA and Institutional Controls	Surface Barrier - Evapotranspiration Cap	RTD to the Total Depth of Soil Contamination above Surface Water and Groundwater Protection PRGs, 16 m (52.5 ft) bgs, using Deep Excavation and Disposal at ERDF
118-B-8:1	No Action	MNA and Institutional Controls	Surface Barrier - Asphalt Cap	Surface Barrier - Asphalt Cap
118-B-8:3	No Action	Monitored Natural Attenuation and Institutional Controls	MNA and Institutional Controls	RTD of Pipelines using Deep Excavation, 7 m (23 ft) bgs, and Disposal at ERDF
132-B-2	No Action	MNA and Institutional Controls	MNA and Institutional Controls	RTD/Demolition of Stack using Standard Excavation and Disposal at ERDF
132-B-5	No Action	MNA and Institutional Controls	RTD to 3.3m (10.8 ft) bgs using Standard Excavation and Disposal at ERDF	RTD to the Total Depth of Soil Contamination above PRGs, 3.3m (10.8 ft) bgs, using Standard Excavation and Disposal at ERDF
1607-B5	No Action	MNA and Institutional Controls	RTD to 3.5m (11.5 ft) bgs using Standard Excavation and Disposal at ERDF	RTD to the Total Depth of Soil Contamination above PRGs, 3.5 m (11.5 ft) bgs, using Standard Excavation and Disposal at ERDF

Table J-1 (Appendix J provide additional information for each waste site evaluated in the development of alternatives. Details regarding the development of cost estimates are presented in *100-BC Cost Estimate Scoping Form for Feasibility Study Alternative Costing* (ECF-100BC-11-0150 in Appendix K.

Remedial action completion will be determined by obtaining site closure. Once the waste sites have been remediated and verification sampling demonstrates acceptable levels of COCs, closure will be obtained by using the procedures contained in the ROD and the RD/RAWP.

9.2.1 S-1—No Action

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative. The No Action Alternative, which serves as a baseline for evaluating other remedial alternatives, is retained throughout the FS process. No action means that no further remediation would be implemented to alter the existing conditions.

For this alternative, it has been assumed that all site remedial activities and interim actions with the exception of backfilling any open excavations, would be discontinued no later than December 2012. No conceptual design or cost estimate are prepared for Alternative S-1 because no actions are proposed.

9.2.2 S-2—Maintain Existing Soil Cover (MESC), Monitored Natural Attenuation (MNA) and Institutional Controls

As suggested by EPA guidance (*The Feasibility Study: Development and Screening of Remedial Action Alternatives* [OSWER Directive 9355.3-01FS3]), Alternative S-2 uses a strategy of limited additional actions and builds off the interim actions previously completed at applicable waste sites.

The primary components of this alternative include: supplemental institutional controls and maintenance of existing clean soil cover to minimize the potential for exposure until MNA reduces COC concentrations to PRGs.

Periodic surveillance activities will be performed at all 10 waste sites included in the FS to confirm that potential exposure pathways are incomplete.

Table 9-4 describes the individual components for this alternative. Appendix J presents a summary of the remedial components for each waste site, along with conceptual design details for each site, including the estimated areas and volumes.

Table 9-4. Description of Alternative Components for Alternative S-2— MESC, MNA, and Institutional Controls

Waste Site Components[a,b]	No Action	No actions are taken at waste sites remediated under interim actions where results are expected to confirm the interim actions completed under the *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)* (EPA/ROD/R10-99/039) meet PRGs.
	Institutional Controls	Institutional controls to be implemented during remediation within 100-BC for land use management and waste site information management include: • Excavation permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents • Land use and real property controls (for example, proprietary controls including easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents • Warning notices providing visual identification and warning of hazardous

Table 9-4. Description of Alternative Components for Alternative S-2— MESC, MNA, and Institutional Controls

		or sensitive areas • Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit the access of humans to particular hazardous or sensitive areas • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination • Irrigation restrictions for sites with exceedances of surface/ groundwater protection criteria. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8). Post remediation institutional controls implemented at specific waste sites are identified in Table 9-1.
	MESC	Periodic inspection of existing soil cover performed to assess its physical condition and to identify the need for corrective action/maintenance. Maintenance of the existing soil cover includes repair of any erosion damage and routine spraying to control vegetation/rodents.
	MNA	Monitoring conducted to confirm the effectiveness of radioactive decay to attain PRGs. Types of monitoring and the parameters and frequency will be defined in the SAP developed during remedial action.

Notes:

a. Additional information on the conceptual design details for common components is presented in Section 9.1.3 Detailed information necessary for cost estimate preparation (for example, number of sites evaluated, areas, and volume of material treated) is presented in Appendix J. Table 9-1 presents the information on institutional controls.

b. Shallow soil is defined as less than 6.1 m (20 ft) below ground surface (bgs).

9.2.3 Alternative S-3 – Limited RTD Optimized with Other Technologies

Alternative S-3 includes a combination of RTD, surface barriers, and Institutional Controls.

RTD is implemented at sites 100-B-22:1, 100-B-34, 100-C-9:4, 132-B-5, and 1607-B5. RTD addresses PRG exceedances by removing soil and debris contamination as follows:

- Excavation of the waste site structures, waste material or vadose zone soil where COC concentrations exceed HH PRGs for direct contact with soil to a maximum depth of 4.6m (15 ft.) bgs
- Treatment of excavated soil and debris as needed to meet disposal facility waste acceptance criteria
- Disposal of excavated material at an approved disposal facility (typically the ERDF)
- Backfilling the excavation to the original ground surface
- Regrading/revegetating the waste site

Figures 8-8, 8-9, and 8-10 illustrate the components of RTD, which has been the primary interim action performed for the waste sites at the Hanford Site. This alternative assumes standard excavation methods (Figure 8-8) for the excavation of shallow soil and debris (up to 6.1 m [20 ft]).

Implementation of surface barriers is proposed for waste sites where active remedial alternatives such as RTD are not practical because of the waste site proximity to a reactor or at waste sites where tritium contamination may pose an unacceptable risk to surface water or groundwater quality. Installation of a surface barrier is proposed under this alternative at sites 118-B-1, 118-B-6, and 118-B-8:1. Surface barriers are constructed over contaminated waste sites to control the vertical entry of natural infiltration into contaminated media, which in turn reduces leaching of soluble contaminants to groundwater. In addition to their hydrological performance, barriers can function as physical impediments to prevent against intrusion by humans; limit wind and water erosion; and provide a radiological barrier. For cost estimating purposes, asphalt barriers or evapotranspiration barriers are assumed for this FS.

Appendix J presents a summary of the remedial components for the waste sites along with conceptual design details for each site, including the areas and volumes of individual waste sites assumed for cost estimating. Table 9-5 summarizes the components of Alternative S-3.

Table 9-5. Description of Alternative Components for Alternative S-3 Limited RTD Optimized with Other Technologies

Waste Site Components[a,b]	No Action	• No actions are taken at Waste sites remediated under interim actions Sites where results are expected to confirm the interim actions completed under the *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)*Interim ROD (EPA/ROD/R10-99/039) meet PRGs.
	Institutional Controls	• Institutional controls are proposed for sites 18-B-8:3 and 132-B-2 to prevent the disturbance of the structures and inadvertent human exposure. • Institutional controls are proposed for sites 118-B-1, 118-B-6, and 118-B-8:1 to prevent intrusion through the barriers and prevent irrigation of the sites. • No institutional controls for the other 5 waste sites are proposed because all contamination above PRGs are assumed to be removed. • Institutional controls may be used in lieu of further excavation, in the event that cleanup verification identifies COCs at concentrations above PRGs, and it is determined that removal of this material is not necessary (due to depth of contamination) or cost-effective, A cost-benefit evaluation will be performed to help make this determination. • Permits for land disturbance and restrictions on land disturbance for sites with human health deep direct exposure risk or potential shallow human health direct contact risk.
	Surface Barrier (for example, Asphalt Barrier)	• Surface barrier, such as an asphalt or evapotranspiration barrier, for sites located in proximity to a reactor or sites that represent a surface water or groundwater protection hazard.
	RTD	• Demolition of structures (for example, buildings) when necessary. • Standard excavation methods for sites which exceed shallow PRGs up to 6.1 m (20 ft). • Treatment at the ERDF as required to meet waste acceptance criteria. • Disposal of excavated soil at the ERDF.

Table 9-5. Description of Alternative Components for Alternative S-3 Limited RTD Optimized with Other Technologies

Notes:

a. Additional information on the conceptual design for common remedy components is presented Section 9.1.3. Detailed information necessary for cost estimate preparation (for example, number of sites evaluated, areas, and volume of material treated) is presented in Appendix J.

b. Shallow soil is defined as less than 6.1 m (20 ft) below ground surface (bgs).

9.2.4 Alternative S-4 – Aggressive RTD

Alternative S-4 uses RTD at all of the waste sites, with the exception of site 118-B-8:1, where a surface barrier is proposed because of its proximity to the 105-B Reactor. The primary difference between Alternatives S-4 and S-3 is that Alternative S-4 extends RTD to the total depth of contamination at the 118-B-1 and 118-B-6 instead of placing a surface barrier over each site. RTD addresses PRG exceedances by removing soil contamination as follows:

- Excavation of the waste site structures, waste material or vadose zone soil where contaminant concentrations exceed PRGs
- Treatment of excavated soil and debris as needed to meet disposal facility waste acceptance criteria
- Disposal of excavated material at an approved disposal facility (typically the ERDF)
- Backfilling the excavation to the original ground surface
- Regrading/revegetating the waste site

Figures 8-8, 8-9, and 8-10 illustrate the components of RTD, which has been the primary interim action performed for the waste sites at the Hanford Site.

Alternative S-4 proposes a strategy of rapidly achieving PRGs by removing contaminated vadose zone soil with concentrations above PRGs using an observational approach. This alternative complements the interim actions previously completed at waste sites by using the same overall approach. This alternative assumes standard excavation methods (Figure 8-8) for the excavation of shallow soil (up to 6.1 m [20 ft]). Deep excavation methods with additional layback or shoring techniques (Figure 8-9) will be used to excavate vadose zone soil at depths greater than 6.1 m (20 ft).

RTD activities at the two waste sites, 118-B-8:3 and 132-B-2, associated with 105-B Reactor Museum would also present additional requirements. Excavation and demolition work would require coordination with the National Park Service, and extensive design work to prevent damage to the museum. It is unlikely that this alternative will be implemented at these two sites as long as the 105-B Reactor remains a National Historic Landmark.

Alternative S-4 uses a surface barrier at site 118-B-8:1. Due to its proximity to the 105-B Reactor, RTD cannot performed at the site. Surface barrier technologies are applicable for human health and surface water/groundwater quality protection (*Central Plateau Vadose Zone Remediation Technology Screening Evaluation* [RPP-ENV-34028]). Surface barriers are constructed over contaminated waste sites to control the vertical entry of natural infiltration into contaminated media, which in turn reduces leaching of soluble contaminants to groundwater. In addition to their hydrological performance, barriers can function as physical impediments to prevent against intrusion by humans; limit wind and water erosion; and provide

a radiological barrier. For cost estimating purposes, a surface asphalt barrier is assumed for this FS. Given the historical status of the 105-B Reactor, the surface cap is intended to remain functional until the radionuclides decay below HH PRGs in 2203.

Appendix J presents a summary of the remedial components for the waste sites along with conceptual design details for each site, including the areas and volumes of individual waste sites assumed for cost estimating. Table 9-6 summarizes the components of Alternative S-4.

Table 9-6. Description of Alternative Components for Alternative S-4—Aggressive RTD

Media	Remedy Component	Description
Waste Site Components[a,b]	No Action	• No additional remedial actions are taken at Waste sites remediated under interim actions sites where results are expected to confirm the interim actions completed under the *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)*, (EPA/ROD/R10-99/039) meet PRGs.
	Institutional Controls	Institutional controls are only proposed for site 118-B-8:1 to prevent intrusion through the surface barrier until HH PRGs are achieved in 2203. • No institutional controls are proposed for the other 9 waste sites because all contamination above PRGs are assumed to be removed. • I Institutional controls may be used in lieu of further excavation, in the event that cleanup verification identifies COCs at concentrations above PRGs, and it is determined that removal of this material is not necessary (due to depth of contamination) or cost-effective. A cost-benefit evaluation will be performed to help make this determination.
	Surface Barrier (for example, Asphalt Barrier)	• Surface barrier, such as an asphalt barrier, for sites located in close proximity to a reactor.
	RTD	• Demolition of structures (for example, buildings, pipelines) when necessary. • Standard excavation methods for sites which exceed shallow PRGs up to 6.1 m (20 ft). • Deep excavation methods (that is, sloping, benching, and shoring) for sites where PRGs are exceeded at depths greater than 6.1 m [20 ft]). • Treatment at the ERDF as required to meet waste acceptance criteria. • Disposal of excavated soil at the ERDF.

a. Additional information on the conceptual design for common remedy components is presented Section 9.1.3. Detailed information necessary for cost estimate preparation (for example, number of sites evaluated, areas, and volume of material treated) is presented in Appendix J.

b. Shallow soil is defined as less than 6.1 m (20 ft) bgs.

Table 9-6. Description of Alternative Components for Alternative S-4—Aggressive RTD

Media	Remedy Component	Description

9.3 Description of Groundwater Alternatives

Under CERCLA, groundwater remedial action is warranted when EPCs for the identified COCs exceed MCLs or nonzero MCLGs where groundwater is deemed a current or future drinking water source. Groundwater remedial action is also required where contaminated groundwater may cause an exceedance of a surface water quality protection ARAR.

The groundwater alternatives were also developed to align with the NCP, which specifies under "Remedial Investigation/Feasibility Study and Selection of Remedy" (40 CFR 300.430 (e)(4) and (e)(5)) that groundwater response actions shall include as appropriate:

- **(e) (4):** a limited number of remedial alternatives that attain site-specific remediation levels within different restoration time periods utilizing one or more different technologies.
- **(e) (5):** one or more innovative treatment technologies for further consideration if those technologies offer the potential for comparable or superior performance or implementability; fewer or lesser adverse effects than other available approaches; or lower costs for similar levels of performance than demonstrated treatment technologies.

As described in Chapter 6 and Section 8.3.1, three COCs were identified for groundwater: Cr(VI), strontium-90, and tritium. Remedial action for these COCs is required to restore the unconfined aquifer groundwater beneficial use and to protect surface water quality. Based on these requirements, the following alternatives were developed:

- **Alternative GW-1:** No Action. This alternative is required by the NCP under "Remedial Investigation/Feasibility Study and Selection of Remedy"(40 CFR 300.430 (e)(6)).
- **Alternative GW-2:** MNA and Institutional Controls. This alternative uses institutional controls to prevent COC exposure until MNA reduces concentrations to PRGs. Monitoring activities will include periodic sampling of monitoring wells, aquifer tubes (at the river shoreline), and pore water sampling below the river bottom. A contingent pump-and-treat remedy is proposed under this alternative if natural attenuation fails to reduce COC concentrations and plume size as expected or biotic monitoring identifies unexceptable effects to ecological receptors in the Columbia River.
- **Alternative GW-3:** River Protection Pump-and-Treat. This alternative uses pump-and-treat operated for a period of 65 years with ex-situ treatment of Cr(VI) and strontium-90. Following 65 years of active pump-and-treat, the Cr(VI)AWQC is achieved throughout most of the current plume area. The strontium-90 and tritium plumes are remediated primarily through MNA.
- **Alternative GW-4:** Aggressive Pump-and-Treat . This alternative uses pump-and-treat with ex-situ treatment technology for Cr(VI) and strontium-90 operated for a period of 25 years. Following 25 years of active pump-and-treat, MNA is used to achieve PRGs throughout the current plume area. The strontium-90 and tritium groundwater plumes are remediated primarily through MNA.

Table 9-7 summarizes the retained technologies identified in Chapter 8 as they apply to the groundwater remedial alternatives.

Table 9-7. Retained Technologies Applied to Groundwater Remedial Action Alternatives

Remedial Technology	Process Option	Alternative 1	Alternative 2	Alternative 3	Alternative 4
No Action	No Action	X			
Monitored Natural Attenuation	Monitored Natural Attenuation		X	X	X
Pump-and-Treat – Collection	Groundwater Extraction Systems			X	X
Pump-and-Treat – Ex Situ Treatment	Ion Exchange			X	X
Pump-and-Treat – Discharge	Groundwater Injection Wells			X	X
Containment	Hydraulic Containment via Extraction			X	X

Note:

a. Pump-and-treat includes the combination of groundwater extraction using vertical wells, ex situ ion exchange treatment, and groundwater injection using vertical wells.

The primary focus for groundwater remedial action alternative development was the Cr(VI) plume, while the strontium-90 and tritium plumes are addressed through coextraction and treatment or MNA as follows:

- **Hexavalent chromium**—The groundwater risk analysis in Chapter 6 identified the 90th percentile, 95th UCL, and maximum concentration EPC for Cr(VI) in the near river exposure area to be 50 µg/L, 30 µg/L, and 57 µg/L, respectively. The 90th percentile concentration of 50 µg/L is slightly above the 48 µg/L drinking water standard and is modeled to decline below the standard within 1 to 2 years. However, along the Columbia River shoreline hexavalent chromium occurs at concentrations above the 10 µg/L MTCA freshwater chronic criteria or AWQC. Therefore, remediation of the hexavalent chromium plume, where present at concentrations above the AWQC, is the focus for the remedial action alternatives to protect the Columbia River.

- **Tritium**—The groundwater risk analysis in Chapter 6 identifed the 90th percentile, 95th UCL, and maximum concentration EPC for tritium in the near river exposure area to be 33,200 pCi/L, 17,779 pCi/L, and 69,000 pCi/L, respectively. The 90th percentile concentration is above the 20,000 pCi/L drinking water standard. Groundwater containing tritium will be co-extracted using groundwater extraction wells, treated as necessary for other COCs, and re-injected into upgradient wells to allow the tritium to naturally decay. The modeling results suggest that the current tritium concentrations in groundwater will decay to levels below the 20,000 pCi/L drinking water standard within 5 to 15 years.

- **Strontium-90**—The groundwater risk analysis in Chapter 6 identified the 90th percentile, 95th UCL, and maximum concentration EPC for strontium-90 in the near river exposure area to be 38 pCi/L, 20 pCi/L, and 49 pCi/L, respectively. The 90th percentile concentration is above the 8 pCi/L drinking water standard. However, based on the maximum concentration present and its 29.1 year half-life, strontium-90 will radioactively decay to a concentration less than the drinking water standard within

52 to 72 years. It is expected that several wells for the pump-and-treat alternatives will extract groundwater that has strontium-90 levels that are greater than the 8 pCi/L drinking water standard, therefore, aboveground treatment of this COC is proposed at several well locations.

This section provides an overview of the groundwater remedial alternative concepts developed for detailed and comparative analysis and cost estimating.

The conceptual designs presented are developed to the level required to prepare a cost estimate that will allow comparison of the alternatives. More detail on the selected remedy for 100-BC will be developed during the design phase after finalization of the ROD. A RD/RAWP will be developed that will discuss in detail the design of the specific components for each groundwater plume.

Groundwater modeling was conducted to establish baseline conditions in the aquifer and evaluate the groundwater remediation alternatives. Results of groundwater modeling (*Modeling of RI/FS Design Alternatives for 100-BC-5* [ECF-100BC5-11-0115, in Appendix F, provide a prediction of COC plumes and trends. The groundwater data collected during the RI was used to prepare initial condition plume maps for each of the groundwater COCs. Vertical contaminant profile data collected during the RI allowed for more accurate representations of COC distributions in the aquifer. Figures 9-1 through 9-3 present the initial plume conditions used in the groundwater model simulations for Cr(VI), strontium-90, and tritium, respectively. The concentration ranges shown in the figures reflect the maximum concentrations calculated from the model simulation. The four layers of the groundwater model are shown in each figure. Layer 1 represents the saturated Hanford Formation (where present) and layers 2, 3, and 4 represent progressively deeper horizons of the Ringold E Unit. The areal extent of each plume was developed by combining the areal extent within each layer and projecting it to the surface. The maximum areal extent for each COC plume is illustrated on the figures using dashed lines. The presentation of four model layers for the 100-BC alluvial aquifer differs from the plume maps presented for the other 100 Area OUs. This level of detail was made possible by the greater saturated thickness of the alluvial aquifer present at 100-BC and the vertical contaminant profile data collected during the RI.

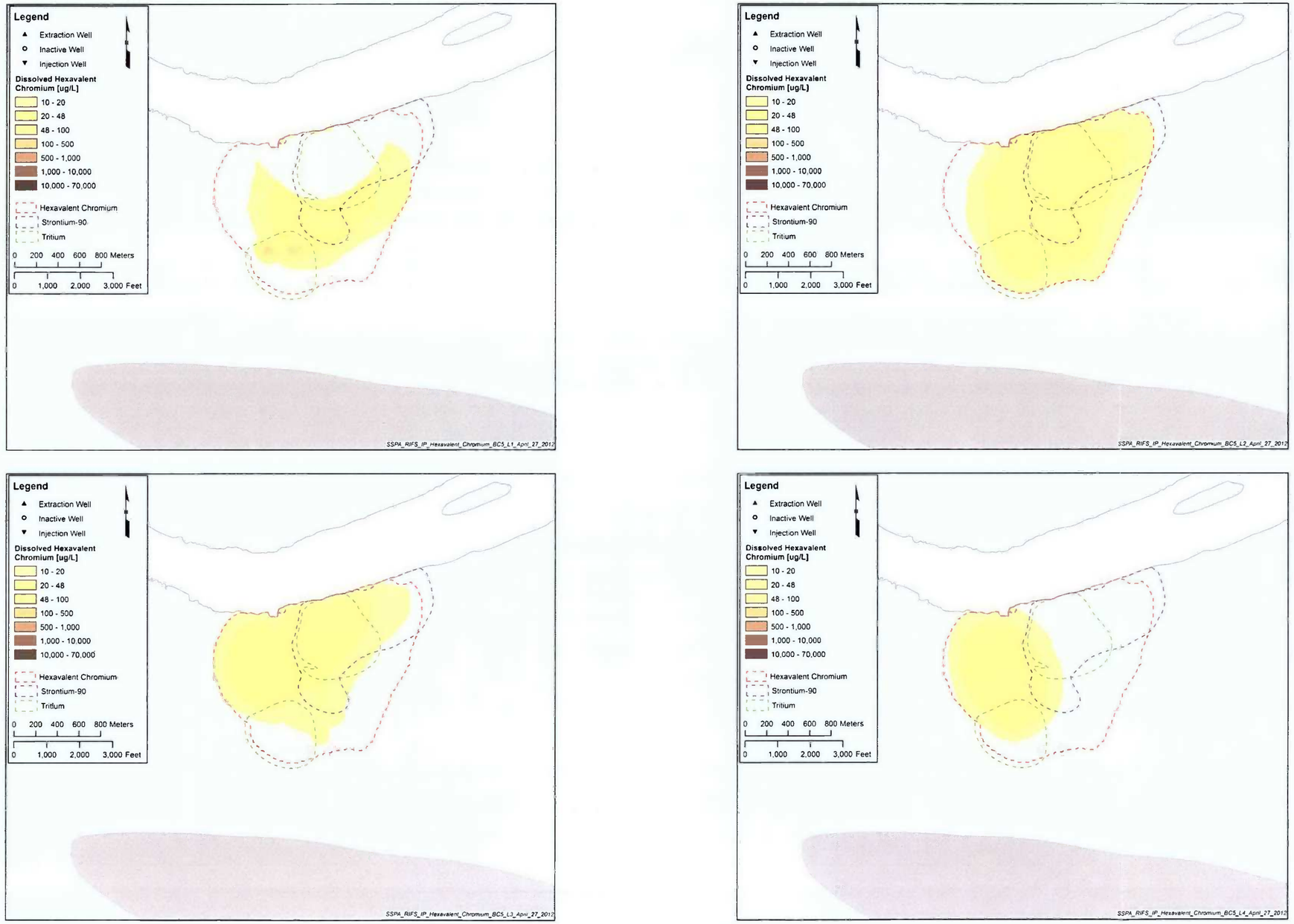


Figure 9-1. Modeled Cr(VI) Plume, Initial Conditions

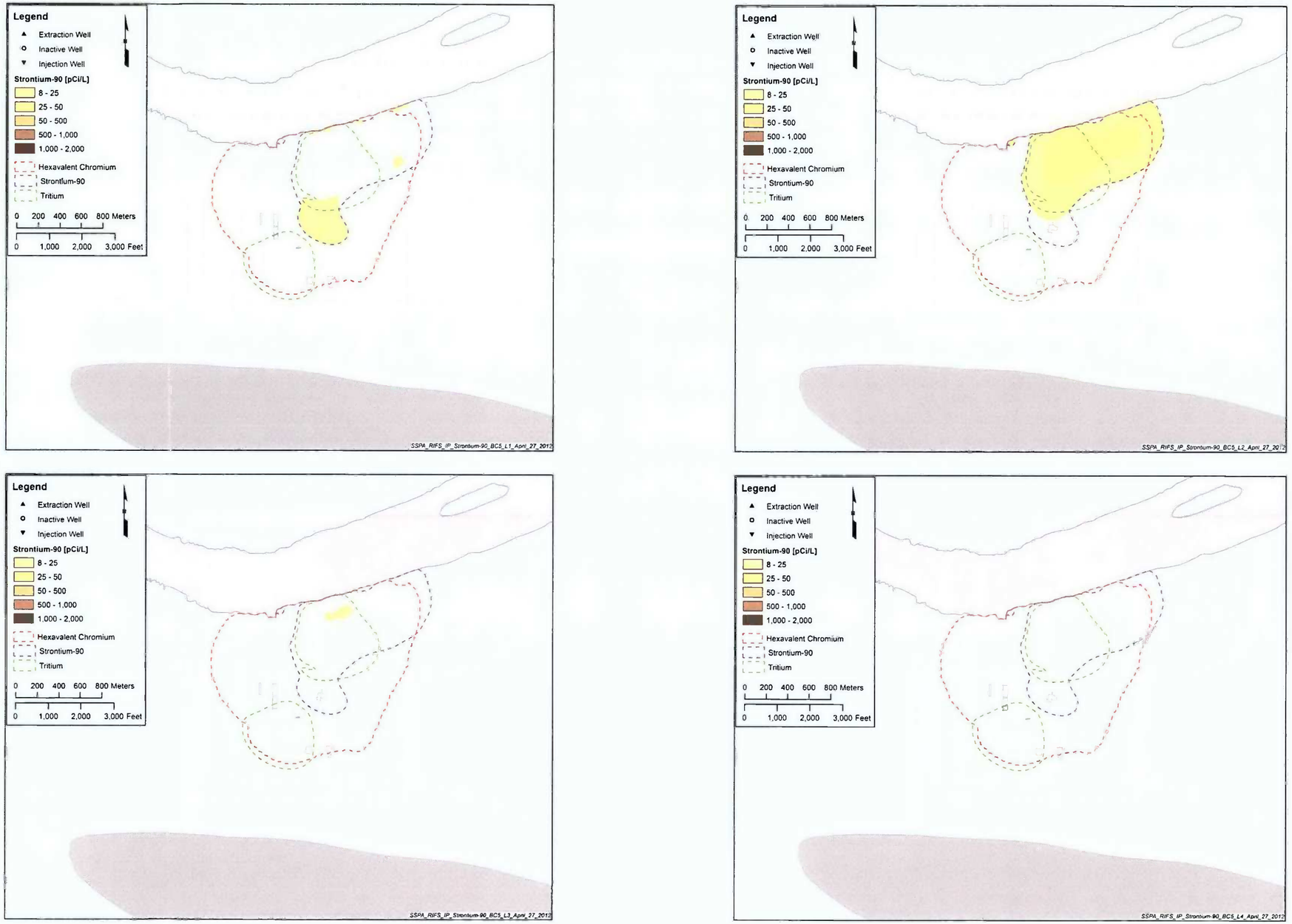


Figure 9-2. Modeled Strontium-90 Plume, Initial Conditions

Figure 9-3. Modeled Tritium Plume, Initial Conditions

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Groundwater model simulations were run for time periods of at least 75 years to evaluate the progress of groundwater plume remediation. All groundwater model simulations assume that there are no continuing sources of groundwater contamination.

The predicted concentration trends for Cr(VI), strontium-90, and tritium in the aquifer and at the shoreline under each alternative are shown in Figures 9-4 through 9-6, respectively. These figures present trends for the maximum concentration (Cmax), mean concentration, median concentration, and the 90th percentile concentration. As discussed in Chapter 6, Section 6.3.9.2, the 90th percentile value is considered a reasonable estimate of the EPC. Therefore, the groundwater remediation timeframes presented in the FS are the range to achieve the 90th percentile concentration and Cmax.

The shoreline concentration trends in the figures reflect transient conditions in the aquifer from water-level changes because of river stage variation. The simulations are discretized into 12 monthly stress periods, for the first 25 years of the simulation, to reflect the seasonal varying river stage. For the period beyond 25 years, a single transient stress period is used with the river stage elevation remaining constant to reflect the average annual conditions.

Table 9-8 summarizes the model predicted time to achieve PRGs for each groundwater COC based on the 90th percentile and maximum concentrations in the aquifer and at the shoreline. Groundwater PRGs are eventually achieved under all the groundwater remediation alternatives.

Figures 9-7 through 9-9 present frequency diagrams for the percent of remaining plume mass below specific concentration levels for Cr(VI), strontium-90, and tritium, respectively. Frequency curves are presented for model time steps between 0 and 150 years for each groundwater COC. These figures allow for the direct comparison of the time required to decrease the plume mass below PRG concentrations under each groundwater alternative.

9.3.1 Alternative GW-1—No Action

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy"[40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative. The No Action Alternative, which serves as a baseline for evaluating other RAAs, is retained throughout the FS process. No action means that no remediation would be implemented to alter the existing conditions. No conceptual designs or cost estimates are prepared for Alternative GW-1 because no actions are proposed.

Figures 9-10 through 9-12 present the groundwater model predicted Cr(VI) plume at 25, 50, and 75 years, respectively. Under the No Action Alternative, significant Cr(VI) mass removal is predicted to occur through natural flushing. However, the groundwater model predicts that small areas of the site will have Cr(VI) groundwater concentrations above the AWQC PRG of 10 µg/L at the end of the 75-year period. The model also predicts the Cr(VI) groundwater plume continues to discharge to the river at concentrations above the 10 µg/L PRG throughout the 75 year simulation period. Recent pore water sampling indicates that Cr(VI) concentrations in groundwater discharging to the river are above the AWQC PRG (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]).

Figures 9-13 through 9-15 present the groundwater model predicted strontium-90 plume at 25, 50, and 60 years, respectively. The groundwater model predicts that the strontium-90 plume attenuates by the end of the 75 year simulation period. Figures 9-16 through 9-18 present the groundwater model predicted tritium plume at 5, 10 and 15 years, respectively. The groundwater model predicts that the tritium plume attenuates through natural flushing and radioactive decay within 15 years.

As shown in Figures 9-5, 9-6, 9-8, and 9-9, the time to reach PRGs for strontium-90 and tritium is not significantly reduced by active groundwater remediation alternatives such as pump-and-treat. This suggests that natural attenuation by radioactive decay is the dominant remediation process for these two COCs. Therefore, the discussion for Alternatives GW-2, GW-3, and GW-4 will focus on the groundwater modeling results for the Cr (VI) plume. The modeled fate of the strontium-90 and tritium plumes for Alternatives GW-2, GW-3, and GW-4 are presented in Appendix F *(Modeling of RI/FS Design Alternatives for 100-BC-5* (ECF-100BC5-11-0115.

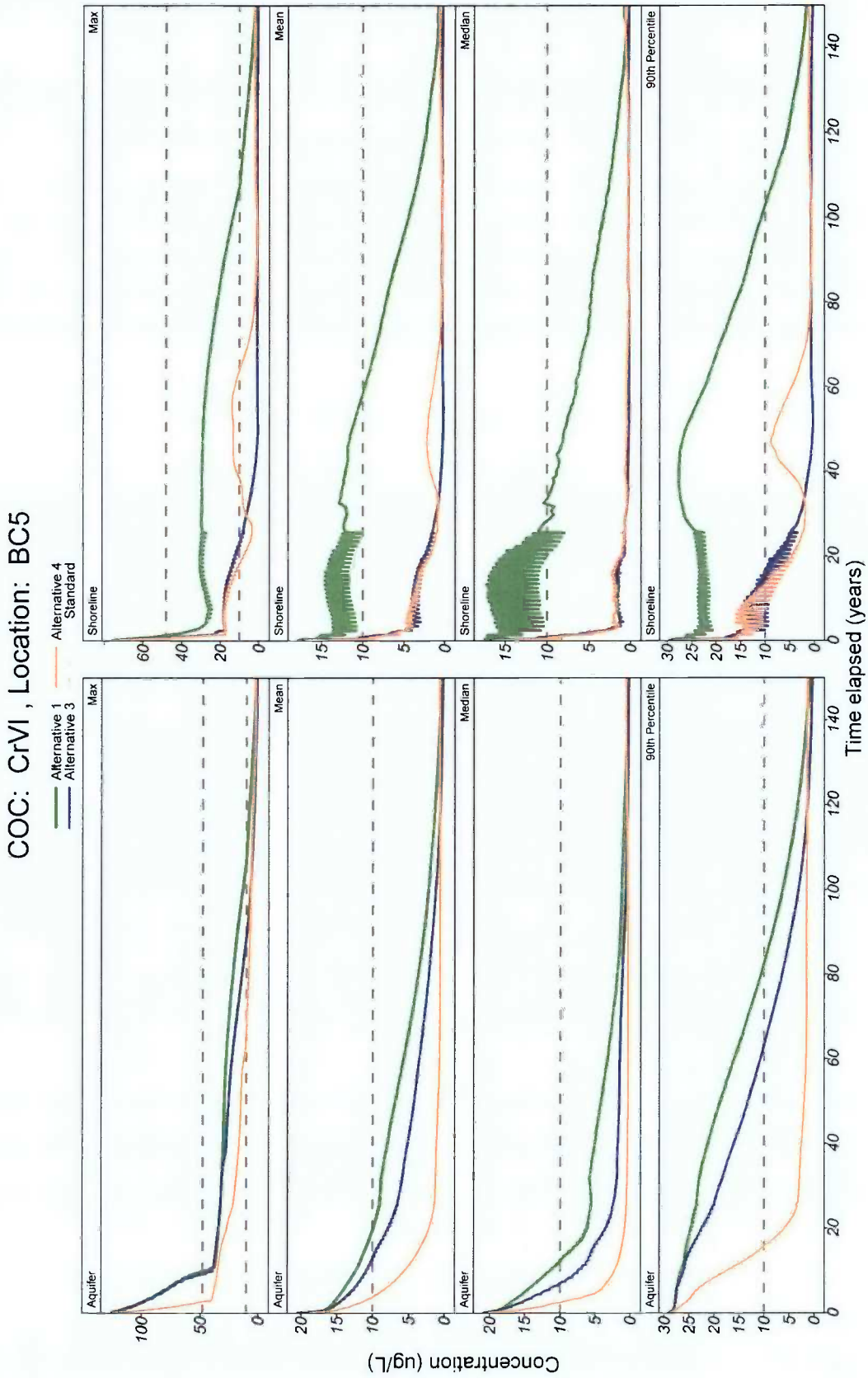

Figure 9-4. Modeled Cr(VI) Concentration Trends for all Alternatives

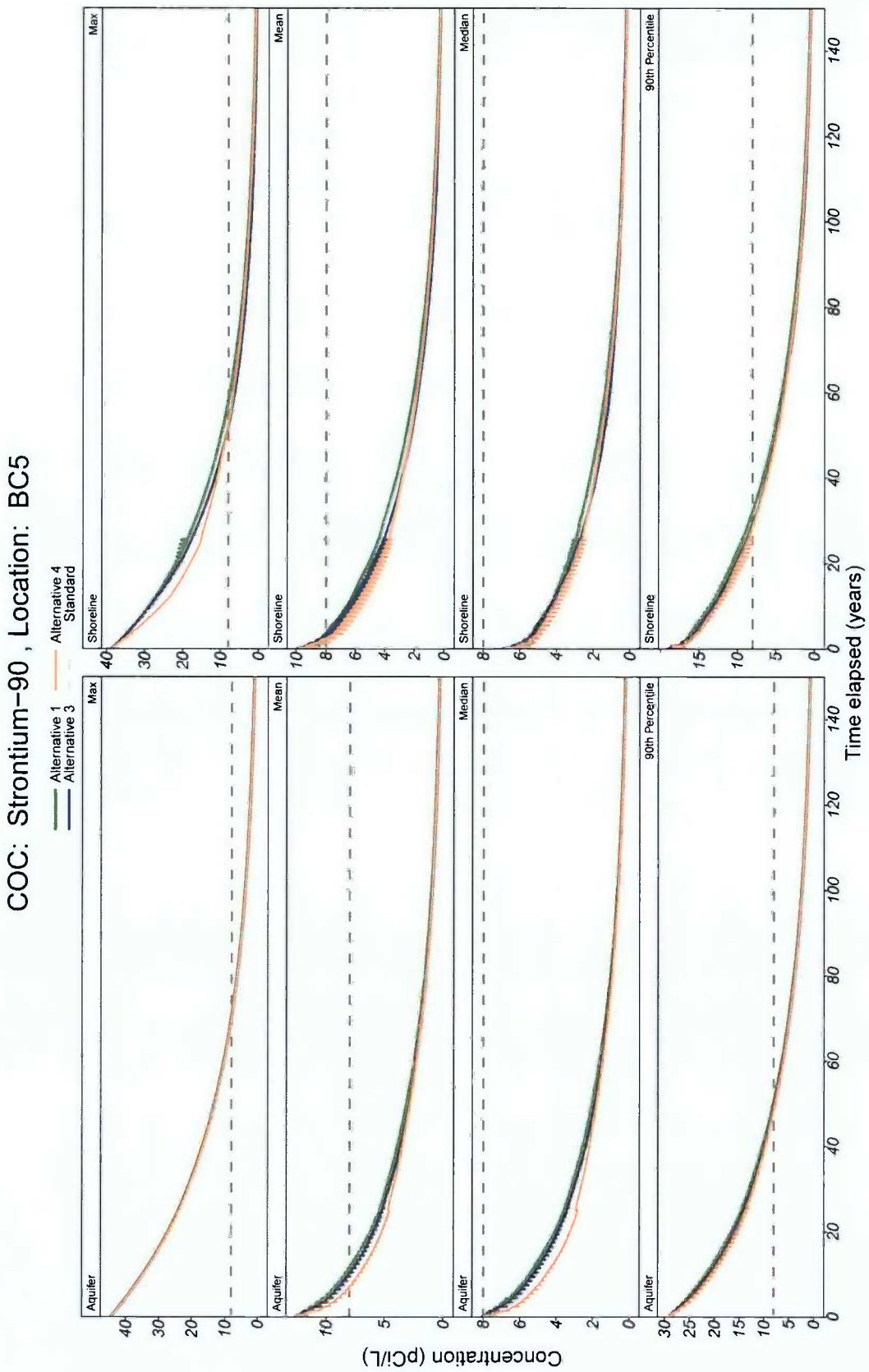

Figure 9-5. Modeled Strontium-90 Concentration Trends for all Alternatives

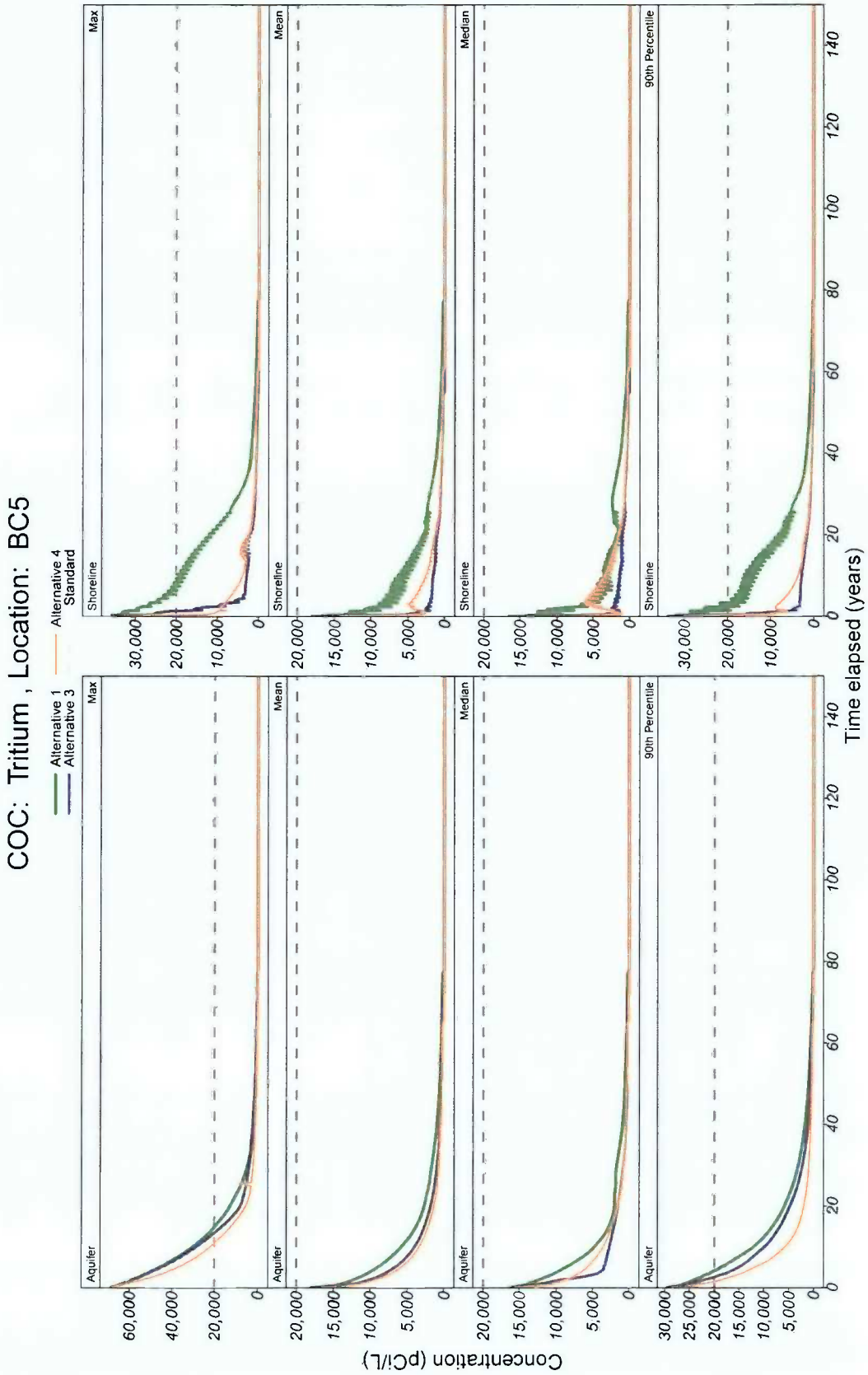

Figure 9-6. Modeled Tritium Concentration Trends for all Alternatives

Table 9-8. Model Predicted Time to Achieve Groundwater PRGs

Groundwater PRG	Alternatives 1 and 2		Alternative 3		Alternative 4	
(units)	Aquifer	Shoreline	Aquifer	Shoreline	Aquifer	Shoreline
Cr(VI) drinking water standard (48 ug/L)	0 to 11 years	0 to 2 years	0 to 10 years	0 to 1 year	0 to 3 years	0 to 1 year
Cr(VI) AWQC (10 ug/L)	83 to 108 years	104 to 108 years	64 to 90 years	17 to 23 years	16 to 67 years	14 to 65 years
Strontium-90 MCL (8 pCi/L)	52 to 72 years	33 to 60 years	49 to 71 years	30 to 53 years	49 to 71 years	28 to 53 years
Tritium MCL (20,000 pCi/L)	5 to 15 years	3 to 9 years	3 to 14 years	1 to 2 years	2 to 12 years	1 year

Notes: The remediation time presented represents the range to achieve PRGs based on the 90th percentile concentration and the maximum concentration.

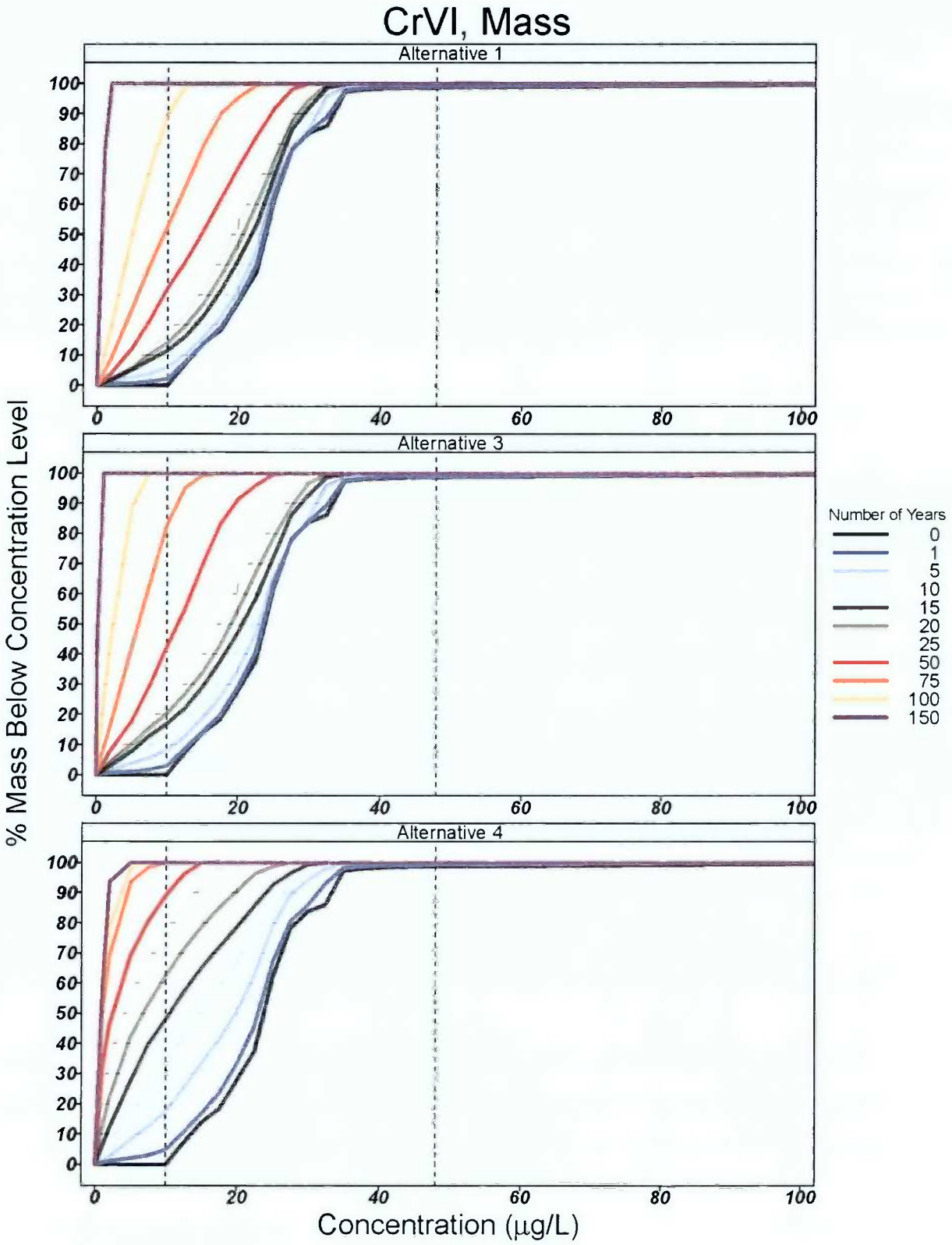

Figure 9-7. Frequency Diagrams of Cr(VI) Mass in the Aquifer for all Alternatives

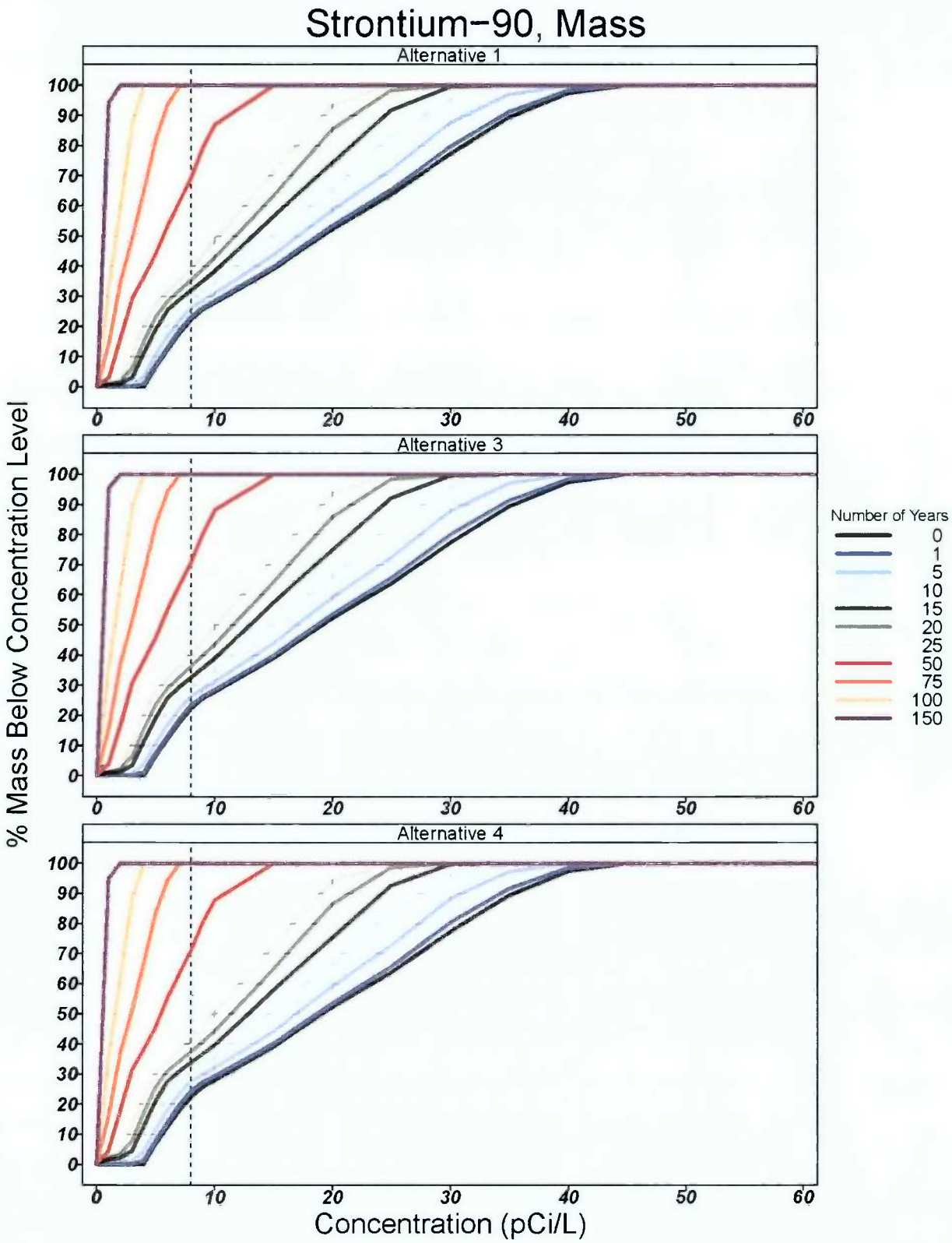

Figure 9-8. Frequency Diagrams of Strontium-90 Mass in the Aquifer for all Alternatives

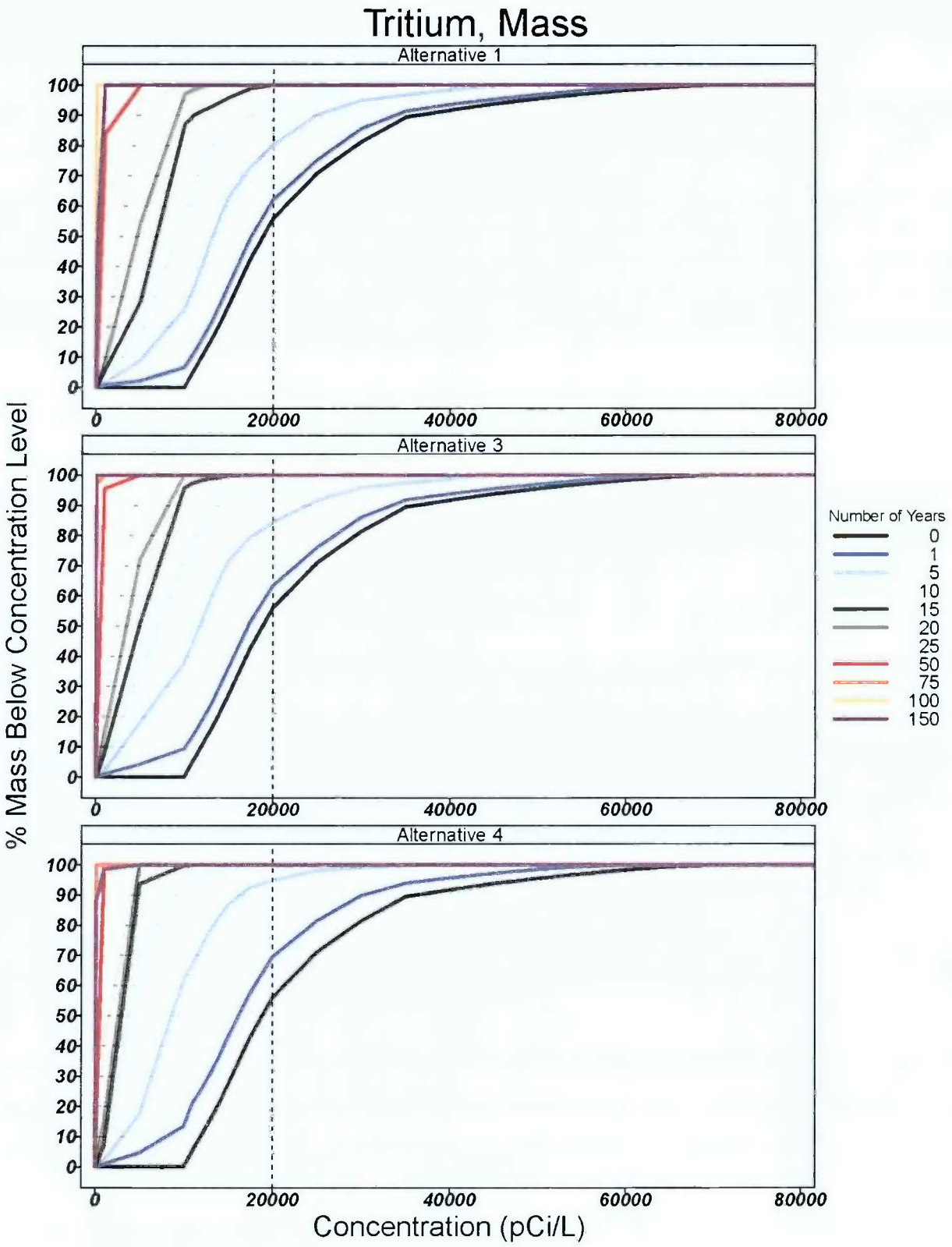

Figure 9-9. Frequency Diagrams of Tritium Mass in the Aquifer for all Alternatives

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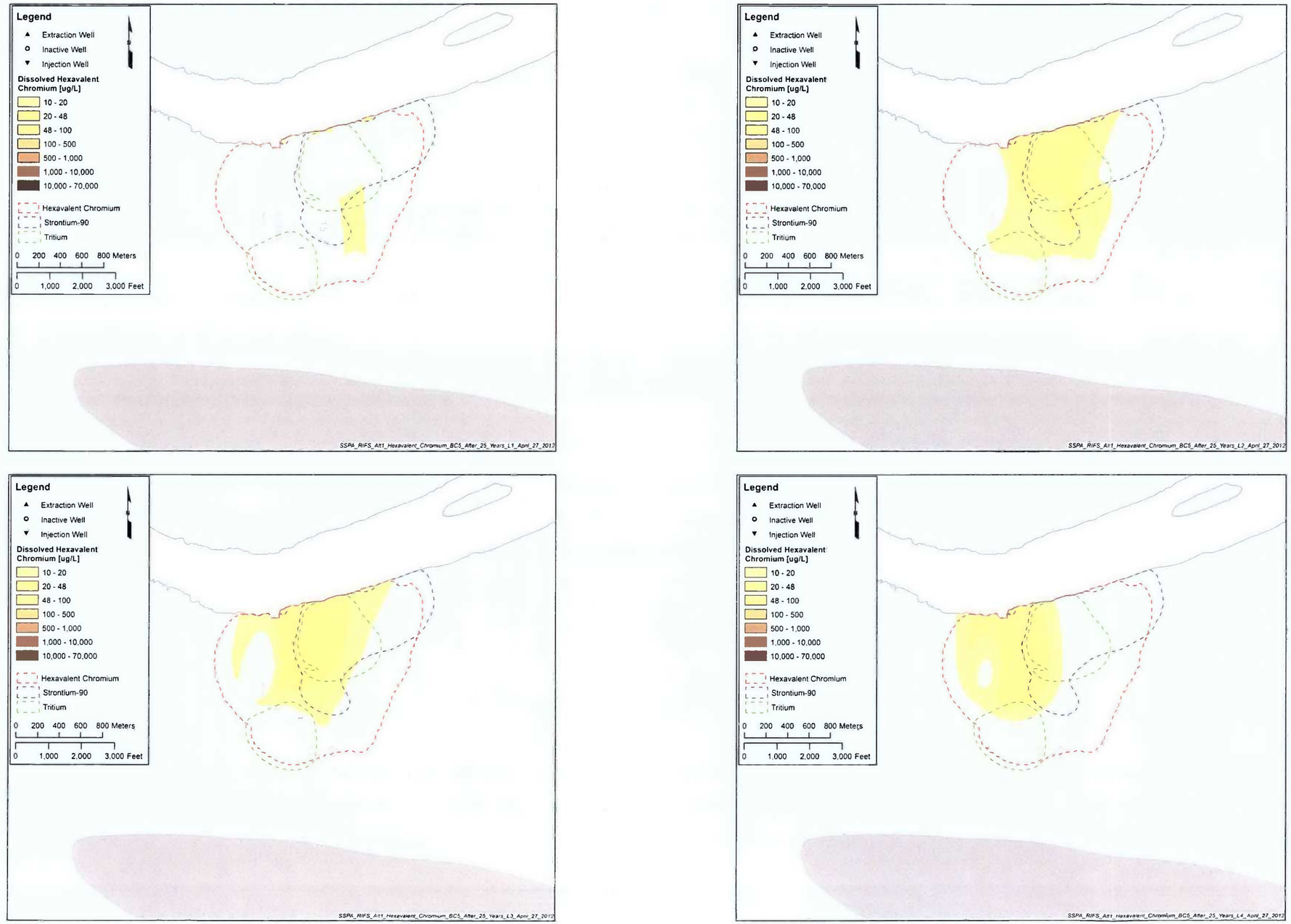

Figure 9-10. Alternative GW-1 - Modeled Cr(VI) Plume, Year 25

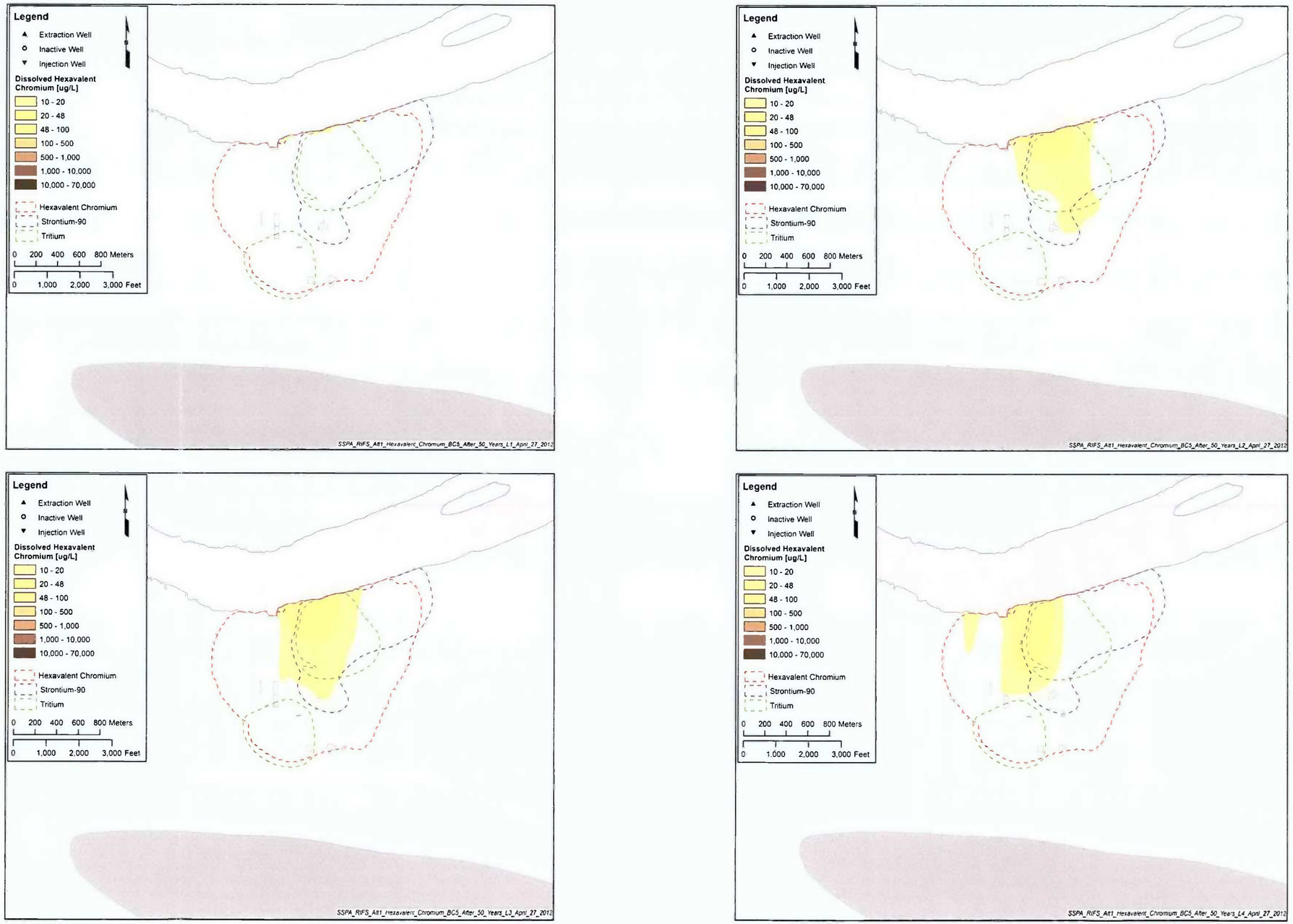

Figure 9-11. Alternative GW-1 – Modeled Cr(VI) Plume, Year 50

Figure 9-12. Alternative GW-1 – Modeled Cr(VI) Plume, Year 75

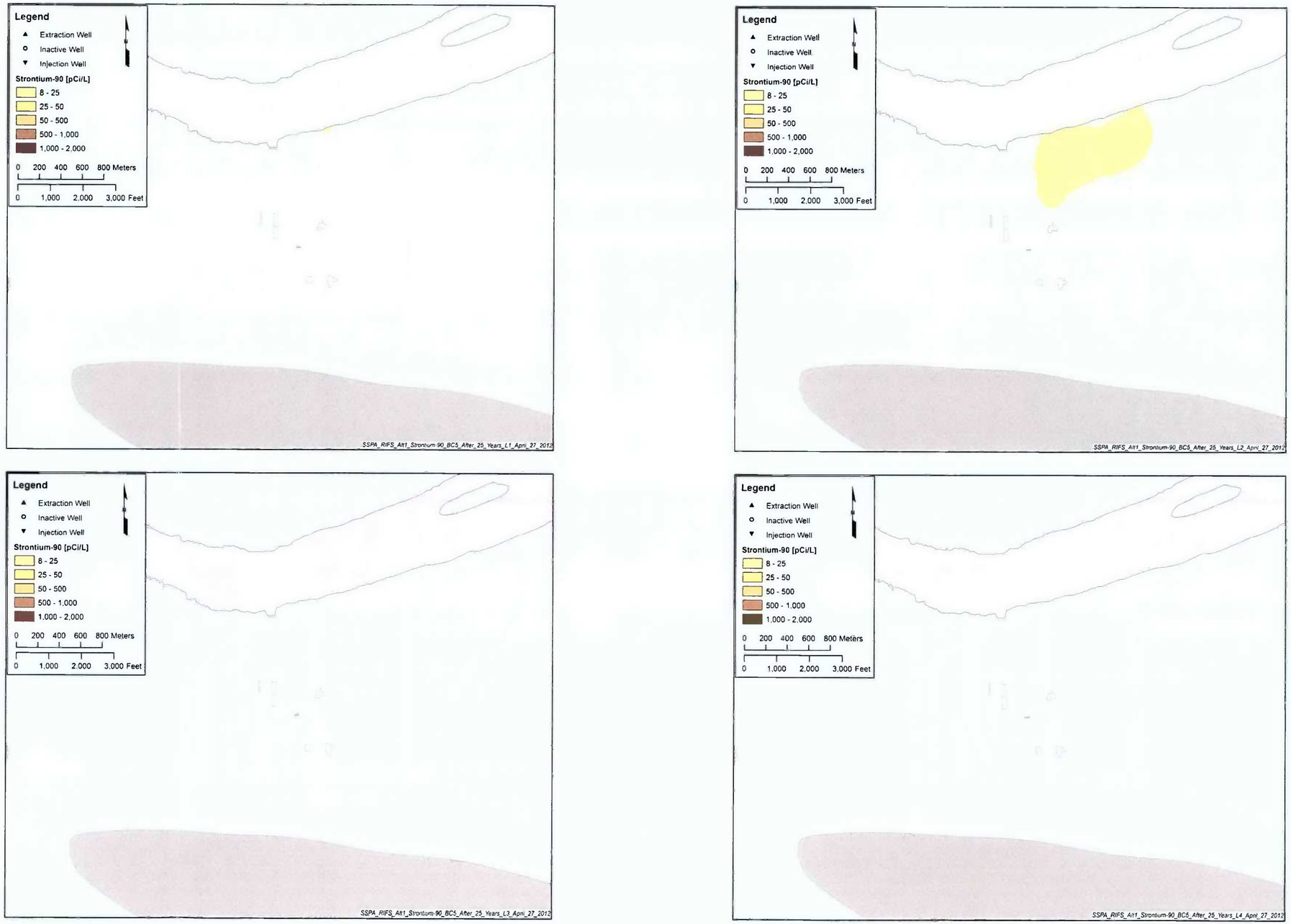

Figure 9-13. Alternative GW-1 - Modeled Strontium-90 Plume, Year 25

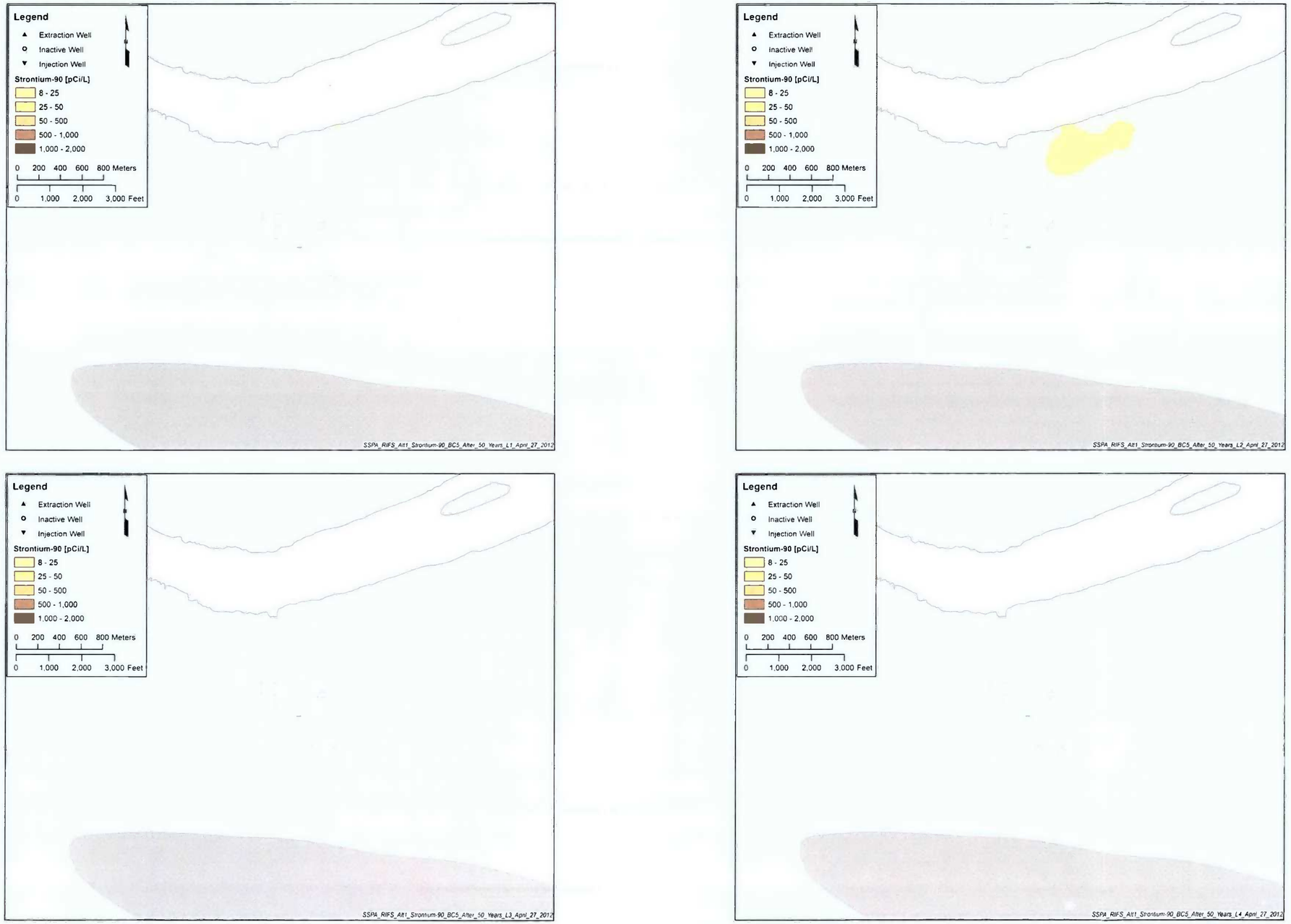

Figure 9-14. Alternative GW-1 – Modeled Strontium-90 Plume, Year 50

Figure 9-15. Alternative GW-1 – Modeled Strontium-90 Plume, Year 60

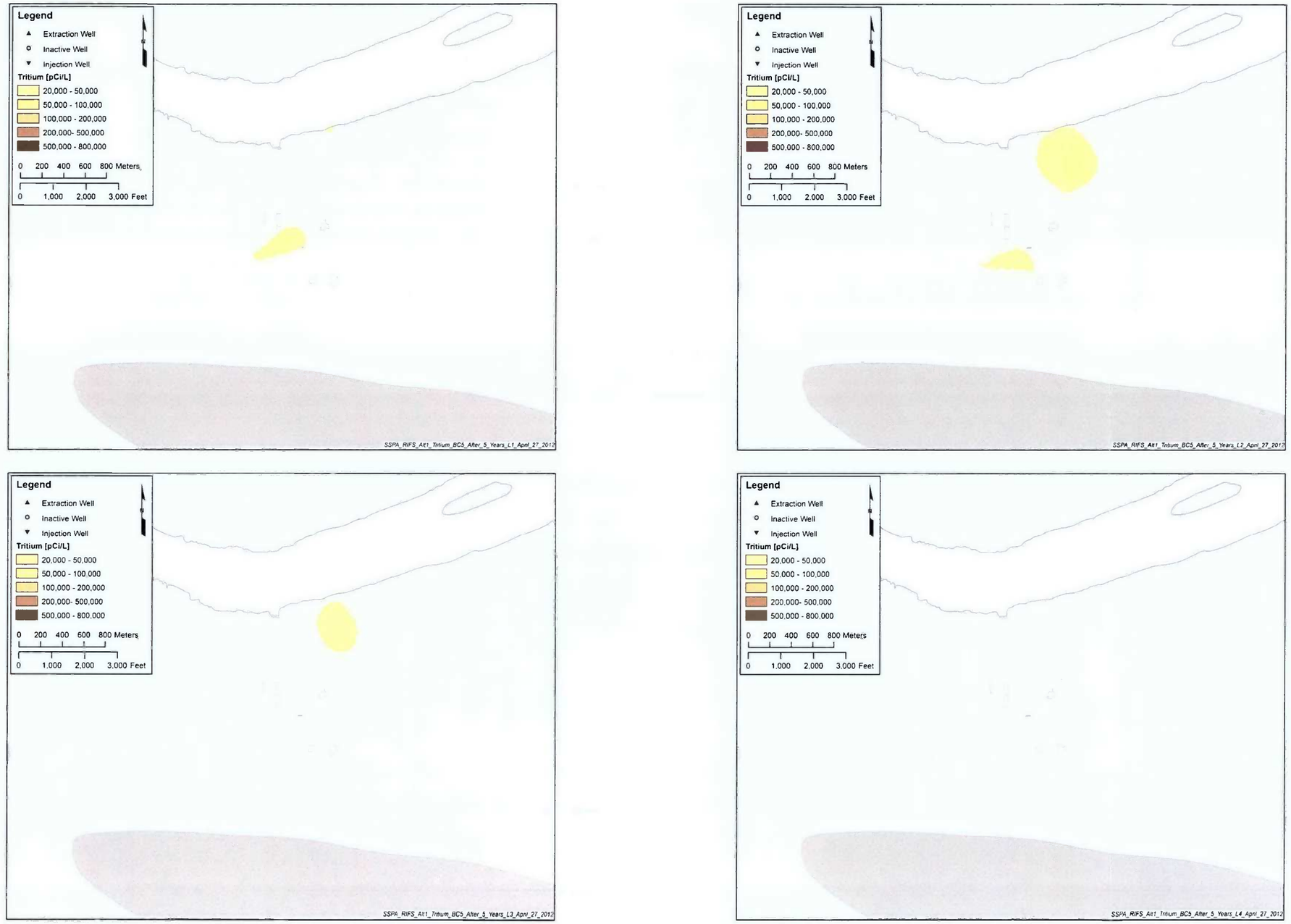

Figure 9-16. Alternative GW-1 – Modeled Tritium Plume, Year 5

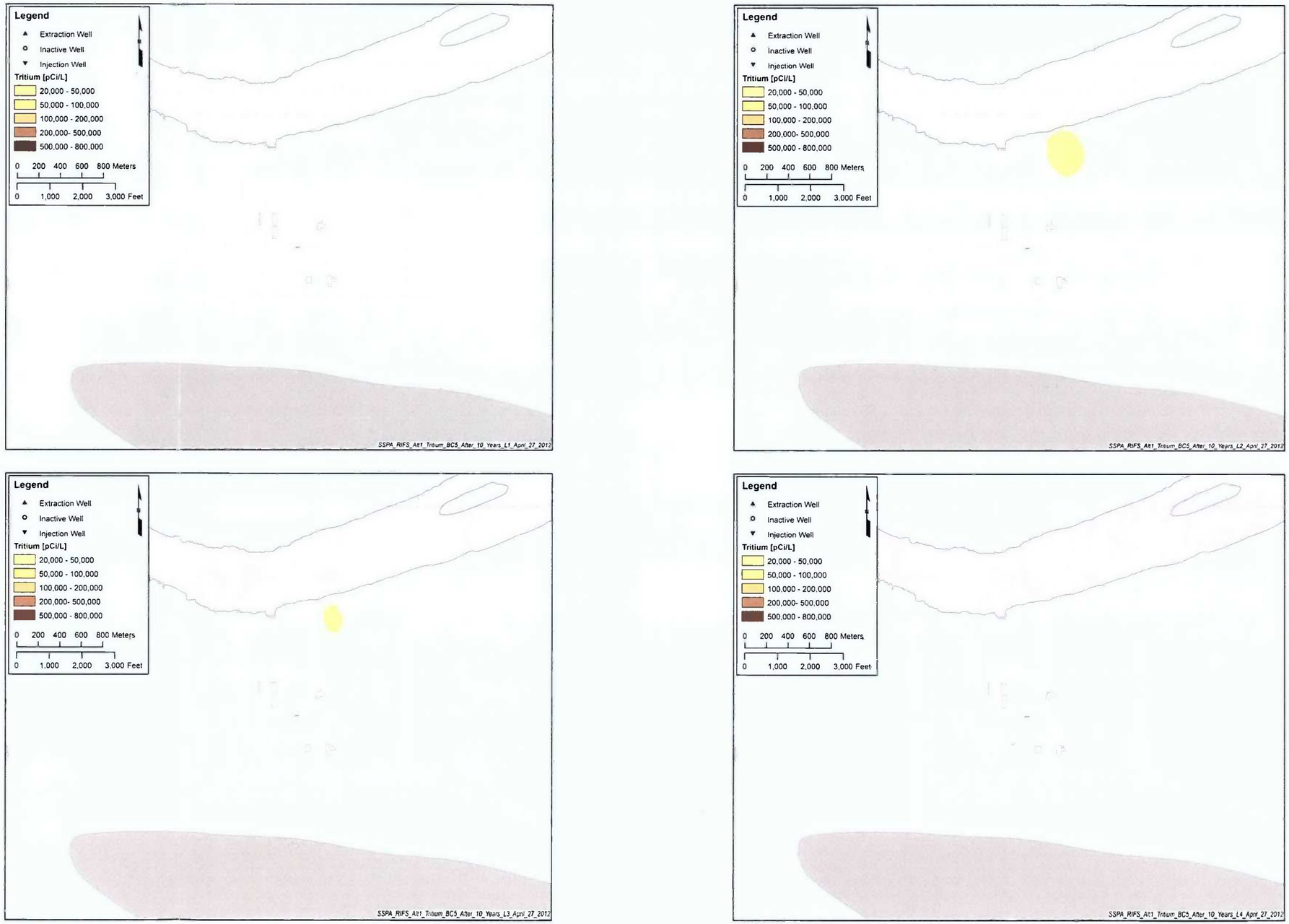

Figure 9-17. Alternative GW-1 – Modeled Tritium Plume, Year 10

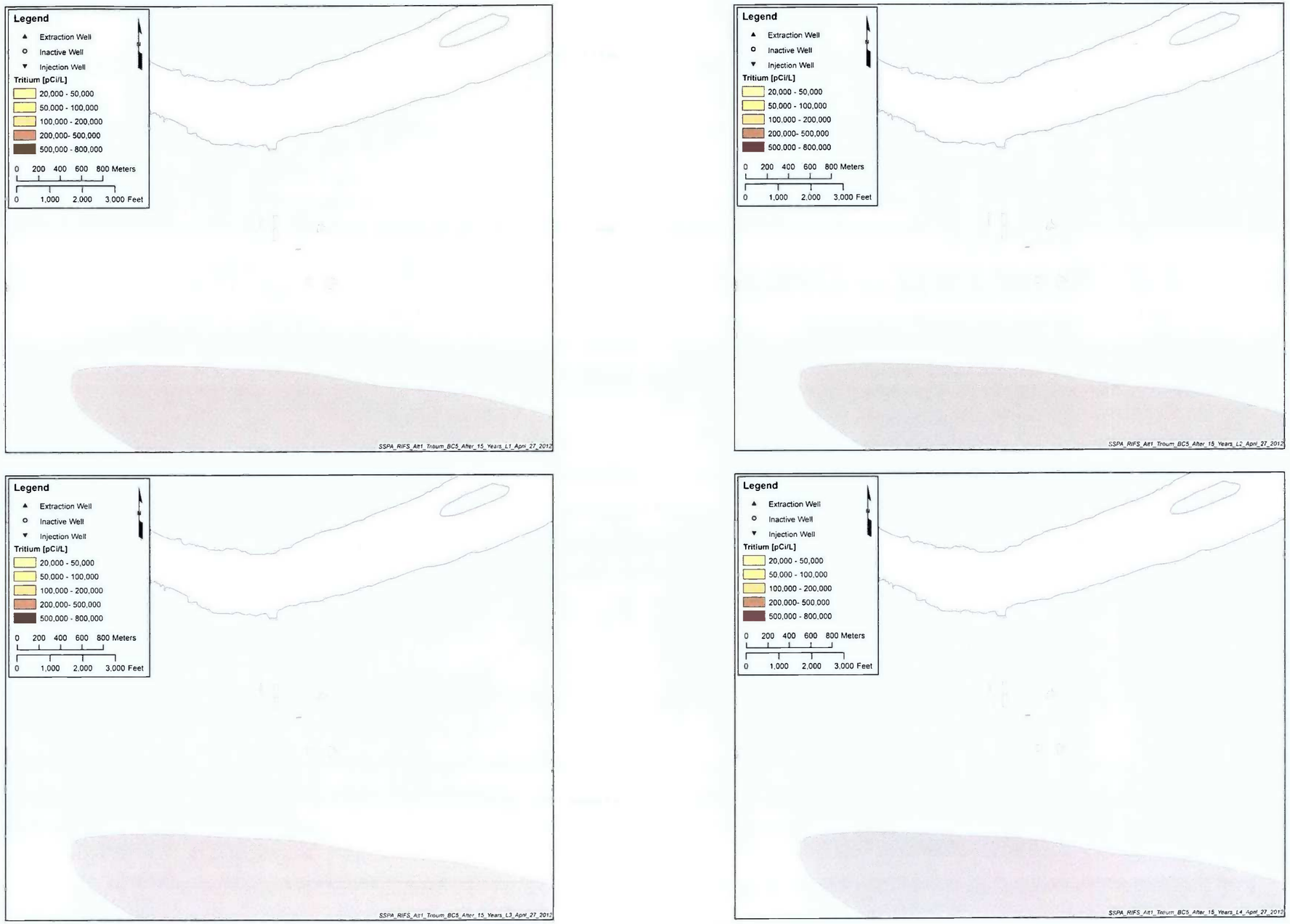

Figure 9-18. Alternative GW-1 – Modeled Tritium Plume, Year 15

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9.3.2 Alternative GW-2—MNA and Institutional Controls

Alternative GW-2 assumes use of MNA and institutional controls for the three groundwater COCs. The purpose of Alternative GW-2 is to reduce the likelihood of exposure pathways becoming complete through implementation of institutional controls until MNA processes reduce COC concentrations to PRGs.

Figures 9-19 through 9-22 present the groundwater model predicted Cr(VI) plume at 10, 25, 50, and 75 years, respectively. Table 9-9 provides a summary of remedy components for Alternative GW-2.

Under Alternative GW-2, significant Cr(VI) mass removal is predicted to occur through natural flushing with 100 percent of the plume mass remaining in the aquifer below the 48 µg/L drinking water standard PRG and 55 percent of the mass below the 10 µg/L AWQC PRG after 75 years (Figure 9-7). Based on the 90th percentile concentration and the maximum concentration, the groundwater Cr(VI) concentrations decline below the 48 µg/L drinking water standard PRG between year 0 and year 11 (Table 9-8). However, the groundwater model predicts that a small area of the site will still have groundwater Cr(VI) concentrations that are above the AWQC PRG of 10 µg/L at the end of the 75-year period (Figure 9-21). The model also predicts that the Cr(VI) groundwater plume continues to discharge to the river at concentrations above the 10 µg/L AWQC throughout the 75 –year simulation period (Figure 9-4). Under Alternative GW-2, the groundwater Cr(VI) concentrations are reduced to levels below the 10 µg/L AWQC between 83 and 108 years (Table 9-8).

The groundwater model predicts that strontium-90 and tritium groundwater concentrations decay below their PRGs after 52 to 72 years and 5 to15 years, respectively (Table 9-8).

9.3.3 Alternative GW-3—River Protection Pump-and-Treat

Alternative GW-3 reduces the groundwater concentrations of Cr(VI) and strontium-90 through pump-and-treat using ex-situ treatment technologies while tritium concentrations are reduced primarily through natural attenuation processes. Groundwater pump-and-treat systems can be used to limit groundwater plume migration through hydraulic containment and to remediate the groundwater plumes through extraction of contaminant mass. The pump-and-treat system concept developed for Alternative GW-3 consists of extraction and injection well networks configured to provide river protection along with conveyance piping and infrastructure, and treatment systems for the removal of Cr(VI) and strontium-90. Figure 9-23 shows the preliminary design layout of Alternative GW-3.

The groundwater extraction and injection wells will be optimally located to minimize plume discharge to the Columbia River, control the groundwater flow path, and provide extraction well capture efficiency. The primary objective of the extraction well locations is to contain the Cr(VI) groundwater plume discharge to the Columbia River. As shown on Figures 9-8 and 9-9, the active groundwater remediation alternatives do not have a significant effect on removing strontium-90 and tritium mass from the aquifer. Since the strontium-90 and tritium plumes are remediated primarily through natural attenuation (radioactive decay), placement of extraction wells in the strontium-90 plume for active extraction and treatment is a secondary consideration. Extracted groundwater will be treated using ion exchange systems for removal of Cr(VI) and strontium-90. The six excavation wells in the conceptual design were placed in the high concentration area of the Cr(VI) plume. The discharge from the six wells is expected to require treatment to remove Cr(VI). Two of the six extraction wells shown in the conceptual design are located in the strontium-90 plume with discharge from these two wells potentially requiring treatment to remove strontium-90. Under Alternative GW-3, the pump-and-treat system is designed to operate for a period of 75 years.

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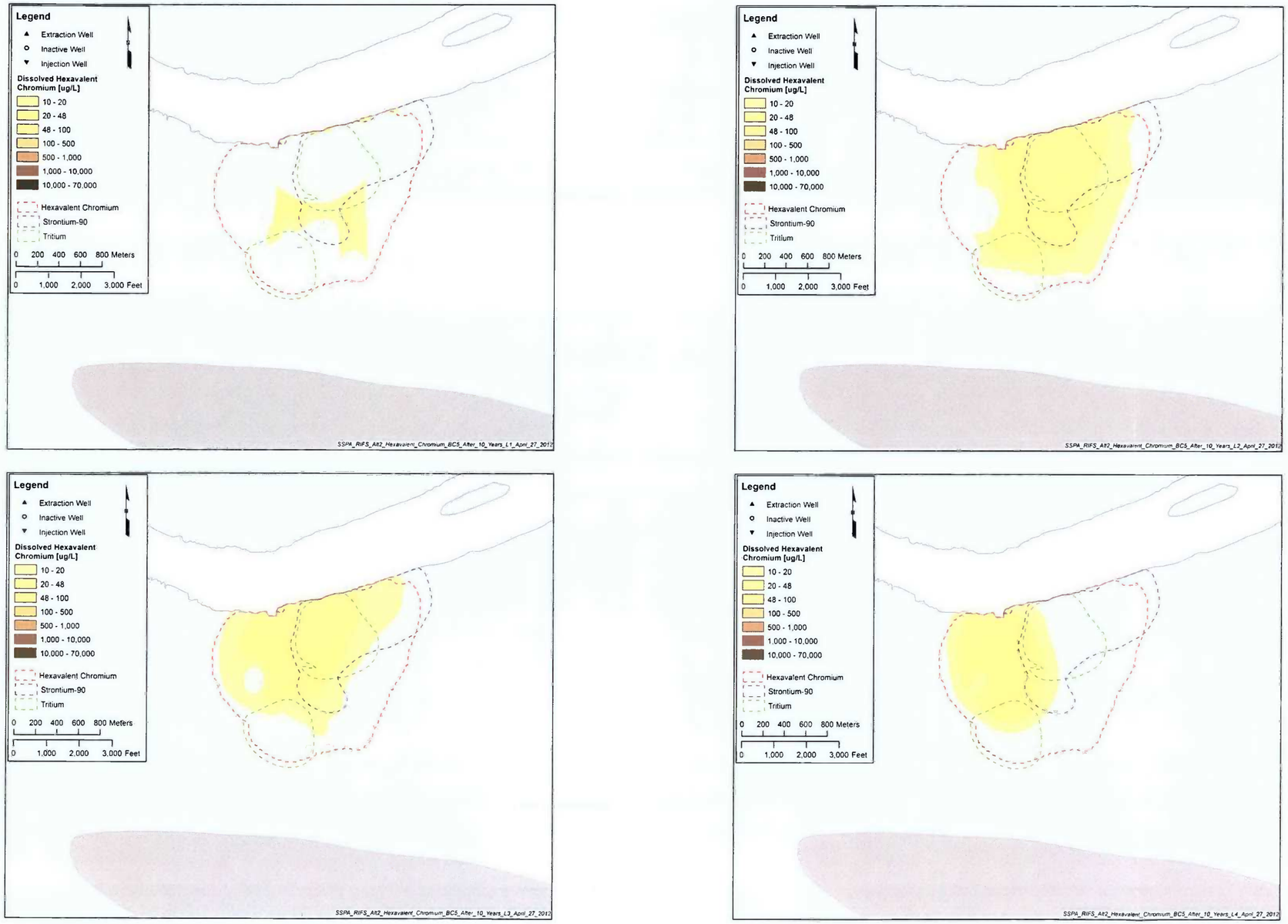

Figure 9-19. Alternative GW-2 - Modeled Cr(VI) Plume, Year 10

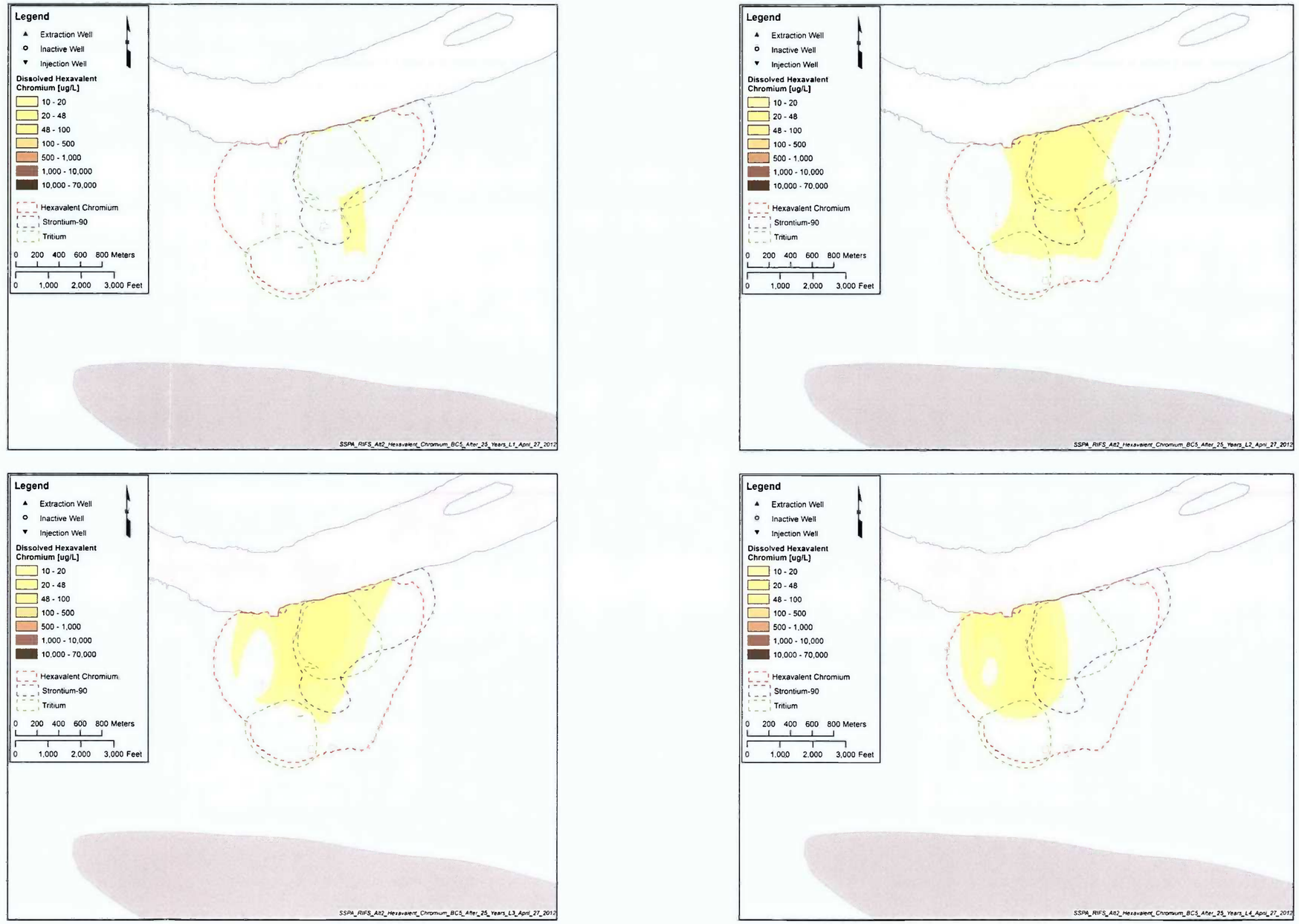

Figure 9-20. Alternative GW-2 - Modeled Cr(VI) Plume, Year 25

Figure 9-21. Alternative GW-2 – Modeled Cr(VI) Plume, Year 50

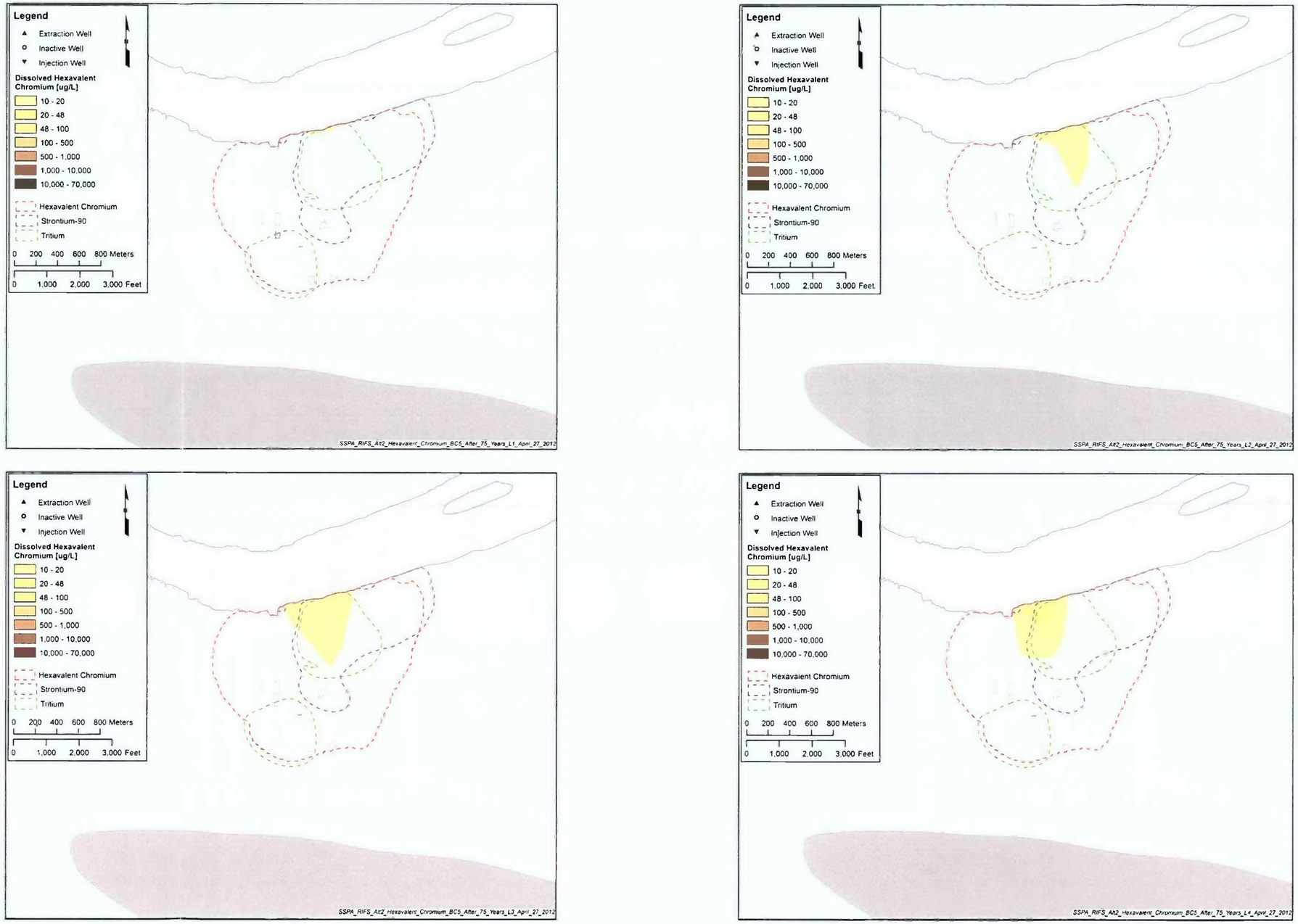

Figure 9-22. Alternative GW-2 – Modeled Cr(VI) Plume, Year 75

Table 9-9. Description of Alternative Components for Alternative GW-2—MNA and Institutional Controls

Media	Remedy Component	Description
Groundwater Components* (Additional information on common components provided in Section 9.1.3)	Institutional Controls	• Maintain existing sitewide institutional controls (including groundwater use restrictions) already in place under *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) with modifications to include area-specific supplemental institutional controls. • Institutional controls are maintained for the duration of the remedy.
	Natural Attenuation Monitoring Requirements	• Monitoring of Cr(VI), strontium-90, tritium to track the attenuation processes through periodic sampling of the monitor well network. • Monitoring network will include the 31 existing monitor wells and aquifer tubes, 11 new monitoring wells, and pore water sample locations below the river bottom. • Monitoring will be defined in the DQO and SAP developed as part of the RD. Monitoring will be performed quarterly for the first year to establish baseline conditions, with reduced frequency to annual monitoring over the next 10 years, and potentially further reduction in frequency thereafter to coincide with CERCLA 5-Year Reviews.

* Table 9-1 presents information on institutional controls.

Table 9-10 provides a summary of remedy components for Alternative GW-3. Figures 9-24 through 9-28 present the modeled Cr(VI) groundwater plume at years 5, 10, 25, 50, and 75 for Alternative GW-3. After the 75 year operational period, 100 percent of the remaining Cr(VI) mass is predicted to be below the 48 µg/L drinking water standard and 85 percent of the remaining mass is predicted to be below the 10 µg/L AWQC (Figure 9-7). The modeling predicts that the pump-and-treat system drastically reduces the Cr(VI) concentrations discharging into the river within 3 years (Figure 9-4) and prevents groundwater with Cr(VI) concentrations above 10 µg/L from entering the river within 17 to 23 years. A small area of the aquifer remains contaminated with Cr(VI) concentrations above the 10 µg/L AWQC at the end of 75 year remediation period. However, groundwater Cr(VI) concentrations are reduced below the 10 µg/L PRG after 64 to 90 years (Table 9-8).

Under Alternative GW-3, the groundwater model predict that strontium-90 and tritium groundwater concentrations decay below their PRGs after 49 to 71years and 3 to14 years, respectively (Table 9-8).

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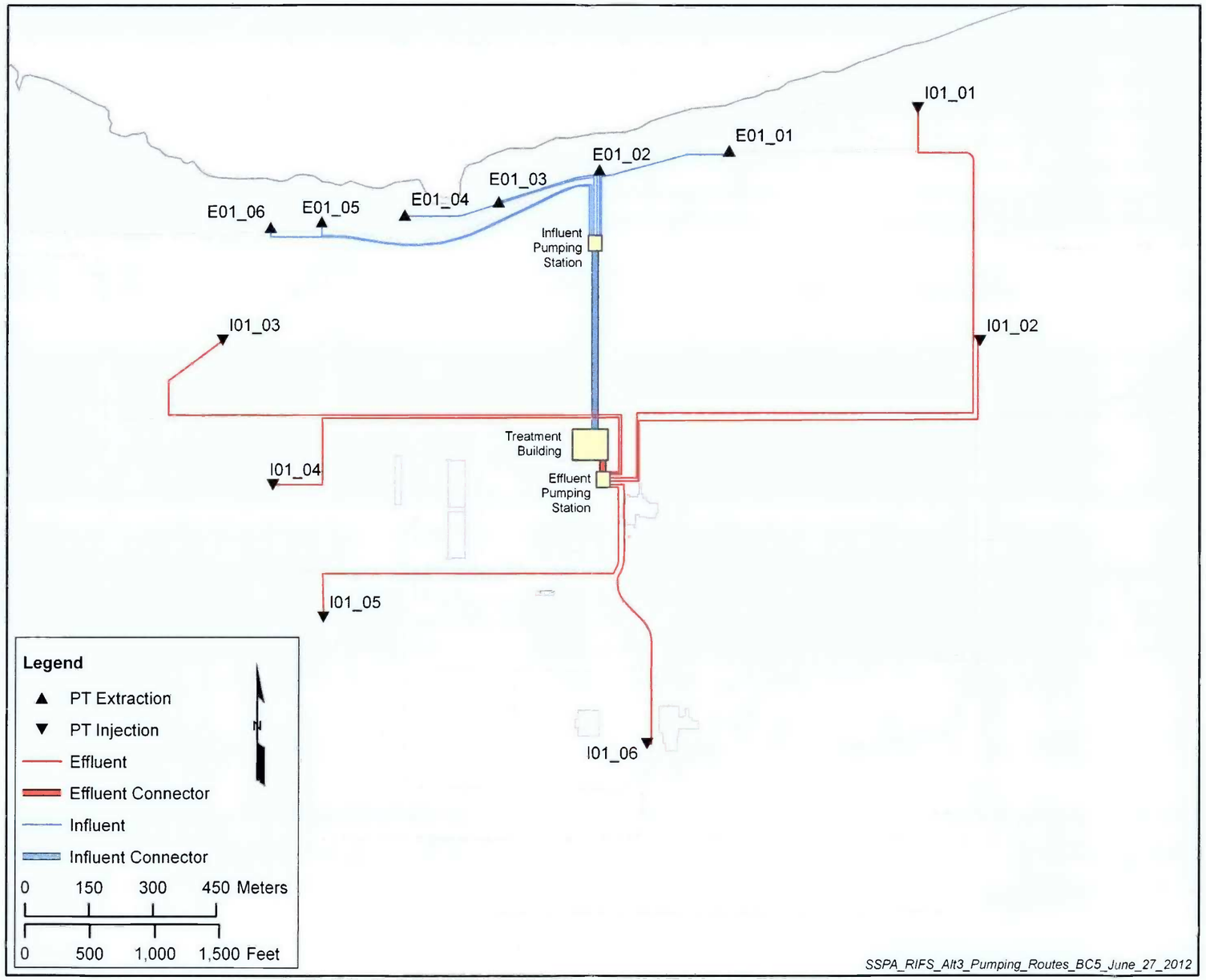

Figure 9-23. Preliminary Design of Groundwater Remediation Components for Alternative GW-3

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Table 9-10. Description of Alternative Components for Alternative GW-3 River Protection Pump-and –Treat

Groundwater Components	Pump-and-Treat System	• Operation of pump-and-treat system with ex situ treatment. • Installation of 6 extraction wells operating at 75 gpm each for a total extraction rate of 450 gpm. • Installation of 6 injection wells capable of injecting at a minimum of 75 gpm each for a total injection rate of 450 gpm • Designed with active remediation of the Cr(VI) plume out to 10 µg/L contour. • Treatment of extracted water through ion exchange for Cr(VI) and strontium-90 removal. Ion exchange treatment plant capacity of 450 gpm for Cr(VI) removal and 150 gpm well head treatment capacity for Strontium-90 removal. • Assumed run time of 85 percent capacity. • Operation of pump-and-treat system and ion exchange components for 65 years.
	MNA and Institutional Controls	• Manage the plumes until concentrations are below the action levels in the fringes of the plume as well as after the pump-and-treat system is shut off. • Monitoring of Cr(VI), strontium-90, and tritium to track the attenuation processes. • Institutional controls including groundwater use restrictions.
	Monitoring Requirements	• Remedy performance monitoring will be defined in the SAP developed as part of the remedial design. • Conducted to evaluate the effectiveness of the selected alternative to attain the cleanup levels. • For cost estimating purposes, it has been assumed that the 31 existing and 11 new monitoring wells will be used for the groundwater monitoring program. Tritium and Strontium-90 will be included in the groundwater monitoring program. • Tritium and Strontium-90 will not be considered in the compliance program. The CERCLA Five-Year Review process will evaluate the approach taken with tritium andStrontium-90. • Monitoring will be performed quarterly for the first year to establish baseline conditions, with reduced frequency to annual monitoring over the next 10 years, and potential further reductions in frequency thereafter will coincide with CERCLA 5-Year Reviews.

Notes:

a. Table 9-1 presents information on institutional controls.

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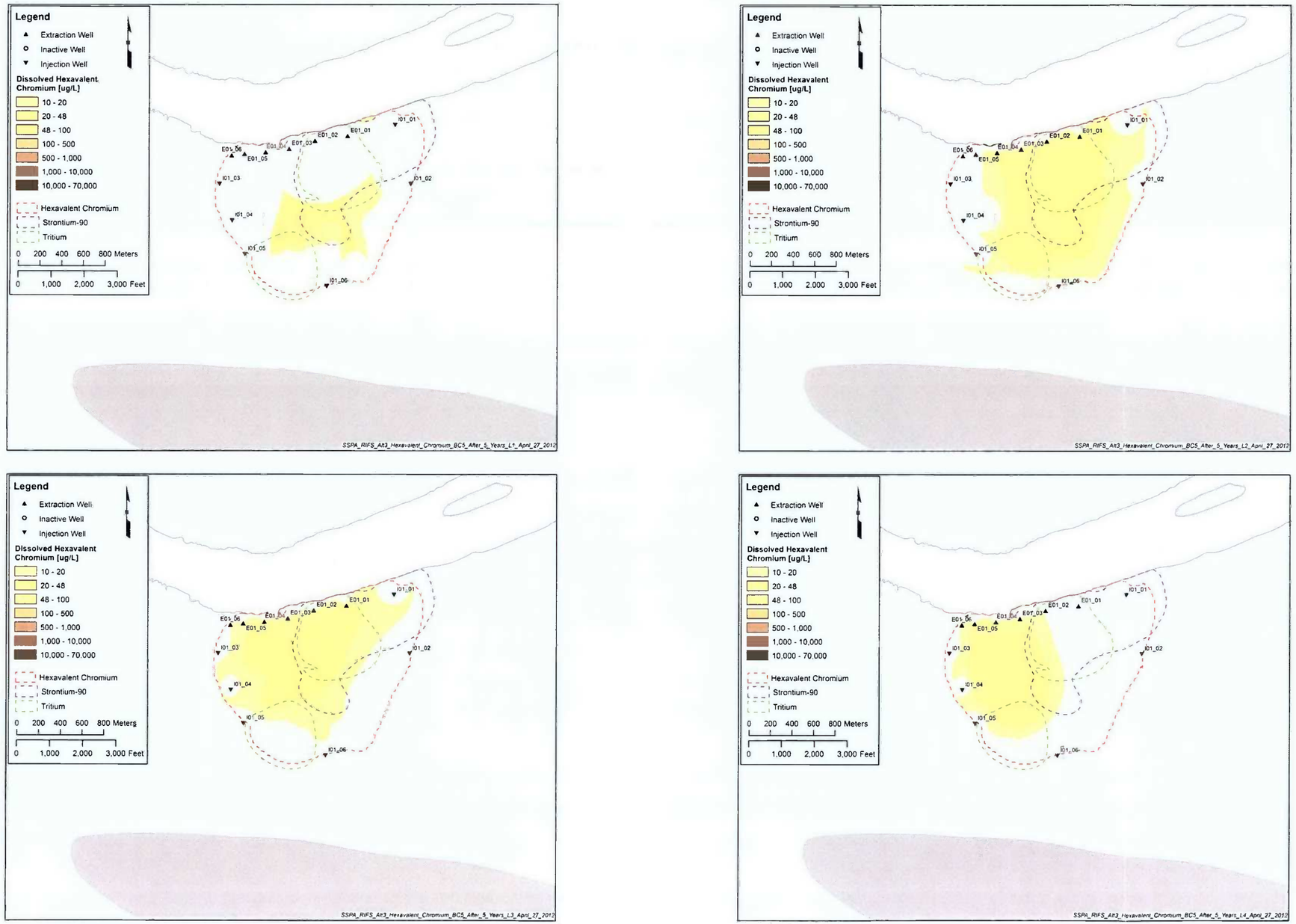

Figure 9-24. Alternative GW-3 - Modeled Cr(VI) Plume, Year 5

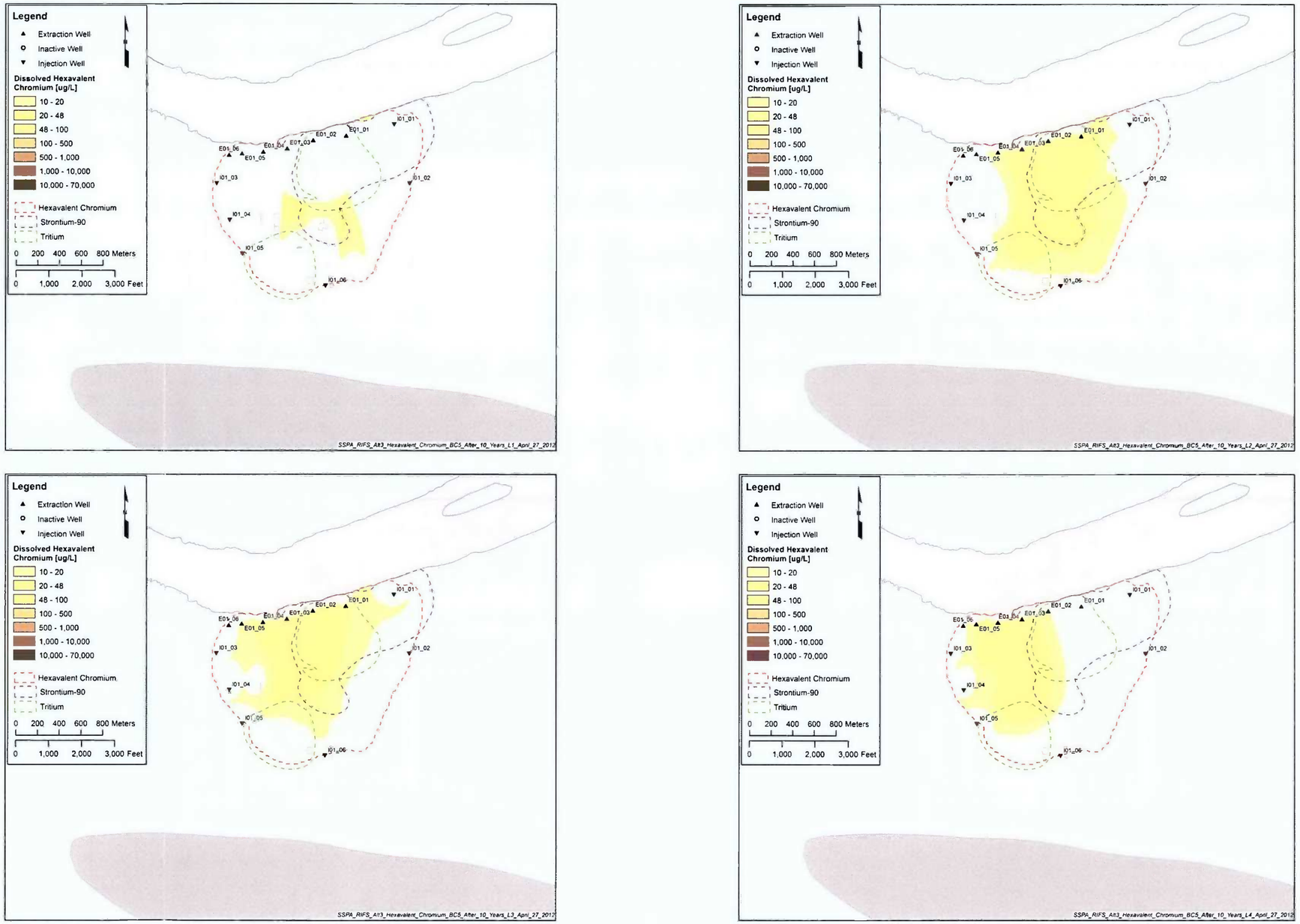

Figure 9-25. Alternative GW-3 - Modeled Cr(VI) Plume, Year 10

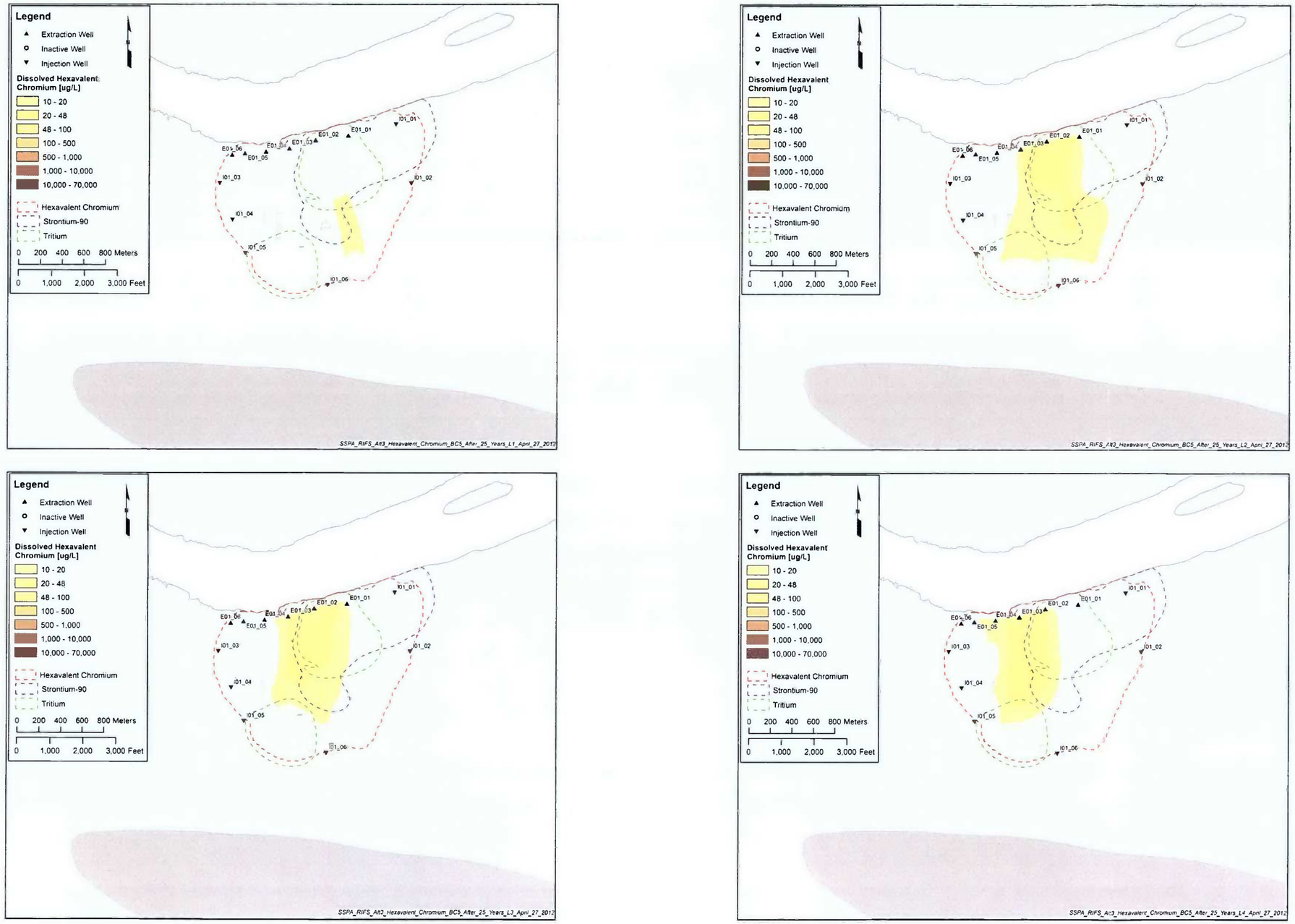

Figure 9-26. Alternative GW-3 - Modeled Cr(VI) Plume, Year 25

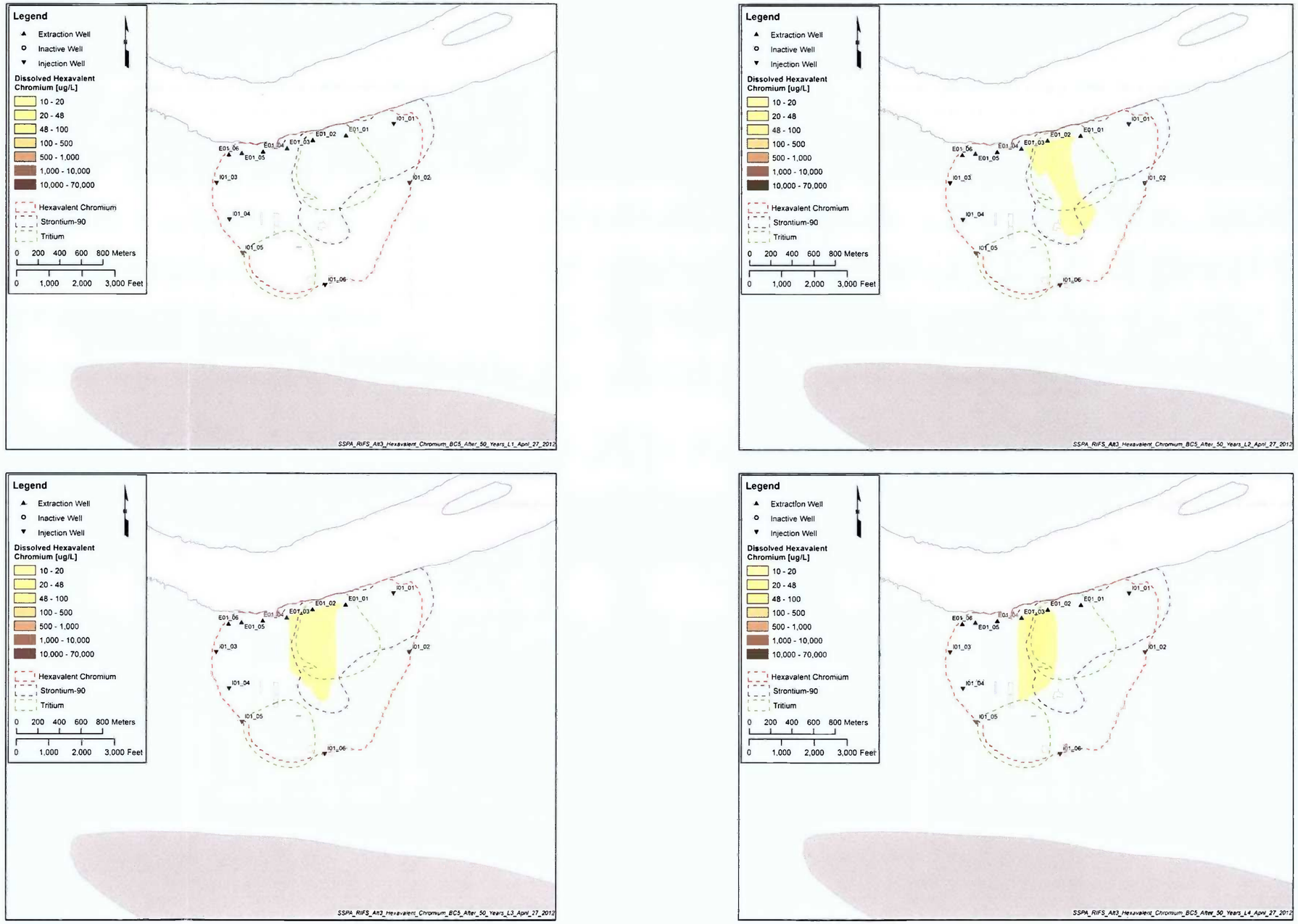

Figure 9-27. Alternative GW-3 – Modeled Cr(VI) Plume, Year 50

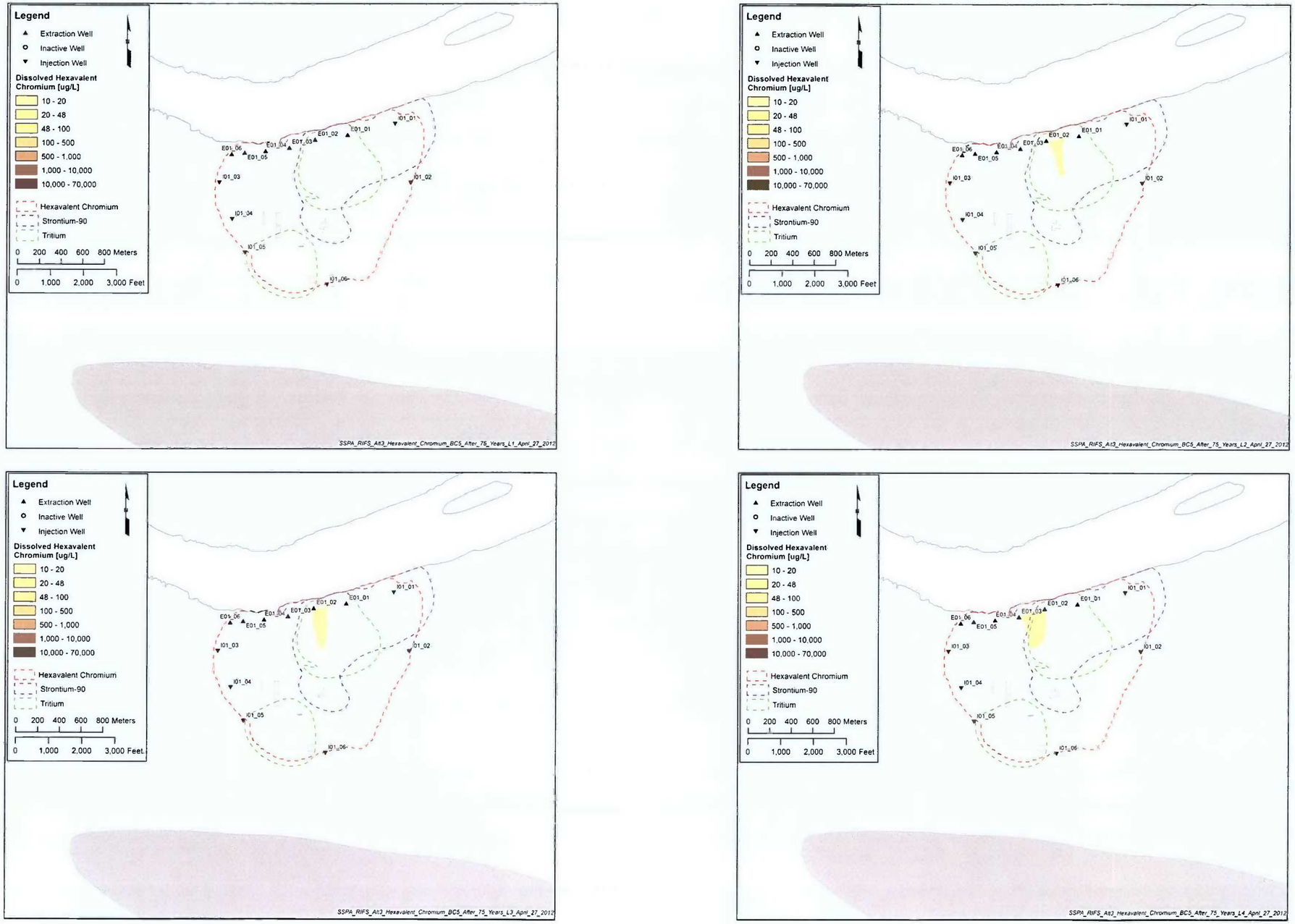

Figure 9-28. Alternative GW-3 – Modeled Cr(VI) Plume, Year 75

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9.3.4 Alternative GW-4 —Aggressive Pump-and-Treat

Alternative GW-4 reduces the groundwater concentrations of Cr(VI) and strontium-90 through pump-and-treat using ex-situ treatment technologies while strontium-90 and tritium concentrations are also reduced through natural attenuation processes. Groundwater pump-and-treat systems can be used to limit groundwater plume migration through hydraulic containment and to remediate the groundwater plume through extraction of contaminant mass. The pump-and-treat system concept developed for Alternative GW-4 consists of extraction and injection well networks, conveyance piping and infrastructure, and an ex-situ treatment system. The groundwater extraction and injection wells will be optimally located to extract contaminant mass, control the groundwater flow path, increase extraction well capture efficiency, and minimize Cr(VI) plume discharge to the Columbia River. The ex situ groundwater treatment system assumes ion exchange treatment for Cr(VI) and strontium-90. Figure 9-29 shows the preliminary layout of the pump-and-treat system for Alternative GW-4.

Under Alternative GW-4, the primary objective of the extraction well locations is to remove Cr(VI) mass from the aquifer. As shown on Figures 9-8 and 9-9, Alternative GW-4 does not have a significant effect in reducing strontium-90 and tritium concentrations in the aquifer. Since the strontium-90 and tritium plumes are remediated primarily through natural attenuation (radioactive decay), placement of extraction wells in the strontium-90 plume for active extraction and treatment is a secondary consideration. Extracted groundwater will be treated using ion exchange systems for removal of Cr(VI) and for strontium-90 if needed. The 12 excavation wells were placed in the high concentration area of the Cr(VI) plume. The discharge from all 12 wells is expected to require treatment to remove Cr (VI). Four of the 12 extraction wells shown in the preliminary design are located in the strontium-90 plume with discharge from these 4 wells potentially requiring treatment to remove strontium-90. Under Alternative GW-4, the pump-and-treat system is designed to operate for a period of 25 years and MNA is used to achieve PRGs following system shutdown.

Table 9-11 provides a summary of remedy components for Alternative GW-4. Figures 9-30 through 9-34 present the modeled Cr(VI) groundwater plume at years 5,10, 25, 50, and 75. After 75 years, 100 percent of the Cr(VI) mass remaining in the aquifer is below the 10 µg/L PRG (Figure 9-7). The groundwater model predicts that groundwater Cr(VI) concentrations are reduced below the 10 µg/L AWQC in the aquifer after 16 to 67 years (Table 9-8).

Under Alternative GW-4, the groundwater model predict that strontium-90 and tritium groundwater concentrations decay below their PRGs after years 49 to71 and years 2 to12, respectively (Table 9-8).

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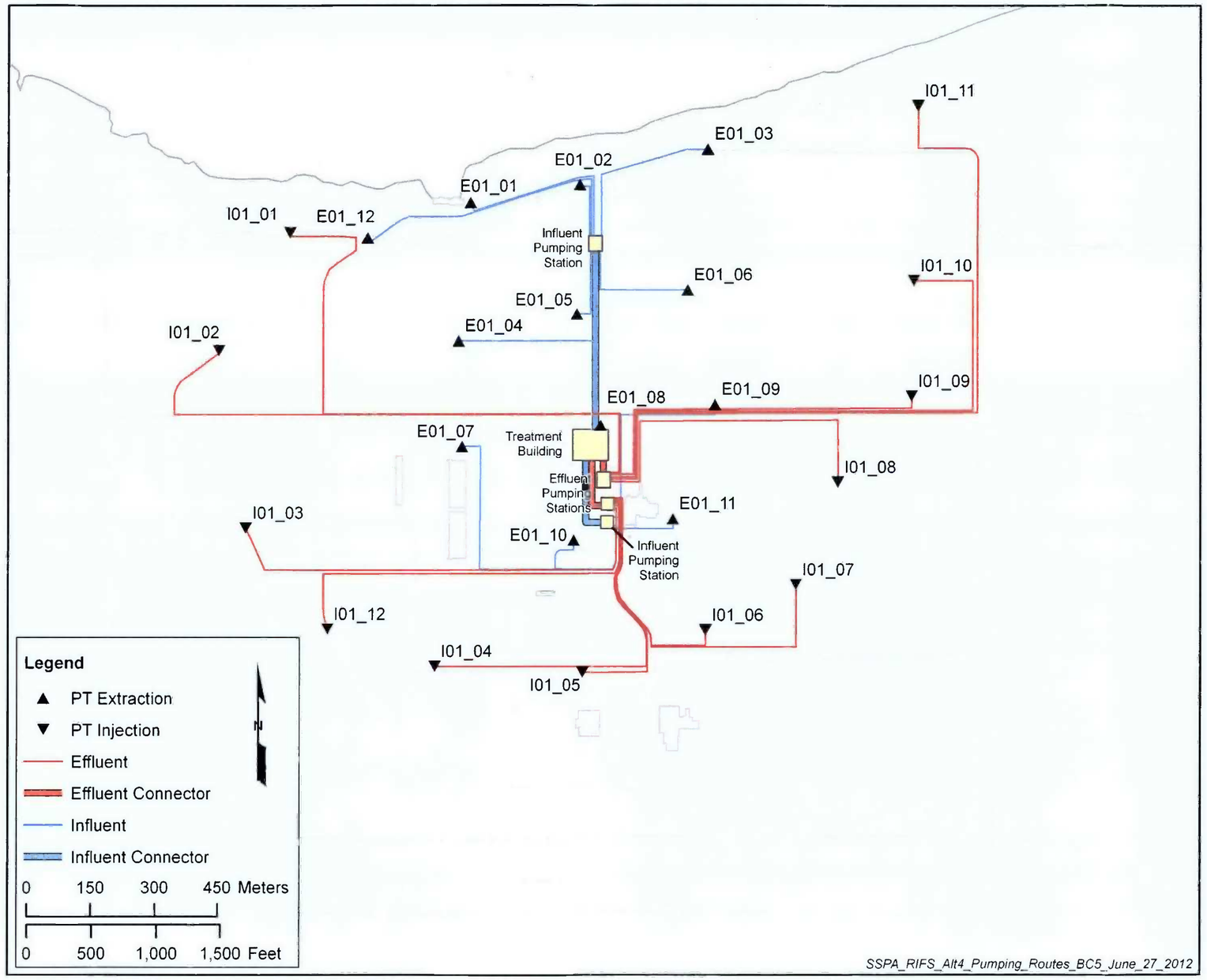

Figure 9-29. Preliminary Design of Groundwater Remediation Components for Alternative GW-4

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Table 9-11. Description of Alternative Components for Alternative GW-4 – Aggressive Pump-and-Treat

Media	Component	Description
Groundwater Components [a]	Pump-and-Treat	• Installation and operation of a pump-and-treat system. • Installation of 12 extraction wells. • Installation of 12 injection wells. • Designed with active remediation out to the 10 ppb Cr(VI) contour. • Treatment of extracted water through ion exchange to remove Cr(VI) and Strontium-90. • Includes installation of approximately 900 gpm ion exchange system for Cr(VI) removal and 300 gpm ion exchange treatment capacity. • Assumed run time of 85 percent capacity. • Operation of pump-and-treat system for 25 years and MNA for up to an additional 25 years until PRGs are achieved for all COCs.
	Institutional Controls	• Institutional controls including groundwater use restrictions until the plumes are completely remediated.
	Monitoring Requirements	• Performance monitoring for Cr(VI), Strontium-90, and Tritium for up to 50 years to evaluate the effectiveness of the selected alternative to attain the cleanup levels. • Remedy performance monitoring will be defined in the DQO and SAP developed as part of the remedial design • For cost-estimating purposes, it has been assumed that the 31 existing and 11 new monitoring wells will be used for the performance monitoring program. Tritium and strontium-90 will be included in the groundwater monitoring program. • Performance monitoring of monitoring wells will be performed quarterly for the first year to establish baseline conditions, with reduced frequency to annual monitoring over the next 10 years, and potential further reductions in frequency thereafter to coincide with CERCLA 5-Year Reviews. • Performance monitoring of the extraction and injection wells will be performed quarterly for the duration of pump-and-treat operations, approximately 25 years. • Tritium and strontium-90 will not be considered in the compliance program. The CERCLA Five-Year Review process will evaluate the approach taken with strontium-90.

Notes:

a. Table 9-1 presents information on institutional controls.

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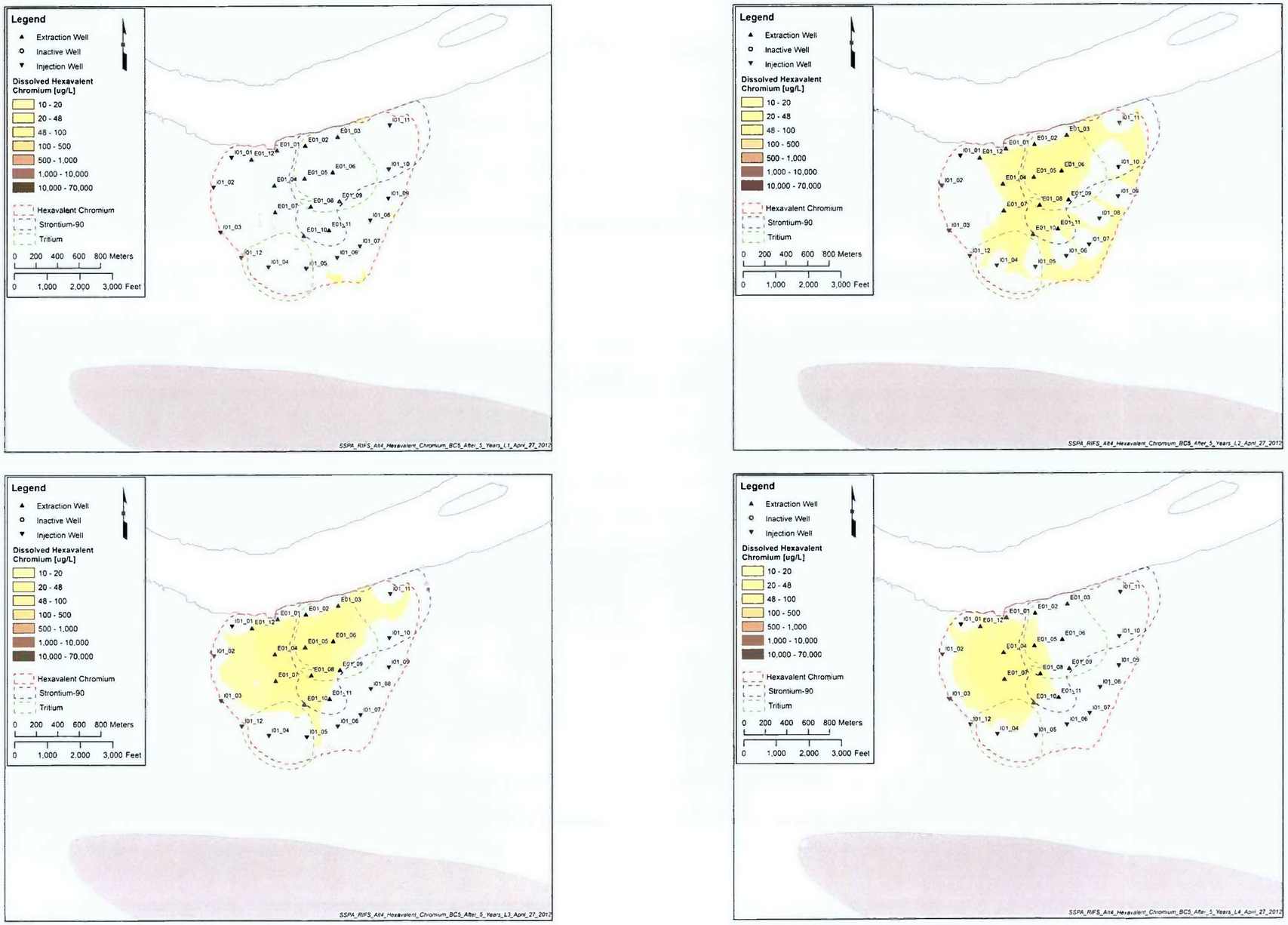

Figure 9-30. Alternative GW-4 – Modeled Cr(VI) Plume, Year 5

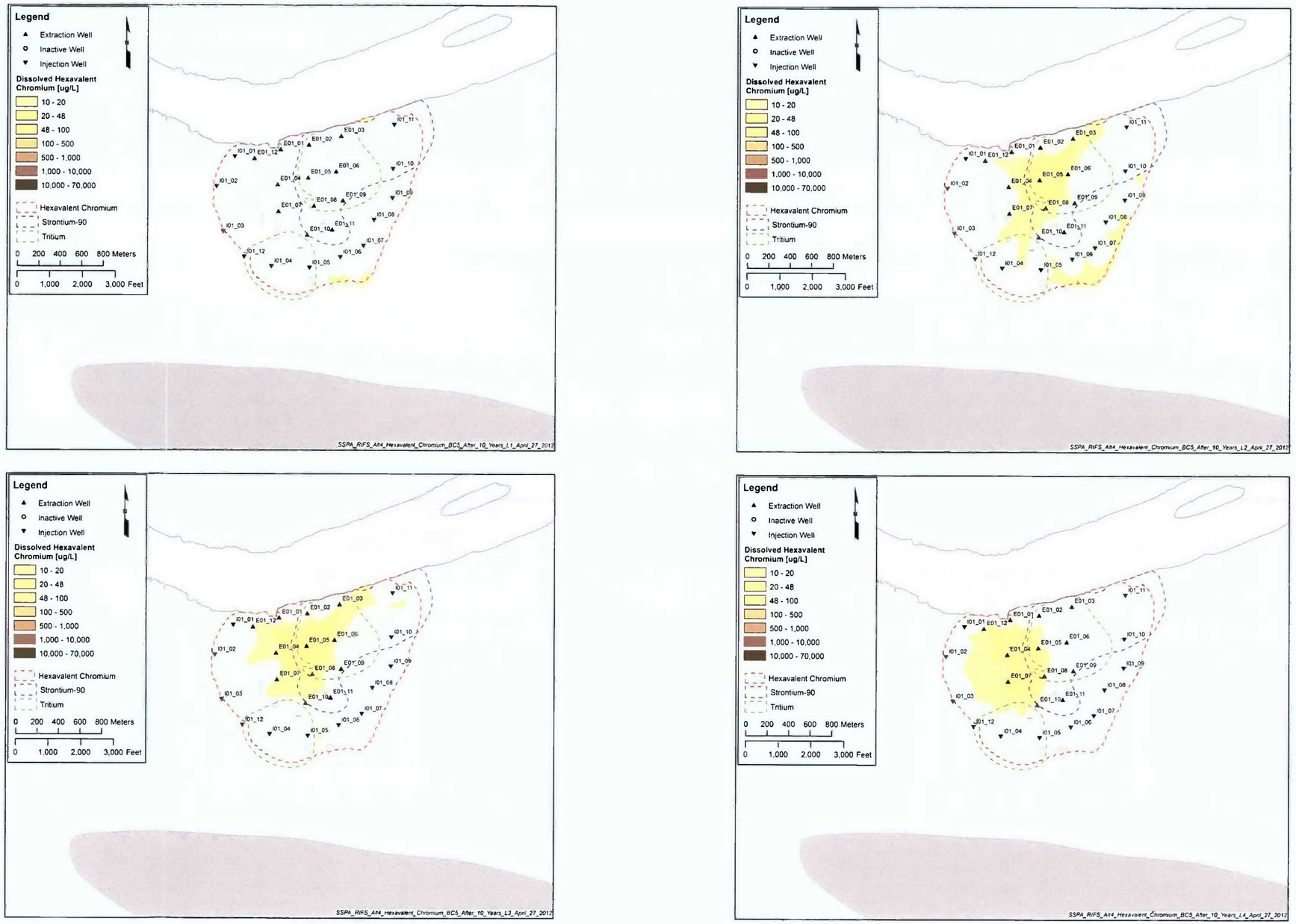

Figure 9-31. Alternative GW-4 – Modeled Cr(VI) Plume, Year 10

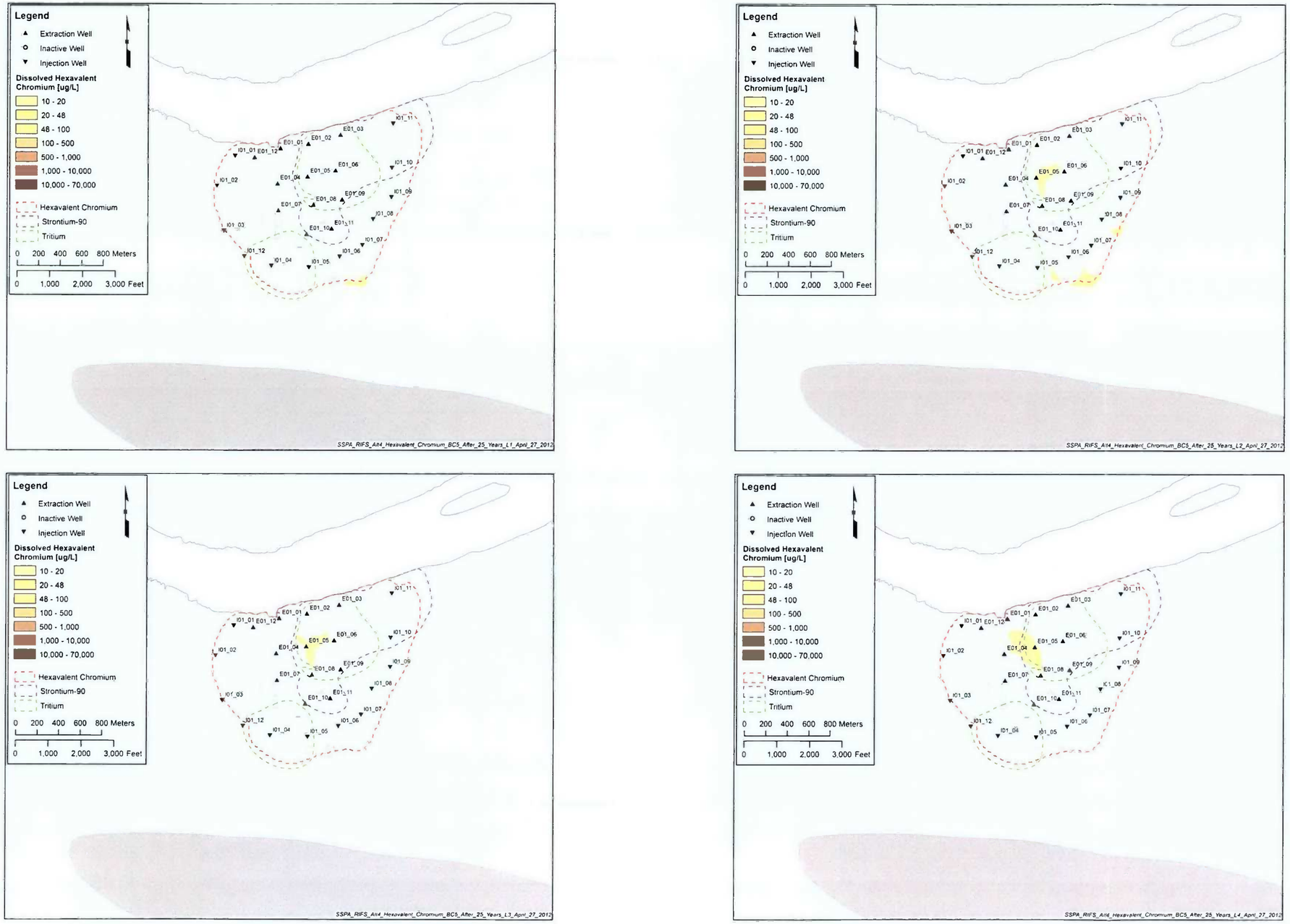

Figure 9-32. Alternative GW-4 – Modeled Cr(VI) Plume, Year 25

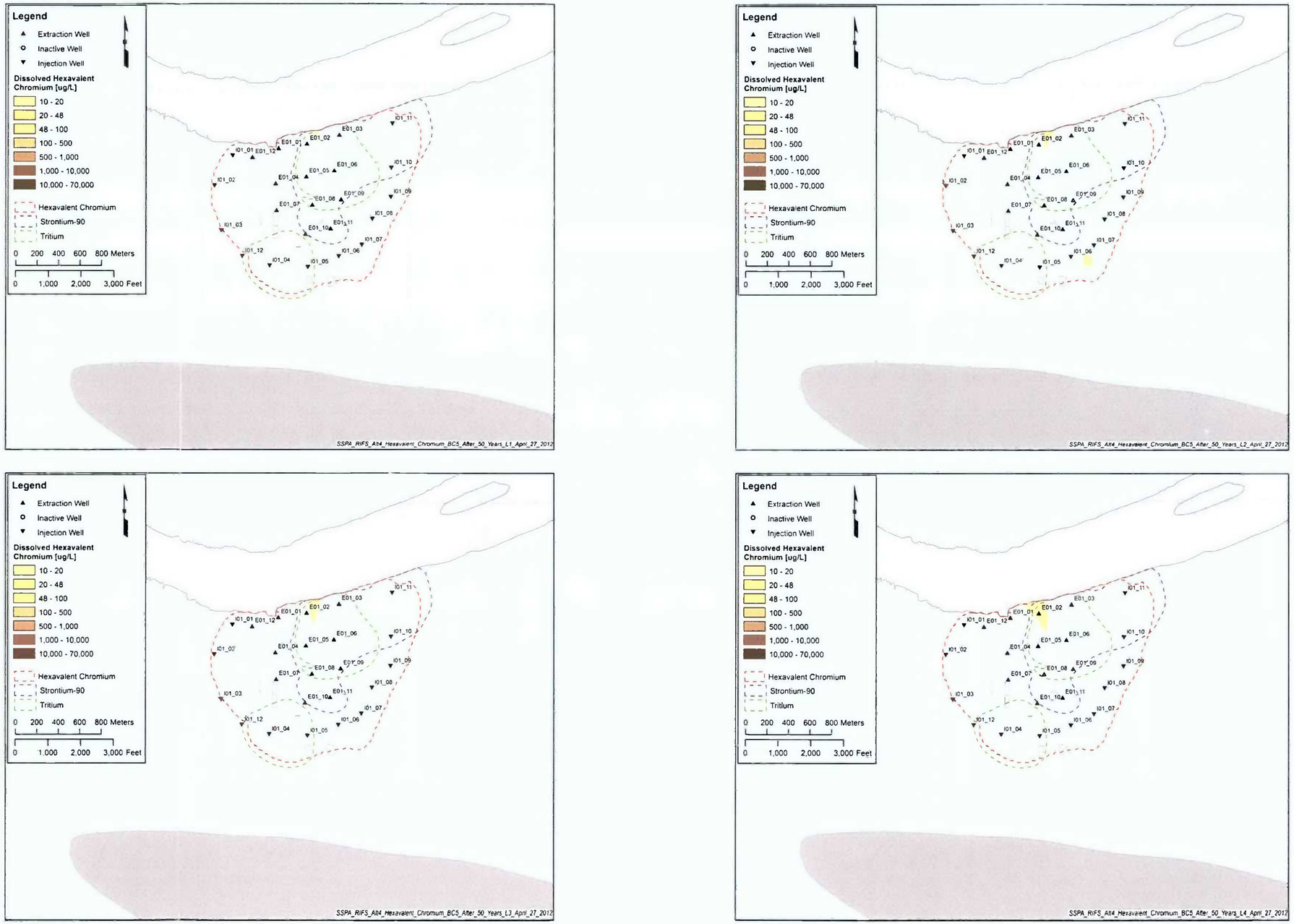

Figure 9-33. Alternative GW-4 – Modeled Cr(VI) Plume, Year 50

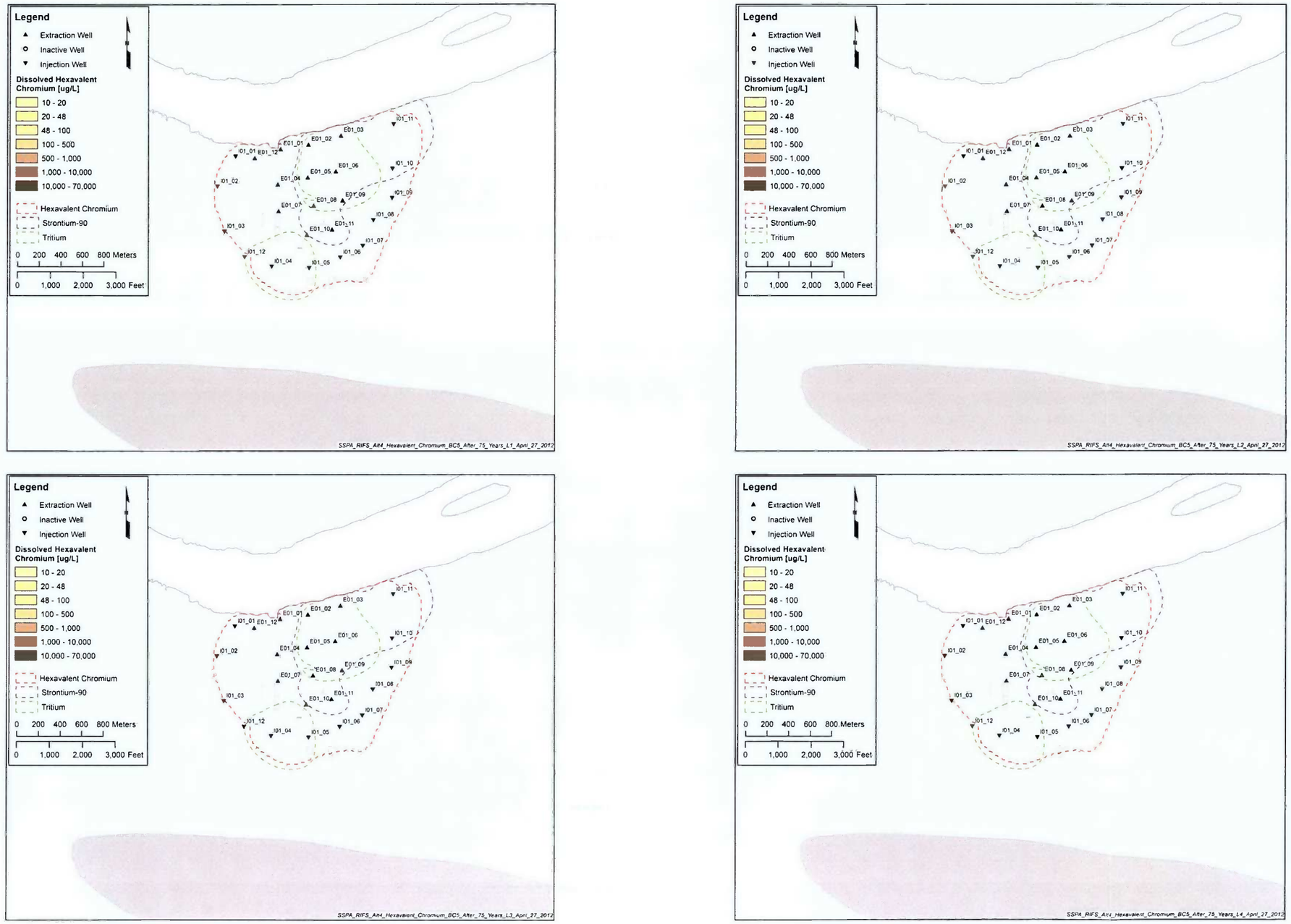

Figure 9-34. Alternative GW-4 – Modeled Cr(VI) Plume, Year 75

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9.4 Remedial Alternative Screening Evaluation

As discussed in *The Feasibility Study: Development and Screening of Remedial Action Alternatives*, Fact Sheet, (OSWER Directive 9355.3-01FS3), screening of alternatives can be used to provide a preliminary evaluation of alternatives based on effectiveness, implementability, and cost before being carried into the detailed evaluation in Chapter 10. The purpose of this screening step is to eliminate those alternatives that are not effective, implementable, or cost effective.

9.4.1 Waste Site Alternative Screening

The following alternatives have been developed for waste sites with PRG exceedances:

- Alternative S-1: No Action[1]
- Alternative S-2: MESC, MNA, and institutional controls.
- Alternative S-3: RTD Optimized with Other Technologies
- Alternative S-4: Aggressive RTD

9.4.1.1 Effectiveness

Alternative S-2 effectively addresses the exposure pathway by maintaining existing soil cover and institutional controls that minimize the likelihood of human receptors coming into contact with COCs at the 132-B-5, 118-B-1, 118-B-6, 118-B-8:1 sites while COC concentrations are reduced below PRGs through radioactive decay. Alternative S-3 effectively eliminates the exposure pathway at each waste site by removal of soil, structures, and debris containing COCs in excess of PRGs and surface capping to prevent infiltration of recharge and maintain physical separation between contaminated materials and potential receptors. Alternative S-4 more effectively eliminates the exposure pathway at each waste site by removal of soil, structures, and debris containing COCs in excess of PRGs to the total depth of contamination.

No waste site alternatives were screened out on the basis of effectiveness.

9.4.1.2 Implementability

The MNA and institutional controls components of Alternative S-2 can be easily implemented and have precedent at the Hanford Site through use of sitewide institutional controls.

The RTD remedy proposed in Alternative S-3 and S-4 is highly implementable using proven construction practices and techniques for removal of vadose zone soil. Disposal of excavated soil at the ERDF is commonly used at the Hanford Site. The surface capping remedies proposed in Alternative S-3 are also highly implementable using proven construction practices. Implementation of RTD under Alternative S-4 at the B Reactor Museum sites, 118-B-8:3 and 132-B-2, is unlikely because of the National Historic Landmark Status of the reactor building.

No waste site alternatives are screened out on the basis of implementability.

9.4.1.3 Cost

Alternative S-2 represents a low cost approach for managing risk through exposure pathway controls while Alternatives S-3 and S-4 provide a more aggressive approach. Alternative S-2 has lower capital

[1] The No Action Alternative is included per NCP requirements, but fails the screening for effectiveness that would generally warrant elimination.

costs for implementation than Alternatives S-3 and S-4, but has higher long-term O&M costs to maintain erosion controls and perform site monitoring.

No waste site alternatives were screened out based on cost.

9.4.2 Groundwater Alternatives Screening

The following alternatives have been developed for groundwater:

- Alternative GW-1: No Action[2]
- Alternative GW-2: MNA and Institutional Controls with Contingency
- Alternative GW-3: River Protection Pump-and-Treat
- Alternative GW-4: Aggressive Pump-and-Treat

9.4.2.1 Effectiveness

The groundwater alternatives have been developed to provide an increasing level of effectiveness through more aggressive and comprehensive remedy components. The groundwater modeling predicts that all the groundwater alternatives eventually achieve PRGs in the aquifer, but not within the 75 year period considered reasonable for groundwater remediation. Groundwater concentrations fall below the Cr(VI) AWQC PRG after 104 to108 years, 64 to 90 years, and 16 to 67 years for Alternatives GW-2, GW-3, and GW-4, respectively. Each alternative is retained to provide the widest possible range of alternatives for evaluation.

No groundwater alternatives were screened out on the basis of effectiveness.

9.4.2.2 Implementability

Each of the groundwater alternatives have been designed using commonly available and proven remedial technologies and process options. No groundwater alternatives were screened out on the basis of implementability.

9.4.2.3 Cost

The MNA proposed in Alternative GW-2 is anticipated to have the lowest capital and overall cost. Alternative GW-3 is expected to have lower capital costs and but higher O&M costs than Alternative GW-4. Alternative GW-4 is the most costly of all the alternatives, but is also the fastest at achieving groundwater PRGs. All four groundwater alternatives were retained to provide the widest possible range of alternatives for evaluation.

[2] The No Action Alternative is included per NCP requirements, but fails the screening for effectiveness that would generally warrant elimination.

10 Detailed and Comparative Analysis of Alternatives

This chapter provides a detailed analysis of the remedial alternatives developed for waste sites and groundwater at 100-BC. This analysis follows the development of alternatives presented in Chapter 9 and precedes the Proposed Plan, which includes the selection of a preferred alternative.

This chapter evaluates the remedial alternatives defined in Chapter 9, using seven of the nine CERCLA criteria described in the NCP ("Remedial Investigation/ Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(9)]).

The CERCLA evaluation criteria are presented in Section 10.1, and each of the remedial alternatives is evaluated individually and comparatively against the CERCLA criteria in Sections 10.2 and 10.3, respectively. The remaining two modifying criteria are formally assessed during preparation of the Proposed Plan (state acceptance) and following review of public and stakeholder comments (community acceptance) on the Proposed Plan. The purpose of the detailed and comparative analysis is to develop the information necessary to recommend a preferred alternative in a Proposed Plan. Following public and stakeholder review of the Proposed Plan, the Tri-Parties will select a final remedial action alternative for 100-BC that will lead to a ROD.

Key concepts of this chapter include the following:

- The alternatives developed and initially screened in Chapter 9 are evaluated in this chapter against the CERCLA threshold and balancing criteria. Evaluation against the CERCLA modifying criteria will be performed in the Proposed Plan and ROD Responsiveness Summary following public review of the Proposed Plan.

Highlights

Remedial alternatives were developed and evaluated separately for waste sites and groundwater. The following summarizes the waste site remedial alternatives:

- Alternative S-1: (No Action) does not meet threshold criteria.
- Alternative S-2: (MESC, MNA, and Institutional Controls) meets threshold criteria, and is considered to have moderate short-term effectiveness, moderate long-term effectiveness, and moderate reduction of TMV. This alternative is considered to be readily implementable.
- Alternative S-3: (RTD Optimized with Other Technologies) meets threshold criteria and is considered to have moderate short-term effectiveness, good reduction of TMV, and high long-term effectiveness. This alternative is considered to be readily implementable.
- Alternative S-4: (Aggressive RTD) meets the threshold criteria and is considered to moderate short-term effectiveness, high reduction of TMV, and high long-term effectiveness. This alternative is considered to be moderately implementable.
- Alternatives S-3 and S-4 perform better than Alternative S-2 for long-term effectiveness and reduction of TMV. Alternative S-2 is the lowest cost alternative and Alternative S-4 is the highest cost alternative.

The following summarizes the groundwater remedial alternatives:

- Alternative GW-1: (No Action) does not meet threshold criteria.
- Alternative GW-2: (MNA and Institutional Controls) meets threshold criteria, and is considered to have moderate short-term effectiveness, moderate long-term effectiveness, and low to moderate reduction of TMV. This alternative is considered to be readily implementable.
- Alternative GW-3: (River Protection Pump-and-Treat) meets threshold criteria and is considered to have moderate short-term effectiveness, high reduction of TMV, and moderate to high long-term effectiveness. This alternative is considered to be implementable.
- Alternative GW-4: (Aggressive Pump-and-Treat) meets threshold criteria and is considered to have moderate to high short-term effectiveness, high reduction of TMV, and high long-term effectiveness. This alternative is considered to be implementable.
- Alternative GW-4 performs better than Alternative GW-2 and GW-3 for long-term effectiveness and reduction of TMV. Alternative GW-2 is the most readily implemented of the three alternatives that meet the threshold criteria. Alternative GW-2 is the lowest cost alternative.

The analysis provides enough information to be able to recommend preferred alternatives for waste sites and groundwater in the Proposed Plan.

- Alternatives for waste sites and groundwater were developed separately to facilitate evaluation and provide greater flexibility for final remedy selection.
- Waste site soil alternatives retained for evaluation include:
  - Alternative S-1: No Action
  - Alternative S-2: MESC, Institutional Controls, and MNA
  - Alternative S-3: RTD Optimized with other Technologies
  - Alternative S-4: Aggressive RTD
- Groundwater alternatives retained for evaluation include:
  - Alternative GW-1: No Action
  - Alternative GW-2: Institutional Controls and MNA
  - Alternative GW-3: River Protection Pump-and-Treat
  - Alternative GW-4: Aggressive Pump-and-Treat
- Waste site remediation alternatives will be implemented at 10 sites.
- Groundwater alternatives will be implemented to address three contaminant plumes.

10.1 Description of CERCLA Evaluation Criteria

The nine CERCLA evaluation criteria upon which the detailed and comparative evaluations are based are designed to enable the analysis of each alternative to address the statutory, technical, and policy considerations necessary for selecting a final remedial alternative. These evaluation criteria (Table 10-1) provide the framework for conducting the detailed analysis of alternatives and selecting an appropriate remedial action. Table 10-1 describes each of the criteria and the associated analysis factors.

The evaluation criteria are divided into three categories (threshold, balancing, and modifying) based on the function of each category in the remedy selection process. The NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" (40 CFR 300.430(f)) states that the first two criteria, protection of human health and the environment, and compliance with ARARs are "threshold criteria" that must be met by the selected remedial action unless a waiver can be granted under Section 121(d)(4) of CERCLA.

The five "balancing criteria" represent technical conditions upon which the detailed analysis is primarily based, and include long-term effectiveness and permanence; reduction of toxicity, mobility, and volume (TMV) through treatment; short-term effectiveness; implementability; and cost. The preferred alternative will be the alternative that is protective of human health and the environment, is ARAR compliant, and ranks highest relative to the balancing criteria.

The final two criteria, state and community acceptance, are "modifying criteria," which are formally assessed during preparation of the Proposed Plan (state acceptance) and following review of public and stakeholder comments (community acceptance) on the Proposed Plan. Community and state acceptance are not addressed in the FS. Based on information from public participation, the Tri-Parties may modify some aspects of the preferred alternative or decide that another alternative is more appropriate.

Table 10-1. Summary of CERCLA Criteria

Threshold Criteria	
Overall Protection of Human Health and the Environment	Human health groundwater risk management Ecological surface water risk management Human health direct exposure risk management Ecological risk management from exposure to soil Soil to groundwater/surface water pathway risk management Draws on assessments conducted under other criteria, especially long-term effectiveness, short-term effectiveness, and ARARs
Compliance with ARARs	Chemical-specific ARARs Action-specific ARARs Location-specific ARARs Compliance with Other Criteria, Advisories, and Guidance
Balancing Criteria	
Long-Term Effectiveness and Permanence	Magnitude of residual risk Adequacy and reliability of controls
Reduction of Toxicity, Mobility, and Volume Through Treatment	Amount of hazardous materials destroyed or treated Degree of expected reduction in TMV Degree to which treatment is irreversible Type and quantity of residuals remaining after treatment
Short-Term Effectiveness	Protection of community during remedial actions Protection of workers during remedial actions Environmental impacts Time until RAOs are achieved
Implementability	Ability to construct, operate, and monitor the technology Reliability of the technology Ease of undertaking additional remedial action, if necessary Ability to monitor the remedy's effectiveness Ability to coordinate and obtain approvals from other agencies Availability of equipment, specialists, prospective technologies, offsite treatment, storage or disposal services, and capacity
Cost	Capital costs Annual O&M costs Total present worth cost of all capital, annual O&M, and periodic costs (net present value) Total nondiscounted cost all capital, annual O&M, and periodic costs

Table 10-1. Summary of CERCLA Criteria

Modifying Criteria	
State Acceptance*	Indicates whether the state concurs with, opposes, or has no comment on the preferred alternative.
Community Acceptance*	Assesses the public response to the preferred alternative. Although public comment is an important part of the decision-making process, EPA is required by law to balance community concerns with the above criteria.

* These criteria are not assessed in this report.

10.1.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment is the primary requirement that remedial actions must meet under CERCLA. This evaluation criterion is an assessment of whether each alternative achieves and maintains adequate protection of human health and the environment, in both the short and long term, from unacceptable risks posed by contaminants. Alternatives are protective by eliminating, reducing, or controlling exposure through applicable exposure pathways (NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(2)(i)]). Overall protection of human health and the environment draws on the assessments of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

10.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Compliance with ARARs is the second threshold criterion of remedy selection. This evaluation criterion is used to determine whether an alternative meets the federal, state, and local ARARs identified for the site, as listed in Table 8-3. Alternatives are assessed to determine whether they meet ARARs and other requirements, or if a basis exists for invoking one of the waivers cited in NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" (40 CFR 300.430(f)(l)(ii)(c)).

10.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence are criteria that evaluate the anticipated ability of an alternative to maintain reliable protection of human health and the environment for the duration of time the risk is above allowable levels. Alternatives are assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful in achieving the RAOs. The following factors are considered in this assessment:

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial action, including the TMV (final risk assessment). Magnitude of residual risk is defined as the risk remaining from untreated waste or treatment residuals after remediation.

- The adequacy and reliability of controls that can be used to manage treatment residuals or residual contamination that remains at the site, such as containment systems or institutional controls. For example, this factor addresses uncertainties associated with land disposal for providing long-term protection from treatment residuals, the assessment of the potential need to replace technical components of the alternative such as a treatment system, and the potential exposure pathways and risks posed if the remedial action needs to be replaced.

10.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This evaluation criterion concerns the statutory preference for remedies that employ treatment to reduce the TMV of the hazardous substances. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction in contaminant mobility, or reduction of the total mass or total volume of contaminated media. This criterion is specific to evaluating how the treatment reduces toxicity, mobility, or volume.

The degree to which the alternative employs treatment that reduces TMV will be assessed. The following factors are considered for the evaluation:

- Treatment process and the materials treated
- Amount of hazardous substances, pollutants, or contaminants that will be destroyed or treated
- Degree of expected reduction in TMV
- Degree to which the treatment is irreversible
- Type and quantity of residuals that will remain following treatment, taking into consideration the persistence, toxicity, mobility, and propensity of hazardous substances and their constituents to bioaccumulate
- Degree to which treatment reduces the inherent hazards posed by the principal threats

10.1.5 Short-Term Effectiveness

This criterion focuses on short-term impacts of the remedial alternatives by examining the effectiveness of alternatives in protecting human health and the environment during the construction and implementation phase until RAOs are achieved. As outlined by the CERCLA guidance, this criterion includes four analysis factors:

- Protection of the community during remedial actions (for example, dust from excavations, transportation of hazardous materials)
- Protection of workers during remedial actions
- Potential adverse environmental impacts (for example, waste and generation of green house gas emissions) and the effectiveness and reliability of mitigating measures
- Time until RAOs are achieved

10.1.6 Implementability

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

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

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

10.1.7 Cost

Cost plays an important role in the detailed evaluation of RAAs because there is a CERCLA statutory requirement that the remedial alternative selected in a ROD must be cost-effective. A RAA is cost-effective if its "costs are proportional to its overall effectiveness" (NCP "Remedial Investigation/ Feasibility Study and Selection of Remedy" [40 CFR 300.430(f)(1)(ii)(D)). The overall effectiveness of a RAA is determined by evaluating the following three of the five balancing criteria: long-term effectiveness and permanence; reduction in TMV through treatment; and short-term effectiveness. The Proposed Plan presents the overall effectiveness evaluation.

The cost estimates for each alternative presented in this FS include allowances for capital costs, O&M costs, and periodic costs. Capital costs consist primarily of expenditures incurred to construct the remedial action (for example, construction of a groundwater treatment system and related site work). Capital costs also include all labor, equipment, and material costs, including contractor markups such as overhead and profit, associated with mobilization/demobilization; site work; installation of extraction, containment, or treatment systems; and disposal. Capital costs also include expenditures for professional/technical services that are necessary to support the alternative's design and construction.

O&M costs are the post-construction costs necessary to support the remedial action until RAOs are achieved. These costs are estimated on an annual basis. Annual O&M costs include labor, equipment, and materials, including contractor markups such as overhead and profit, associated with activities such as monitoring; operating and maintaining extraction, injection, and treatment systems; and waste disposal. Annual O&M costs also include expenditures for professional/technical services necessary to support O&M activities.

Periodic costs are those costs that occur only once every few years (for example, 5-year reviews, equipment replacement, and well rehabilitation and replacement) or expenditures that occur only once during the entire remedial timeframe (decommissioning costs).

The cost estimate for the 100-BC Operable Units was developed in accordance with *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA-540/R-00-002) and *Cost Estimating Procedure for Response Action Decision-Making* (PRC-PRO-EP-40282).The TRACE V3 cost estimating workbook in conjunction with the Remedial Action Cost Engineering and Requirements (RACER™) Cost Estimator software were used to develop the cost estimate for each of the removal action alternatives. This cost estimate has been prepared for guidance in project evaluation from the information available at the time of the estimate. The final cost of the project will depend on final design, selected scope of work, actual labor and material costs, competitive market conditions, implementation schedule and other variable factors. As a result, the final project costs will vary from the estimate presented here. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

The cost estimates contain a breakdown of capital, O&M, and periodic costs, while also providing a total net present value (NPV) and total nondiscounted cost. These latter two cost categories facilitate comparisons between alternatives with different remedial action timeframes. The NPV cost represents the dollars that would need to be set aside today, at the defined interest rate, to ensure that funds would be available in the future as they are needed to perform the remedial alternative.

Present worth costs were estimated using the real discount rate published in Appendix C, "Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses," of "Guidelines and Discount Rates for

Benefit-Cost Analysis of Federal Programs (OMB Circular No. A-94). Programs with durations longer than 30 years use the 30-year interest rate of 2.7 percent. Those with a timeframe of 15 years or less employ a discount rate of 1.7 percent. The NPV for all future O&M costs, and periodic costs, is based on the overall RA timeframe and the timeframe when the cost is incurred. NPV costs were calculated by RACER™ 2010, version 10.3 and manually entered into the Microsoft Excel NPV workbook template described further in *Environmental Cost Estimate for 100 BC Vadose Zone and Groundwater RI/FS* (ECE-100BC111-00007).

The cost estimates are for comparison purposes and were prepared to meet the -30 to +50 percent range of accuracy recommended in CERCLA RI/FS Guidance (EPA/540/G-89/004). The cost estimate details, uncertainties, and supporting information are included in Appendix K - *Environmental Cost Estimate for 100 BC Vadose Zone and Groundwater RI/FS* (ECE-100BC111-00007).

10.2 Individual Analysis of Alternatives

This section evaluates each of the RAAs defined in Chapter 9 against the CERCLA threshold and balancing criteria described in Section 10.1. The modifying criteria of state acceptance will be addressed during preparation of the Proposed Plan. Community acceptance will be addressed following receipt of public comments on the Proposed Plan.

10.2.1 Waste Site Alternatives

This section presents the evaluation of alternatives for the 10 waste sites where residual COCs may pose a threat to human health and/or the environment. The alternatives retained from the preliminary screening conducted in Chapter 9 included:

- S-1: No Action
- S-2: MESC, Institutional Controls, and MNA
- S-3: RTD Optimized with Other Technologies
- S-4: Aggressive RTD

10.2.1.1 Alternative S-1: No Action

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires that a No Action Alternative be included in the FS to serve as a baseline for comparison to other RAAs. As described in Chapter 9, this alternative presumes all ongoing site- related activities including existing institutional controls and planned interim actions (with the possible exception of backfilling any open excavations) would cease by December 2012. Because all future site-related activities would be discontinued, no costs are associated with implementation of this alternative.

Evaluation of the No Action Alternative against the CERCLA threshold criteria (Table 10-2) for the 10 waste sites indicates that that this alternative does not protect human health nor does it comply with ARARs under unrestricted use/unrestricted exposure assumptions. Although the potential for inadvertent human exposure to residual COCs is low at all 10 waste sites, there are no provisions under this alternative to control or prevent exposure. Residual COCs (radionuclides) are not expected to pose a threat to the environment because of their low mobility and depth of occurrence. Because this alternative does not protect human health or comply with ARARs, it cannot be selected under CERCLA. Consequently, an evaluation against the CERCLA balancing criteria was not performed.

Table 10-2. CERCLA Evaluation Summary for Alternative S-1: No Action

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	No	***Does not protect Human Health or Surface and Groundwater*** • Contains no provisions to protect against inadvertent exposure. • COCs occur at depths between 1 and 22 m (0 and 72 ft); therefore, the potential for inadvertent exposure exists. • Radioactive decay reduces concentrations for most COCs to soil PRG levels within about 150 years. • Radionuclide COCs have K_d values ranging between 25 (strontium-90) and 200 (europium-152/europium-154); therefore, potential for subsurface migration is low. • No radionuclide COCs are present at concentrations above ecological PRGs.
Compliance with ARARs	No	***Does not comply*** Since there is no action, ARARs for waste sites will not be met.
Long-term Effectiveness and Permanence	N/A	Because this alternative does not meet threshold criteria, it cannot be selected. Therefore, an evaluation against the balancing criteria was not performed.
Reduction of TMV through Treatment	N/A	
Short-term Effectiveness	N/A	
Implementability	N/A	
Cost	N/A	No costs are associated with this alternative.

10.2.1.2 Alternative S-2: MESC, MNA and Institutional Controls

This alternative includes the following components:

- MESC. The existing soil cover over the waste sites, which ranges from about 1 to 4 m (3.3 to 13.1 ft) in thickness, would be maintained at grade until RAOs are achieved. The existing soil cover provides a barrier against direct contact exposure and wind erosion of COC-contaminated material.
- MNA. COC concentrations would be reduced through radioactive decay. Each radionuclide COC has a half-life ranging between 5.3 and 5,730 years. Based on the maximum detected COC concentrations, PRGs would be achieved within different timeframes ranging from 21 years to 191 years.
- An annual surveillance program to visually track waste site integrity for the sites for a period of up to 150 years. The information obtained from the program would be used to assess waste site stability and determine the need for additional surveillance. Surveillance results would be communicated annually during the September Unit Managers Meeting.
- Institutional Controls. The existing institutional controls described in Chapter 9, and the Site-Wide Institutional Control Plan (DOE/RL-2001-41) would be reviewed to assess their adequacy and supplemented as necessary to achieve RAOs. Institutional controls would be maintained until PRGs are met or up to a maximum of 150 years.
- 5-year reviews. Would be conducted to confirm that the remedy remains protective of human health and the environment until final PRGs are achieved.

Evaluation of Alternative S-2 against the CERCLA threshold and balancing criteria (Table 10-3) indicates this alternative protects human health and the environment. Continuation of the institutional controls implemented under the 100 Area Remaining Sites interim action ROD provides a broad array of overlapping measures to control or prevent inadvertent intrusion to the identified waste sites. Compliance with ARARs would be achieved once PRGs are achieved. Alternative 2 performs moderately to very well against each of the balancing factors.

10.2.1.3 Alternative S-3: RTD Optimized with Other Technologies

The major components of this alternative include:

- RTD is applicable to the 100-B-22:1, 100-B-34, 100-C-9:4, 132-B-5 and 1607-B5 sites and consists of the following elements.
  - Design investigation. Direct-push vadose zone borings would be advanced and soil samples collected to refine excavation and setback boundaries for remedial design.
  - Removal of clean overburden material placed during interim actions.
  - Excavation of contaminated soil within the defined remedial action target area at each of the twelve identified waste sites. An open cut excavation method (no shoring) is assumed for each waste site.
  - Verification sampling.
  - Backfilling of the excavations with overburden fill and setback material, and imported fill from a local borrow pit.

- Grading and restoration of a native vegetative cover across the waste site footprint and adjacent area.

- Transportation and disposal of excavated material at the ERDF or other approved disposal facility.

- Surface barriers are applicable to waste site 118-B-8:1 because of its proximity to the 105-B Reactor and waste sites 118-B-1 and 118-B-6 because of their exceedance of surface water and groundwater protection PRGs.

- Institutional controls are applicable to the two B Reactor Museum sites 118-B-8:3 and 132-B-2 to prevent inadvertent exposure.

- Evaluation of Alternative S-3 against the CERCLA threshold and balancing criteria (Table 10-4) indicates this alternative protects human health and the environment and complies with ARARs. RAOs are achieved in a relatively short timeframe by removing contaminated soil and transferring it to the ERDF, which is designed to provide for long-term management of chemical and radionuclide-contaminated soil until decay reduces concentrations to protective levels.

Table 10-3. CERCLA Evaluation Summary Alternative for S-2: MESC, MNA, and Institutional Controls

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	Yes	***Protects human health*** • Maintenance of existing institutional controls and soil cover protects against inadvertent exposure. • COCs occur as particulates on concrete surfaces at the 132-B-5 at depths below 1 m (3.3 ft), so the potential for exposure is low. • Radioactive decay reduces COC concentrations to PRGs without the need for enhancements or performance monitoring. • Except for carbon-14, COCs have K_d values ranging between 29 (strontium-90) and 200 (europium-152/ europium-154); therefore, the potential for COC migration is low. Although carbon-14 has a K_d of 0, it is only identified at the ARCL waste site and is not expected to be mobile as a particulate sorbed to concrete/debris surfaces. ***Protects the Environment*** • Maintenance of existing soil cover protects against inadvertent exposure to terrestrial receptors at the 118-B-1, 118-B-6, 118-B-8:1, and 118-B-8:3 waste sites. • Information presented in the *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment* (DOE/RL-2007-21, Draft A) indicates that contaminant concentrations in riparian areas do not pose a threat to ecological receptors.
Compliance with ARARs	Yes	***Complies with ARARs*** • Chemical-specific ARARs for protection of human health achieved for most COCs within 191 years. • 5-year reviews will be conducted to ensure that human health are protected.
Long-term Effectiveness and Permanence	○	***Expected to provide a moderate degree of long-term effectiveness and permanence*** *Factors that enable this alternative to perform moderately well against the long-term effectiveness and permanence criterion:* • Residual risk levels will lie within the CERCLA 10^{-4} to 10^{-6} risk range at completion of remedial action. • Institutional controls at the Hanford Site expected to have high degree of reliability due to the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) and ISS requirements. • Radioactive decay reduces COC concentrations at known rates without human intervention or O&M. • Long-term effectiveness and permanence will be evaluated in CERCLA 5-year reviews. *Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires maintenance of institutional controls to mitigate exposure.
Reduction of TMV through Treatment	○	***This alternative does not include active treatment*** • Radioactive decay reduces COC concentrations at known rates without human intervention.

Table 10-3. CERCLA Evaluation Summary Alternative for S-2: MESC, MNA, and Institutional Controls

Criterion	Rating	Detailed Analysis
Short-term Effectiveness	○	***Provides moderate degree of short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of institutional controls and monitoring program because of the remote site location. • Risks to workers from implementation of periodic institutional control and MESC surveillance minimized through a HSP and PPE. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • Time to achieve RAOs of up to 191 years, based on maximum detected concentrations, for all waste sites is longer than the 75 years targeted for cleanup of the 100 Area. The estimated timeframe to achieve RAOs at the ARCL site 132-B-5 is unknown. The estimated timeframe to achieve RAOs at 118-B-1, 118-B-6 and 118-B-8:1 is 69, 21, and 191 years, respectively.
Implementability	○	***Readily implemented*** • No technical or administrative challenges are associated with implementation of institutional controls or MNA programs. Both technologies are currently used at the Hanford Site. • Institutional controls have been previously approved and implemented. • Existing institutional controls expected to require only minor changes under this alternative.
Total Present Value Cost (a)	**Total All Sites: $911,000**	100-B-22:1: $90,727 100-B-34: $90,727 100-C-9:4: $90,727 118-B-1: $90,727 118-B-6: $105,304 118-B-8:1: $84,092 118-B-8:3: $90,727 132-B-2: $90,727 132-B-5: $86,000 1607-B5: $90,727

Table 10-3. CERCLA Evaluation Summary Alternative for S-2: MESC, MNA, and Institutional Controls

Criterion	Rating	Detailed Analysis
Total Cost (undiscounted)	**Total All Sites: $2,689,000**	100-B-22:1: $245,800 100-B-34: $245,800 100-C-9:4: $245,800 118-B-1: $245,800 118-B-6: $152,300 118-B-8:1: $441,300 118-B-8:3: $245,800 132-B-2: $245,800 132-B-5: $374,000 1607-B5: $245,800

* Total present value cost includes allowances for: capital, O&M, and periodic.

O = Performs very well against the criterion with no apparent disadvantages or uncertainty.

O = Performs moderately well against the criterion but with some disadvantages or uncertainty.

Table 10-4. CERCLA Evaluation Summary Alternative for S-3: RTD Optimized with Other Technologies

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	Yes	***Protects human health and the environment*** • RTD eliminates direct contact risk to through physical removal of contaminated soil and debris. • Excavated material transferred to the ERDF, which is designed to provide for long-term management of radionuclide- and chemical-contaminated soil. • Surface barriers at 118-B-8:1 eliminates the potential human health and ecological exposure pathways and at 118-B-1 and 118-B-6 eliminates the potential hazard to surface water and groundwater protection. • Institutional controls at 118-B-8:3 and 132-B-2 limit the inadvertent human health exposure pathway.
Compliance with ARARs	Yes	***Complies with ARARs*** • Remedial action designed to meet chemical-specific, location-specific, and action-specific ARARs.
Long-term Effectiveness and Permanence	O	***Provides high degree of long-term effectiveness and permanence*** *Factors that enable this alternative to perform very well against the long-term effectiveness and permanence criterion:* • RTD used successfully for interim actions to achieve remedial action goals established in interim action RODs. • RTD using conventional equipment is reliable and practiced extensively at the Hanford Site. ERDF disposal is assumed effective and reliable. • Residual risk levels within the CERCLA 10^{-4} to 10^{-6} risk range achieved by transferring contaminated material to the ERDF, which is designed to provide for long-term management of radionuclide-contaminated soil. • Surface barriers have been utilized at multiple DOE facilities as a closure cover over buried waste. Proven long-term effectiveness.
Reduction of TMV through Treatment	O	***Provides high degree of mobility reduction*** *Factors that enable this alternative to perform very well against the reduction of TMV by treatment criterion:* • Excavated soil is transferred to the ERDF where mobility is reduced through placement in an engineered containment facility. • Toxicity and volume reduction occur at the ERDF through radioactive decay. • Surface barriers reduce the potential radionuclide mobility at waste sites 118-B-8:1, 118-B-1, and 118-B-6. *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • RTD physically removes contaminated soil, rather than treatment, and transfers the material to another facility designed specifically for long-term management.

Table 10-4. CERCLA Evaluation Summary Alternative for S-3: RTD Optimized with Other Technologies

Criterion	Rating	Detailed Analysis
Short-term Effectiveness	○	***Overall, expected to have moderate short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of RTD activities due to the remote location. • Physical risks to workers associated with excavations up to 4.6m (15 ft). • Exposure risks minimized through adherence to a HSP and proper PPE. • Achieves RAOs in relatively short timeframe. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • Generation of GHG from use of excavation equipment and disposal to the ERDF. • Generation of GHG from use of construction equipment for grouting and cap construction. • Waste generation from contaminated soil disposal.
Implementability	○	***Readily Implementable*** • Readily implemented using equipment and methods employed for interim actions. • Conventional equipment and vendors for RTD-related tasks, grouting, and capping activities are readily available. • The ERDF widely used for disposal of contaminated material generated from Hanford Site remedial actions. This facility is proven, reliable, and accessible.
Total Present Value Cost (a)	**Total All Sites: $19,323,000**	100-B-22:1: $5,665,558 100-B-34: $1,328,280 100-C-9:4: $4,789,590 118-B-1: $1,271,303 118-B-6: $234,281 118-B-8:1: $252,824 118-B-8:3: $90,727 132-B-2: $90,727 132-B-5: $4,580,000 1607-B5: $1,019,542

Table 10-4. CERCLA Evaluation Summary Alternative for S-3: RTD Optimized with Other Technologies

Criterion	Rating	Detailed Analysis
Total Cost (undiscounted)	**Total All Sites: $20,651,000**	100-B-22:1: $5,778,869 100-B-34: $1,354,846 100-C-9:4: $4,885,382 118-B-1: $1,508,266 118-B-6: $450,504 118-B-8:1: $469,418 118-B-8:3: $245,800 132-B-2: $245,800 132-B-5: $4,671,000 1607-B5: $1,039,933

O = Performs very well against the criterion with no apparent disadvantages or uncertainty.

O = Performs moderately well against the criterion but with some disadvantages or uncertainty.

GHG = greenhouse gas

HSP = health and safety plan

PPE = personal protective equipment

10.2.1.4 Alternative S-4: Aggressive RTD

For this alternative, RTD is used at 9 of the 10 sites included in the FS; the exception is 118-B-8:1, where a surface barrier is the proposed alternative. The primary differences between this alternative and alternative S-3 is that RTD is performed at the B Reactor Museum sites 118-B-8:3 and 132-B-2 instead of implementing institutional controls and RTD is performed at the 118-B-1 and 118-B-6 waste sites that exceed surface water and groundwater protection PRGs. The major components of this alternative include:

- RTD consists of the following elements:
  - Design investigation. Direct-push vadose zone borings would be advanced and soil samples collected to refine excavation and setback boundaries for remedial design.
  - Removal of clean overburden material placed during interim actions.
  - Excavation of contaminated soil within the defined remedial action target area at each of the nine identified waste sites to the limits defined by the design investigation. An open cut excavation method (no shoring) is assumed for each waste site.
  - Verification sampling.
  - Backfilling of the excavations with overburden fill and setback material, and imported fill from a local borrow pit.
  - Grading and restoration of a native vegetative cover across the waste site footprint and adjacent area.
  - Transportation and disposal of excavated material at the ERDF.
- Implementation of RTD at the 118-B-8:3 and 132-B-2 waste sites would be logistically difficult because the waste sites are a part of the B Reactor National Historic Landmark.
- Surface barrier at 118-B-8:1 because of its proximity to the 105-B Reactor.

Evaluation of Alternative S-4 against the CERCLA threshold and balancing criteria (Table 10-5) indicates this alternative protects human health and the environment, and complies with ARARs. RAOs are achieved in a relatively short timeframe by removing contaminated soil and transferring it to the ERDF, which is designed to provide for long-term management of chemical and radionuclide-contaminated soil until decay reduces concentrations to protective levels. Excavation to depths up to 22 m (72 ft) would pose some implementation challenges but excavations to similar depths have been successfully completed under other 100 Area interim action RODs.

Table 10-5. CERCLA Evaluation Summary Alternative for S-4: Aggressive RTD

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	Yes	***Protects human health and the environment*** • RAOs achieved in the shortest timeframe of all waste site alternatives. • RTD eliminates direct contact risk to through physical removal of contaminated soil. • Excavated material transferred to the ERDF, which is designed to provide for long-term management of radionuclide- and chemical-contaminated soil. • Surface barrier at 118-B-8:1 eliminates the potential human health and ecological exposure pathways.
Compliance with ARARs	Yes	***Complies with ARARs*** • Remedial action designed to meet chemical-specific, location-specific, and action-specific ARARs.
Long-term Effectiveness and Permanence	O	***Provides high degree of long-term effectiveness and permanence*** *Factors that enable this alternative to perform very well against the long-term effectiveness and permanence criterion:* • RTD used successfully for interim actions to achieve remedial action goals established in interim action RODs. • RTD using conventional equipment is reliable and practiced extensively at the Hanford Site. ERDF disposal is assumed effective and reliable. • Residual risk levels within the CERCLA 10^{-4} to 10^{-6} risk range achieved by transferring contaminated material to the ERDF, which is designed to provide for long-term management of radionuclide-contaminated soil. • Surface barriers have been utilized at multiple DOE facilities as a closure cover over buried waste. Proven long-term effectiveness.
Reduction of TMV through Treatment	O	***Provides high degree of mobility reduction*** *Factors that enable this alternative to perform very well against the reduction of TMV by treatment criterion:* • Excavated soil is transferred to the ERDF where mobility is reduced through placement in an engineered containment facility. • Toxicity and volume reduction occur at the ERDF through radioactive decay. *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • RTD physically removes contaminated soil, rather than treatment, and transfers the material to another facility designed specifically for long-term management.

Table 10-5. CERCLA Evaluation Summary Alternative for S-4: Aggressive RTD

Criterion	Rating	Detailed Analysis
Short-term Effectiveness	○	***Overall, expected to have moderate short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of RTD activities due to the remote location. • Physical risks to workers associated with excavations up to 22m (72 ft). • Exposure risks minimized through adherence to a HSP and proper PPE. • Achieves RAOs in relatively short timeframe. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • Generation of GHG from use of excavation equipment and disposal to the ERDF. • Generation of GHG from use of construction equipment for grouting and cap construction. • Waste generation from contaminated soil disposal.
Implementability	○	***Implementable*** • Readily implemented at 8 of the 10 waste sites using equipment and methods employed for interim actions. • Conventional equipment and vendors for RTD-related tasks and capping activities are readily available. • The ERDF widely used for disposal of contaminated material generated from Hanford Site remedial actions. This facility is proven, reliable, and accessible. • Difficult to implement at the 118-B-8:3 and 132-B-2 waste sites since they are part of the B Reactor National Historic Landmark.
Total Present Value Cost (a)	**Total All Sites: $103,570,000 $**	100-B-22:1: $5,665,558 100-B-34: $1,328,280 100-C-9:4: $4,789,590 118-B-1: $73,627,944 118-B-6: $6,745,187 118-B-8:1: $252,824 118-B-8:3: $929,882 132-B-2: $4,630,417 132-B-5: $4,580,000 1607-B5: $1,019,542

Table 10-5. CERCLA Evaluation Summary Alternative for S-4: Aggressive RTD

Criterion	Rating	Detailed Analysis
Total Cost (undiscounted)	**Total All Sites: $105,853,000 $**	100-B-22:1: $5,778,869 100-B-34: $1,354,846 100-C-9:4: $4,885,382 118-B-1: $75,100,502 118-B-6: $6,880,090 118-B-8:1: $469,418 118-B-8:3: $948,480 132-B-2: $4,723,026 132-B-5: $4,671,000 1607-B5: $1,039,933

O = Performs very well against the criterion with no apparent disadvantages or uncertainty.

O = Performs moderately well against the criterion but with some disadvantages or uncertainty.

10.2.2 Groundwater Plume Alternatives

This section presents the evaluation of alternatives for the three 100-BC groundwater COC plumes. The four alternatives retained from the initial screening conducted in Chapter 9 include:

- Alternative GW-1: No Action
- Alternative GW-2: MNA and Institutional Controls
- Alternative GW-3: River Protection Pump-and-Treat
- Alternative GW-4: Aggressive Pump-and-Treat

The primary attributes of the 100-BC COC plumes are summarized in Table 10-6.

Table 10-6. 100-BC-5 COC Groundwater Plume Attributes

COC	Units	90th Percentile EPC	PRG		Plume Size Based on Lowest PRG	Estimated Timeframe Before Natural Attenuation Reduces Concentration to PRGs (years)
			DWS or MTCA Groundwater CUL Based PRG	Ambient Water Quality Criteria PRG		
Cr(VI)	µg/L	50	48	10	233 ha (575 acres)	83 to 108
Strontium-90	pCi/L	38	8	--	95 ha (235 acres)	52 to 72
Tritium	pCi/L	33,200	20,000	--	79 ha (195 acres)	5 to 15

10.2.2.1 Alternative GW-1: No Action

The No Action Alternative was developed per NCP requirements ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) to provide a baseline for comparison to other alternatives.

The No Action Alternative represents a scenario where no restrictions, controls, or active remedial actions are applied to a site. Under this alternative, the flux of Cr(VI) and strontium-90 to the Columbia River would not be reduced. The Cr(VI) concentrations in unconfined aquifer groundwater would remain elevated above the AWQC PRG for over 100 years. Sampling from the aquifer tubes located along the river shoreline historically has shown frequent detections of Cr(VI) and strontium-90 concentrations above PRGs. Although COCs have been detected in individual samples from the aquifer tubes at concentrations above PRGs, these occurrences are localized to small sections of the river shoreline. Across a typical aquatic receptor exposure area, COC concentrations are not expected to exceed PRGs.

Evaluation of the No Action Alternative against the CERCLA threshold criteria (Table 10-7) indicates that that this alternative does not protect human health nor does it comply with ARARs. Because this alternative does not protect human health or comply with ARARs, it cannot be selected under CERCLA. Consequently, an evaluation against the CERCLA balancing criteria was not performed.

Table 10-7. CERCLA Evaluation Summary for Alternative GW-1: No Action

Criterion	Rating	Detailed Analysis
Overall Protection of Human health and the Environment	No	***Does not protect human health and the environment*** • Contains no provisions to protect against human exposure to COCs by restricting groundwater use. • Adverse impacts to the environment are expected, as Cr(VI) concentrations in groundwater exceed PRGs. • Because most sources have been addressed under the interim action ROD, COC concentrations will decrease in the future.
Compliance with ARARs	No	***Not expected to be compliant*** • Since there is no action, ARARs for groundwater will not be met for more than 100 years.
Long-term Effectiveness and Permanence	N/A	Because this alternative does not meet threshold criteria it cannot be selected. Therefore, an evaluation against the balancing criteria was not performed.
Reduction of TMV through Treatment	N/A	
Short-term Effectiveness	N/A	
Implementability	N/A	
Cost	N/A	A cost estimate for Alternative GW-1 is not provided because no action is proposed.

10.2.2.2 Alternative GW-2: MNA and Institutional Controls

This alternative includes the following components:

- MNA of groundwater COCs. This includes periodic sampling and analysis from the 31 existing and 11 new monitoring wells, aquifer tubes, and pore water below the river bottom. For cost estimating purposes, it is assumed that sampling would be performed quarterly for the first year to establish baseline conditions, with a reduction to annual monitoring over the next 10 years, and a further reduction in frequency thereafter, to coincide with CERCLA 5-year reviews.
- Strontium-90 and tritium groundwater concentrations will decline to PRGs within 52 to 72 years and 5 to 15 years, respectively. Cr(VI) groundwater concentrations are expected to persist at levels above the AWQC PRG for 83 to 108 years.
- Expand institutional controls developed for the 100-HR-3 and 100-KR-4 Groundwater OUs to include 100-BC-5. This would be accomplished through the Site-Wide IC Plan (DOE/RL-2001-41). Institutional controls would be maintained until COC concentrations decline to PRGs.

Evaluation of Alternative GW-2 against the CERCLA threshold and balancing criteria (Table 10-8) indicates this alternative protects human health by restricting groundwater use until MNA reduces COC concentrations to the human health PRGs. Expansion of the institutional controls implemented under previous interim RODs provides a comprehensive array of measures to control or prevent inadvertent exposure to contaminated groundwater. Groundwater samples collected from aquifer tubes indicate that COC concentrations are below PRGs in a majority of the samples. Therefore, this alternative is protective of the aquatic environment along the shoreline. Future monitoring results will provide information to ensure that this alternative protects the environment in the future. This alternative performs poorly to moderately well against each of the balancing factors.

Table 10-8. CERCLA Evaluation Summary Alternative for GW-2: Institutional Controls and MNA

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	Yes	***Protective of human health. Further analysis needed to evaluate protection of aquatic receptors.*** • RAOs for human health exposure to groundwater and surface water is achieved in 52 to72 years. • RAO for ecological exposure to surface water is achieved in 83 to 108 years. • Institutional controls protect against inadvertent human health exposure to contaminated groundwater. • Levels of Cr(VI) above the AWQC PRGs will persist in groundwater discharge to the river for more than 75 years.
Compliance with ARARs	Yes	***Does not comply with all ARARs*** • Chemical-specific ARARs for protection of groundwater as a drinking water source achieved in 52 to72 years. • Chemical-specific ARARs for Cr(VI) for surface water quality protection is achieved in 83 to 108 years. • Periodic monitoring programs will be designed to comply with relevant location- and action-specific ARARs.

Table 10-8. CERCLA Evaluation Summary Alternative for GW-2: Institutional Controls and MNA

Criterion	Rating	Detailed Analysis
Long-term Effectiveness and Permanence	○	***Provides moderate degree of long-term effectiveness and permanence*** *Factors that enable this alternative to perform well against the long-term effectiveness and permanence criterion:* • Drinking water quality protection-based PRGs achieved at completion of remedial action. • Institutional controls at the Hanford Site expected to have high degree of reliability for next 75 years due to the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) and ISS requirements. • Radioactive decay reduces Strontium-90 and Tritium concentrations at known rates without human intervention or O&M. • Periodic monitoring and verification sampling can track progress toward achievement of RAOs. • Long-term effectiveness and permanence will be evaluated in CERCLA 5-year reviews. *Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:* • Surface water quality protection-based PRGs are not achieved for more than 75 years. • Requires enforcement of institutional controls to mitigate risk. • Cr(VI) will likely attenuate through advection and dispersion versus reductive processes that transform this COC to nonhazardous constituents due to geochemical conditions.
Reduction of TMV through Treatment	○	***Provides low - moderate degree of TMV through treatment*** *Factors that enable this alternative to perform moderately well against the reduction of TMV by treatment criterion:* • Strontium-90 and tritium toxicity and volume reduced in situ through radioactive decay. Up to 72 years required before PRG is achieved throughout the unconfined aquifer. • Significant treatment via in situ biodegradation processes not expected for the Cr(VI) plume. • Treatment of the Cr(VI) plume is accomplished through natural flushing (dispersion and dilution by and subsequent discharge to the Columbia River). *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • No significant treatment occurs under this alternative.

Table 10-8. CERCLA Evaluation Summary Alternative for GW-2: Institutional Controls and MNA

Criterion	Rating	Detailed Analysis
Short-term Effectiveness	○	***Provides moderate degree of short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of institutional controls and monitoring program because of the remote site location. • Risks to workers from implementation of periodic institutional controls surveillance, monitoring and verification sampling programs minimized through a HSP and proper PPE. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • Extended period of time required to achieve AWQC PRG for Cr(VI).
Implementability	○	***Readily implemented*** • No technical or administrative challenges are associated with implementation of institutional controls or MNA monitoring programs. Both technologies are widely used at the Hanford Site. • Institutional controls have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs. • Existing institutional controls expected to require only minor changes under this alternative.
Total Present Value Cost*	**Total: $38,789,000**	
Total Cost (undiscounted)*	**Total: $94,450,000**	

* Total present value cost includes allowances for: capital, O&M, and periodic costs.

○ = Performs very well against the criterion with no apparent disadvantages or uncertainty.
○ = Performs moderately well against the criterion but with some disadvantages or uncertainty.

10.2.2.3 Alternative GW-3: River Protection Pump-and-Treat

This alternative includes the following primary components:

- Implement institutional controls as described for Alternative GW-2.
- Installation of 6 extraction wells operating at rates of 75 gpm each for a total extraction rate of 450 gpm for removal of Cr(VI) and 150 gpm for removal of strontium-90.
- Installation of six injection wells to return treated water to the aquifer.
- Ex-situ treatment will consist of ion exchange for Cr(VI) and strontium-90 for an estimated 65 years to achieve the PRGs.
- The extraction and injection well network will be designed to promote extraction of the Cr(VI) mass while enhancing flow path control to ensure hydraulic containment.
- MNA for strontium-90 and tritium (as described under Alternative GW-2).

Evaluation of Alternative GW-3 against the CERCLA threshold and balancing criteria (Table 10-9) indicates this alternative protects human health and the environment and complies with ARARs. Expansion of the institutional controls implemented under previous interim action RODs provides a comprehensive array of measures to control or prevent inadvertent exposure to contaminated groundwater until PRGs are achieved. This alternative performs moderately well against most balancing factors.

Table 10-9. CERCLA Evaluation Summary Alternative for GW-3: River Protection Pump-and-Treat

Criterion	Rating	Detailed Analysis
Overall Protection of Human health and the Environment	Yes	***Protects human health and the environment*** • RAOs achieved. Cr(VI) requires 64 to 90 years; strontium-90 requires 49 to 71 years; and tritium requires 3 to 14 years to achieve RAOs. • Institutional controls protect against inadvertent exposure to contaminated groundwater until PRGs are achieved. • Cr(VI) concentrations in groundwater along the river shoreline expected to decline below PRGs within 17 to 23 years, providing timely protection for aquatic receptors.
Compliance with ARARs	Yes	***Complies with ARARs*** • Chemical-specific ARARs for protection of groundwater as a drinking water source achieved within 71 years. • Chemical-specific ARARs for surface water quality protection for Cr(VI) achieved within 90 years. • Periodic monitoring programs will be designed to comply with relevant location- and action-specific ARARs.
Long-term Effectiveness and Permanence	○	***Provides moderate degree of long-term effectiveness and permanence expected*** *Factors that enable this alternative to perform well against the long-term effectiveness and permanence criterion:* • Drinking water and surface water quality protection-based PRGs achieved at completion of remedial action. • Institutional controls at the Hanford Site expected to have high degree of reliability for next 75 years due to the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) and ISS requirements. • Radioactive decay reduces strontium-90 and tritium concentrations at known rates without human intervention or O&M. • Periodic monitoring and verification sampling track progress toward achievement of RAOs. • Long-term effectiveness and permanence will be evaluated in CERCLA 5-year reviews. *Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires enforcement of institutional controls to mitigate risk until PRGs are achieved. • Discharge of Cr(VI)-contaminated groundwater above the surface water quality protection PRG may resume at the completion of pump-and-treat operations.

Table 10-9. CERCLA Evaluation Summary Alternative for GW-3: River Protection Pump-and-Treat

Criterion	Rating	Detailed Analysis
Reduction of TMV through Treatment	○	***Provides low to moderate degree of TMV through treatment*** *Factors that enable this alternative to perform moderately well against the reduction of TMV by treatment criterion:* • Cr(VI) and Strontium-90 toxicity and mobility reduced rapidly through treatment. Strontium-90 and tritium toxicity and volume predominantly reduced in-situ through radioactive decay. *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • None identified.
Short-term Effectiveness	○	***Provides moderate degree of short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of institutional controls and monitoring program because of the remote site location. • Risks to workers from implementation of periodic institutional controls surveillance, extraction, injection, and performance monitoring programs minimized through a HSP and proper PPE. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • Extended period of pump-and-treat operation required to reduce groundwater contamination below PRGs.
Implementability	●	***Readily Implementable*** • Pump-and-treat technology used extensively at the Hanford site. • Institutional controls have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs. • Existing institutional controls expected to require only minor changes under this alternative.
Total Present Value Cost*	**Total: $283,166,000**	
Total Cost (undiscounted)*	**Total: $493,775,000**	

* Total present value cost includes allowances for: capital, O&M, and periodic costs.

● = Performs very well against the criterion with no apparent disadvantages or uncertainty.

○ = Performs moderately well against the criterion but with some disadvantages or uncertainty.

10.2.2.4 Alternative GW-4: Aggressive Pump-and-Treat

The primary components of this alternative include:

- Implement Institutional controls as described for Alternative GW-2.
- Installation of 12 extraction wells operating at rates of 75 gpm each for a total extraction rate of 900 gpm for removal of Cr(VI) and 300 gpm for removal of strontium-90.

- Installation of 12 injection wells to return treated water to the aquifer.
- Ex-situ treatment will consist of ion exchange for Cr(VI) and strontium-90.
- Extraction and injection wells will be located to maximize Cr(VI) removal, control the groundwater flow path, and minimize plume migration to the Columbia River.
- The operational duration for the pump-and-treat system is estimated at 25 years. An additional 24 years of MNA will be required before the PRGs are achieved for all COCs throughout the OU.
- MNA for strontium-90 and tritium (as described under Alternative GW-2) for up to 49 years.

Evaluation of Alternative GW-4 against the CERCLA threshold and balancing criteria (Table 10-10) indicates this alternative would provide a high degree of protection for human health and the environment. Expansion of the institutional controls implemented under previous interim action RODs provides a comprehensive array of measures to control or prevent inadvertent exposure to contaminated groundwater until PRGs are achieved through ex situ treatment. This alternative performs moderately to very well against the balancing factors. There is more experience with the ex-situ treatment equipment at the Hanford Site.

Table 10-10. CERCLA Evaluation Summary Alternative for GW-4: Aggressive Pump-and-Treat

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	Yes	***Protects human health and the environment*** • RAOs are achieved . Cr(VI) requires 16 to 67 years; strontium-90 requires 49 to 71 years; and tritium require 2 to 12 years to achieve PRGs. • Institutional controls protect against inadvertent exposure to contaminated groundwater until PRGs are achieved. • Cr(VI) concentrations in groundwater along the river shoreline reduced rapidly providing protection for aquatic receptors.
Compliance with ARARs	Yes	***Complies with ARARs*** • Chemical-specific ARARs for protection of groundwater as a drinking water source achieved within 41 to 71 years. • Chemical-specific ARARs for surface water quality protection for Cr(VI) achieved within 16 to 67 years. • Periodic monitoring programs will be designed to comply with relevant location- and action-specific ARARs.

Table 10-10. CERCLA Evaluation Summary Alternative for GW-4: Aggressive Pump-and-Treat

Criterion	Rating	Detailed Analysis
Long-term Effectiveness and Permanence	○	***Provides moderate to high degree of long-term effectiveness and permanence expected*** *Factors that enable this alternative to perform well against the long-term effectiveness and permanence criterion:* • Drinking water and surface water quality protection-based PRGs achieved at completion of remedial action. • Institutional controls at the Hanford Site expected to have high degree of reliability for next 75 years due to the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) and ISS requirements. • Ex-situ treatment removes COCs from groundwater and returns treated water to the aquifer. • Periodic monitoring and verification sampling track progress toward achievement of RAOs. • Long-term effectiveness and permanence will be evaluated in CERCLA 5-year reviews. *Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires enforcement of institutional controls to mitigate risk until PRGs are achieved.
Reduction of TMV through Treatment	○	***Provides moderate – high degree of TMV through treatment*** *Factors that enable this alternative to perform moderately well against the reduction of TMV by treatment criterion:* • TMV reduced for all COCs. *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • None identified.
Short-term Effectiveness	○	***Provides moderate-high degree of short-term effectiveness*** *Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of pump-and-treat remedy due to remote site location. • Risks to workers from implementation of periodic institutional control surveillance, extraction, injection, and performance monitoring programs minimized through a HSP and proper PPE. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • None identified.

Table 10-10. CERCLA Evaluation Summary Alternative for GW-4: Aggressive Pump-and-Treat

Criterion	Rating	Detailed Analysis
Implementability	●	***Readily implemented*** • Pump-and-treat technology used extensively at the Hanford Site. • Institutional controls have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs. • Existing institutional controls expected to require only minor changes under this alternative.
Total Present Value Cost*	**Total: $317,929,000**	
Total Cost (undiscounted)*	**Total: $405,579,000**	

* Total present value cost includes allowances for: capital, O&M, and periodic costs.

● = Performs very well against the criterion with no apparent disadvantages or uncertainty.

○ = Performs moderately well against the criterion but with some disadvantages or uncertainty.

10.3 Comparative Evaluation of Alternatives

This section summarizes the comparative evaluation of alternatives. The comparative evaluation is designed to assess the advantages and disadvantages of each alternative relative to one another to identify key tradeoffs that should be noted during remedy selection. The comparative evaluation for the waste site alternatives is presented in Table 10-11, while the groundwater alternatives are compared in Table 10-12.

10.3.1 Overall Protection of Human Health and the Environment

10.3.1.1 Waste Site Alternatives for Protection of Human Health and Environment

Each of the alternatives, except S-1: No Action, protect current and future human health and the environment by preventing exposure to contaminated soil through the use of institutional controls until RAOs are achieved. Alternative S-4 provides the highest level of protection because contaminated soil is removed and transported to a secure facility (that is, ERDF).

Table 10-11. Comparative Analysis of Waste Site Alternatives

Criterion	Alternative S-1: No Action		Alternative S-2: MESC, MNA, and Institutional Controls		Alternative S-3: RTD Optimized with other Technologies		Alternative S-4: Aggressive RTD	
	Rating	Detailed Evaluation Summary (Table 10-2)	Rating	Detailed Evaluation Summary (Table 10-3)	Rating	Detailed Evaluation Summary (Table 10-4)	Rating	Detailed Evaluation Summary (Table 10-5)
Waste Sites		All 10 Waste Sites		All 10 Waste Sites		All 10 Waste Sites		All 10 Waste Sites
Overall Protection of Human Health and the Environment	No	***Does not protect human health and the environment*** Contains no provisions to prevent inadvertent exposure. COCs occur at depths between 0 and 22 m (0 and 72 ft), so the potential for inadvertent exposure exists.	Yes	***Protects human health*** Institutional controls protect against human health exposure and prevent irrigation land use until PRGs achieved. COCs occur as particulates on concrete surfaces at 132-B-5 and at depths below 1 m (3.3 ft) at all 10 sites so the potential for exposure is low. ***Protects the Environment*** Maintenance of existing soil cover protects against inadvertent exposure to terrestrial receptors at all 10 sites.	Yes	***Protects human health and the environment*** Institutional controls protect against human health exposure and prevent irrigation land use. RAOs achieved in a short timeframe. Human health and the environment protected by eliminating the exposure pathway (surface barriers) or by moving contaminated soil to ERDF.	Yes	***Protects human health and the environment*** RAOs achieved in a short timeframe. Human health and the environment protected by moving contaminated soil to the ERDF.
Compliance with ARARs	No	***Does not comply*** Because there is no action, ARARs for waste sites will not be met.	Yes	***Complies with ARARs*** Chemical-specific ARARs for protection of human health achieved within 191 years (excludes C-14).	Yes	***Complies with ARARs*** Chemical-specific ARARs for protection of human health and the environment achieved in a short timeframe.	Yes	***Complies with ARARs*** Chemical-specific ARARs for protection of human health and the environment achieved in shortest timeframe of all alternatives.
Long-term Effectiveness and Permanence	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides moderate degree of long-term effectiveness and permanence*** Radioactive decay reduces COC concentrations to PRGs within defined remedial action timeframe. Ranking lower due to extended timeframe.	○	***Provides high degree of long-term effectiveness and permanence*** Uses RTD to move contaminated debris to the ERDF, which is designed for long-term management of contaminated media. Surface barriers provide long term effectiveness.	○	***Provides high degree of long-term effectiveness and permanence*** Uses RTD to move contaminated soil to the ERDF, which is designed for long-term management of contaminated media. RTD used successfully throughout the Hanford Site. No long-term controls required following completion of remedial action.
Reduction of Toxicity, Mobility, or Volume by Treatment	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides moderate degree of TMV through treatment*** Toxicity and volume reduced through radioactive decay. Tritium mobility not reduced at sites 118-B-1 and 118-B-6.	○	***Provides high degree of TMV through treatment*** Mobility threat reduced by surface barriers to eliminate infiltration. Excavated soil is transferred to the ERDF, where mobility is reduced through placement in an engineered containment facility. Toxicity and volume reduction occur through radioactive decay.	○	***Provides high degree of mobility reduction*** Excavated soil is transferred to the ERDF, where mobility is reduced through placement in an engineered containment facility. Toxicity and volume reduction occur at the ERDF through radioactive decay.

Table 10-11. Comparative Analysis of Waste Site Alternatives

Criterion	Alternative S-1: No Action		Alternative S-2: MESC, MNA, and Institutional Controls		Alternative S-3: RTD Optimized with other Technologies		Alternative S-4: Aggressive RTD	
	Rating	Detailed Evaluation Summary (Table 10-2)	Rating	Detailed Evaluation Summary (Table 10-3)	Rating	Detailed Evaluation Summary (Table 10-4)	Rating	Detailed Evaluation Summary (Table 10-5)
Short-term Effectiveness	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides moderate degree of short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE. Lower environmental impacts, as compared to Alternatives 3 and 4 because fewer activities that generate GHG are proposed. Up to 191 years required before PRGs achieved at all waste sites.	○	***Provides moderate degree of short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE.	○	***Overall, expected to have moderate short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE. Deep excavation at 118-B-1 (22m) and 118-B-6 (16m) pose increased worker risks.
Implementability	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	◉	***Readily implemented*** Limited technical or administrative challenges associated with implementation of this alternative. Institutional controls have been approved and implemented under interim action RODs, and are reliable/effective at the Hanford Site.	◉	***Readily implemented*** Limited technical or administrative challenges are associated with implementation of this alternative. Proposed remediation technologies used elsewhere at the Hanford Site.	○	***Moderately Implementable*** Limited technical challenges are associated with implementation of this alternative. Conventional equipment required and vendors readily available. Significant administrative challenges exist for implementing RTD at the 118-B-8:3 and 132-B-2 waste sites since they are a part of the B Reactor National Historical Monument.
Net Present Value of Alternative (Discounted)*	N/A	A cost estimate was not prepared because there are no activities.		Total All Waste Sites: $911,000		Total All Waste Sites: $19,323,000		Total All Waste Sites: $103,570,000

◉ = Performs very well against the criterion with no apparent disadvantages or uncertainty.
○ = Performs moderately well against the criterion but with some disadvantages or uncertainty.

Table 10-12. Comparative Analysis of Groundwater Alternatives

Criterion	Alternative GW-1: No Action		Alternative GW-2: MNA and Institutional controls		Alternative GW-3: River Protection Pump-and-Treat		Alternative GW-4: Aggressive Pump-and-Treat	
	Rating	Detailed Evaluation Summary (Table 10-7)	Rating	Detailed Evaluation Summary (Table 10-8)	Rating	Detailed Evaluation Summary (Table 10-9)	Rating	Detailed Evaluation Summary (Table 10-10)
Overall Protection of Human Health and the Environment	No	***Does not protect human health and the environment*** No provisions for preventing human exposure to COCs in groundwater.	Yes	***Protects human health and the environment*** AWQC PRG for Cr(VI) are achieved within 104 to 108 years. Institutional controls protect against exposure until COC concentrations decline to PRGs.	Yes	***Protects human health and the environment*** RAOs achieved within 64 to 90 years. Uses ex-situ treatment in combination with MNA to address COCs. Cr(VI) concentrations along shoreline rapidly reduced through groundwater extraction .	Yes	***Protects human health and the environment*** RAOs achieved within 49 to 67 years. Uses ex-situ treatment in combination with MNA to address COCs. Cr(VI) concentrations along shoreline rapidly reduced through groundwater extraction.
Compliance with ARARs	No	***Not expected to be compliant*** ARARs in groundwater will not be met for more than 75 years.	Yes	***Complies with ARARs*** Natural attenuation reduces all COCs to ARAR-based PRGs within 5 to 108 years.	Yes	***Complies with ARARs*** Chemical-specific ARARs achieved within 3 to 90 years.	Yes	***Complies with ARARs*** Chemical-specific ARARs achieved within 2 to 71years.
Long-term Effectiveness and Permanence	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides moderate degree of long-term effectiveness and permanence*** COC concentrations are reduced through natural attenuation processes. Significant uncertainty on whether these processes will reduce Cr(VI) concentrations on a long-term basis at the rates needed to achieve PRGs within the projected timeframe.	○	***Provides moderate to high degree of long-term effectiveness and permanence*** Cr (VI) and strontium-90 are removed from groundwater using proven technologies. Strontium-90 and tritium concentrations will decline through radioactive decay.	○	***Provides high degree of long-term effectiveness and permanence*** Cr (VI) and Strontium-90 are removed from groundwater using proven technologies. Strontium-90 and tritium concentrations will decline through radioactive decay.
Reduction of Toxicity, Mobility, or Volume by Treatment	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides low-moderate TMV reduction through treatment*** Toxicity reduced through advection-dispersion and radioactive decay. No reduction in mobility or volume.	○	***Provides moderate degree of TMV reduction through treatment*** Cr(VI) and strontium-90 treated and removed from groundwater using demonstrated technologies. The toxicity of Strontium-90 and tritium are reduced through radioactive decay.	○	***Provides high degree of TMV through treatment*** Most rapid removal of Cr(VI) from groundwater using demonstrated technologies. The toxicity of Strontium-90 and tritium are reduced primarily through radioactive decay.
Short-term Effectiveness	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	○	***Provides moderate short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE. Extended period of time required to achieve PRGs.	○	***Provides moderate degree of short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE	○	***Provides moderate-high degree of short-term effectiveness*** No adverse risks to the community. Risks to workers are minimized through a HSP and proper PPE.

Table 10-12. Comparative Analysis of Groundwater Alternatives

Criterion	Alternative GW-1: No Action		Alternative GW-2: MNA and Institutional controls		Alternative GW-3: River Protection Pump-and-Treat		Alternative GW-4: Aggressive Pump-and-Treat	
	Rating	Detailed Evaluation Summary (Table 10-7)	Rating	Detailed Evaluation Summary (Table 10-8)	Rating	Detailed Evaluation Summary (Table 10-9)	Rating	Detailed Evaluation Summary (Table 10-10)
Implementability	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed.	◉	***Readily implementable*** Limited technical or administrative challenges are associated with implementation of this alternative. Institutional controls and MNA implemented elsewhere at the Hanford Site.	○	***Implementable*** Limited technical challenges are associated with implementation of this alternative. Conventional equipment required and vendors readily available. Groundwater extraction and injection wells may need to be installed in culturally sensitive areas.	○	***Implementable*** Limited technical challenges are associated with implementation of this alternative. Conventional equipment required and vendors readily available. Groundwater extraction and injection wells may need to be installed in culturally sensitive areas.
Net Present Value of Alternative (Discounted)*	**N/A**	A cost estimate was not prepared because there are no activities.		Total All Plumes: $38,789,000		Total All Plumes: $283,166,000		Total All Plumes: $317,929,000

* Detailed cost estimates are presented in Appendix J.

◉ = Performs very well against the criterion with no apparent disadvantages or uncertainty.

○ = Performs moderately well against the criterion but with some disadvantages or uncertainty.

Alternative S-2 relies on maintenance of existing soil covers to eliminate the potential exposure pathway in addition to institutional controls, and MNA to reduce radionuclide COC concentrations in-situ through radioactive decay. The time frame to achieve soil PRGs through MNA ranges up to 191 years. Although an extended timeframe is required, the contaminated soil at the radionuclide-contaminated sites 118-B-1, 118-B-6, 118-B-8:1, and 132-B-5 occurs at depths below 1 m (3.3 ft) where the potential for exposure is deemed low based on current and future land use. Excavation of the contaminated soil under Alternatives S-3 and S-4 brings the material to the surface increasing the potential for short-term exposure.

10.3.1.2 Groundwater Alternatives

Each of the alternatives with the exception of GW-1: No Action protect current human health and the environment by preventing exposure to contaminated groundwater through the use of institutional controls. Alternative GW-2: MNA and Institutional Controls requires an extended period of time to protect ecological receptors due to the limited natural attenuation of the Cr(VI) groundwater plume. Alternative GW-4: Aggressive Pump-and-Treat is expected to provide the highest level of protection for human health and the environment because a majority of the Cr(VI) mass is removed from groundwater and treated by an aboveground facility using technology proven successful elsewhere at the Hanford Site. The Cr(VI) mass is concentrated on a sorption type media (IX), which is either regenerated and reused or disposed at the ERDF.

10.3.2 Compliance with ARARs

10.3.2.1 Waste Site Alternatives

All of the waste site alternatives, except the No Action Alternative, comply with chemical-specific ARARs within the defined remedial action target areas. The timeframe required for attainment of ARARs varies, with Alternative S-4 expected to have the shortest timeframe and Alternative S-2 the longest.

10.3.2.2 Groundwater Alternatives

All the groundwater alternatives, except the No Action Alternative, comply with chemical-specific ARARs. Alternative GW-2: MNA and institutional controls is expected to have the longest remediation timeframe since it relies on natural processes to achieve the ARA-based PRGs. Alternative GW-4 is expected to have the shortest remediation timeframe due to the more aggressive groundwater extraction and treatment. Alternatives GW-2, GW-3, and GW-4 primarily achieve the strontium-90 and tritium chemical-specific ARARs through natural attenuation.

10.3.3 Long-Term Effectiveness and Permanence

10.3.3.1 Waste Site Alternatives

Alternatives S-3 and S-4 provide greater long-term effectiveness and permanence because COC-contaminated soil and debris exceeding PRGs is removed and transported to the ERDF. Once the contaminated soil is removed, there is no need for any further controls. Alternative S-2 requires periodic inspection and maintenance to ensure long-term effectiveness of the erosion control measures and the maintenance of institutional controls for up to 150 years until radioactive decay decreases COC concentrations to PRGs. Alternative S-3 requires the maintenance of institutional controls to prevent site intrusion at the sites where surface barrier technologies are utilized as the remedy. The No Action Alternative S-1 provides the lowest degree of long-term effectiveness and permanence because there are no provisions for treatment or exposure controls.

10.3.3.2 Groundwater Alternatives

Alternative GW- 4 provides a higher degree of long-term effectiveness and permanence because a majority of the Cr(VI) treatment is performed using an above-ground treatment system with less reliance on natural attenuation processes. Alternatives GW-3 and GW-2 provide less long-term effectiveness and permanence than Alternative GW-4 because MNA plays a greater role in achieving PRGs. Alternative GW-1: No Action provides the least long-term effectiveness and permanence because Cr(VI) concentrations will persist for more than 75 years.

10.3.4 Reduction of Toxicity Mobility and Volume through Treatment

10.3.4.1 Waste Site Alternatives

Alternative S-4 provides the highest degree of mobility reduction because COC contaminated material is excavated and moved to a secure facility that is designed to restrict mobility. While toxicity and volume are not reduced through treatment, radioactive decay will reduce COC concentrations over time decreasing toxicity. Cr(VI) concentrations may be reduced if excavated material is blended with other nonchromium-bearing waste.

Alternatives S-2 and S-3 provide some mobility reductions through the use of institutional controls that restrict land use and irrigation Alternative S-3 includes surface capping to reduce potential COC mobility from infiltration. Alternative S-1: No Action provides the least TMV reduction.

10.3.4.2 Groundwater Alternatives

Alternative GW-4: Ex situ treatment provides the highest degree of TMV reduction because a majority of the COC mass is removed from the aquifer using above-ground treatment and the treatment residuals immobilized and disposed at a secure long-term management facility (that is, ERDF). Groundwater extraction and injection wells are also used to contain the COC plumes, preventing their expansion into other uncontaminated areas. Alternative GW-3 still provides significant TMV reduction, however, because a portion of the treatment is performed through natural attenuation, there is less mobility reduction. Alternatives GW-2 and GW-1 provide the least amount of TMV reduction because natural processes, which require up to 108 years to reduce COC concentrations to PRGs, are much slower.

10.3.5 Short-Term Effectiveness

Each of the waste site and groundwater plume alternatives are expected to provide similar levels of short-term effectiveness because the work required under these alternatives can be performed safely with minimal risk to workers and the environment by conducting the work per existing work processes. However, as the complexity of a remedial alternative increases, the potential for worker risk also increases. Therefore, Alternatives S-2 and GW-2 would pose the least short-term risk to workers and Alternatives S-4, GW-3, and GW-4 would provide the highest short-term risk to workers. Because of the remote location of the 100-BC waste sites and COC plumes, no risk to the community is associated with implementation of this group of alternatives.

Alternatives S-4 and GW-4 are expected to have the shortest remedial action timeframes, ranging from several years for the waste site alternatives to 49 years for groundwater. Alternatives S-2 and GW-2 will have the longest timeframes of up to 191 years for soil and up to 108 years for groundwater.

10.3.6 Implementability

All of the waste site and groundwater plume alternatives are readily implemented using existing site work procedures. Alternative S-4 requires deep excavation for the 118-B-1 and 118-B-6 waste sites, which can pose greater resource and technical challenges. Implementation of RTD at sites 118-B-8:3 and

132-B-2 would pose significant administrative and technical challenges because the sites are located within the B Reactor National Historic Landmark.

The No Action Alternative is not expected to be implementable based on regulatory agency acceptance.

10.3.7 Cost

A comparison of alternative costs for individual waste site and groundwater COC plumes, and total alternative costs is presented in Table 10-13 (waste sites) and Table 10-14 (groundwater). Details regarding cost estimates for the proposed alternatives are provided in Appendix K. These cost estimates have been prepared to meet the -30 to +50 percent range of accuracy recommended in the CERCLA RI/FS Guidance (EPA/540/G-89/004). No capital or O&M costs are associated with the No Action alternatives.

10.4 NEPA Values

This section incorporates NEPA values into the analysis in this CERCLA RI/FS document. This is consistent with the DOE policy in *National Environmental Policy Act Compliance Program* (DOE O 451.1B Chg 1), that NEPA values such as socioeconomic, ecological, offsite, and cumulative impacts should be examined in DOE CERCLA documents to the extent practicable.

Alternatives to address contamination at 100-BC are presented in Chapter 9. The waste site alternatives include Alternative S-1 (No Action), Alternative S-2 (Maintain Existing Soil Cover, Monitored Natural Attenuation, and Institutional Controls), Alternative S-3 (RTD Optimized with other Technologies), and Alternative S-4 (Aggressive RTD). The groundwater alternatives include Alternative GW-1 (No Action), Alternative GW-2 (Institutional Controls and MNA), Alternative GW-3 (River Protection Pump-and-Treat) and Alternative GW-4 (Aggressive Pump-and-Treat). Alternatives S-1 and GW-1 would not mitigate the environmental impacts from the hazardous substances. All other alternatives could mitigate the impacts associated with impacted soil and groundwater present at 100-BC.

NEPA values associated with remediation are based on the information presented in this RI/FS, including the area and site characteristics (Chapters 1, 2, and 3), final contaminants of potential concern (Chapter 8), and identification and analysis of remedial actions (Chapter 9). Applying a "sliding scale" of NEPA analysis to 100-BC (using *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements: Second Edition* [DOE, 2004]) and considering the CERCLA ARARs (detailed in Section 8.1.2), the principal resource areas of concern include the contaminants in the soil, contaminants in the groundwater and surface water, solid and liquid radioactive and hazardous waste management, air emissions, potential adverse effects to historic and cultural resources, ecological resources, socioeconomics (including environmental justice concerns), and transportation.

The net anticipated effect could be an overall positive contribution to cumulative environmental effects at the Hanford Site. For sites and alternatives with RTD as the selected remedial action, DOE expects that the primary facility to receive contaminated soil will be the ERDF.

Table 10-13. Comparison of Remedial Alternative Costs [a] for the 100-BC-1 and 100-BC-2 Source Operable Units

Site: Site 100-BC Location: Hanford, WA Phase: Feasibility Study	Base Year: 2013 Date: 7/11/2012			
	Waste Sites with Human Health and Surface Water/Groundwater Protection PRG Exceedances			
	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4
Waste Site	No Action	Institutional Controls and Monitored Natural Attenuation (discounted $)	Remove Treat and Dispose Optimized with Other Technologies (discounted $)	Aggressive Remove Treat and Dispose (discounted $)
Total NPV (Individual Waste Sites)				
100-B-22:1 (process sewer)	$0	$90,727	$5,665,558	$5,665,558
100-B-34 (process sewer)	$0	$90,727	$1,328,280	$1,328,280
100-C-9:4 (pipeline site)	$0	$90,727	$4,789,590	$4,789,590
118-B-1 (burial ground)	$0	$90,727	$1,271,303	$73,627,944
118-B-6 (burial ground)	$0	$105,304	$234,281	$6,745,187
118-B-8:1 (FSB proximal to reactor)	$0	$84,092	$252,824	$252,824
118-B-8:3 (pipelines at reactor)	$0	$90,727	$90,727	$929,882
132-B-2 (reactor stack)	$0	$90,727	$90,727	$4,630,417
132-B-5 (ARCL site)	$0	$86,000	$4,580,000	$4,580,000
1607-B5 (septic tank)	$0	$90,727	$1,019,542	$1,019,542
Total (All Waste Sites) (rounded)				
Estimated Project Duration (years)	0	191	75	75
Capital Cost (non-discounted)	$0	$0	$19,079,000	$105,492,000

Table 10-13. Comparison of Remedial Alternative Costs [a] for the 100-BC-1 and 100-BC-2 Source Operable Units

Site: Site 100-BC **Base Year: 2013**
Location: Hanford, WA **Date: 7/11/2012**
Phase: Feasibility Study

Waste Site	Waste Sites with Human Health and Surface Water/Groundwater Protection PRG Exceedances			
	Alternative S-1	**Alternative S-2**	**Alternative S-3**	**Alternative S-4**
	No Action	**Institutional Controls and Monitored Natural Attenuation (discounted $)**	**Remove Treat and Dispose Optimized with Other Technologies (discounted $)**	**Aggressive Remove Treat and Dispose (discounted $)**
O&M Cost (non-discounted)	$0	$1,505,000	$638,000	$128,000
Periodic Cost (non-discounted)	$0	$1,184,000	$934,000	$233,000
Total Non-Discounted	$0	$2,689,000	$20,651,000	$105,853,000
Total NPV (Discounted)	$0	$911,000	$19,323,000	$103,570,000

Notes:

Present Value discount percent used is 2.0 percent.

Range of accuracy is expected to be +50 percent /-30 percent.

Table 10-14. Comparison of Remedial Alternative Costs for the 100-BC-5 Groundwater Operable Unit

Site: 100-BC-5 **Base Year: 2013**
Location: Hanford, WA **Date: 5/14/2012**
Phase: FS

Cost Category	Alternative GW-1	Alternative GW-2 MNA and Institutional Controls	Alternative GW-3 River Protection Pump-and-Treat	Alternative 4 GW-4 Aggressive Pump-and-Treat
Total Groundwater Extraction Rate L/min (gpm)	0	0	1703 L/min (450 gpm)	3407 L/min (900 gpm)
Total Injection Flow Rate L/min (gpm)	0	0	1703 L/min (450 gpm)	3407 L/min (900 gpm)
Total Pumping Duration (years)	0	0	65	25
MNA Duration, Cr(VI) (years)	0	105	0	0
MNA Duration, Sr-90 (years)	0	52	49	49
MNA Duration, Tritium (years)	0	5	3	2
Total Project Duration (years)	0	107	72	52
Capital Cost	0	$3,823,000	$56,839,000	$96,110,000
Total Annual O&M Cost	0	$37,068,000	$306,169,000	$234,936,000
Total Periodic Cost	0	$54,559,000	$130,767,000	$74,534,000
Total Non-Discounted	0	$95,450,000	$493,775,000	$405,579,000
Total NPV (Discounted)	0	$38,789,000	$283,166,000	$317,929,000

Notes:

Real discount rate used for net present value is 2.0 percent. Range of accuracy for total non-discounted cost and for total NPV, at the stated real discount rate, are expected to be +50 percent /-30 percent.

NEPA values in the planning for the ERDF operation were explained in detail in the *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package* (DOE/RL-94-41) for the *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE/RL-93-99) as described in the most recent ERDF ROD Amendment (*Amendment to the Record of Decision for the USDOE Hanford Environmental Restoration Disposal Facility* [EPA et al., 2007]).

The NEPA values (that is, resource area and relevant NEPA considerations) most relevant to and potentially affected by the actions taking place under this remedial action are described in Table 10-7.

In addition, DOE has included the combined effects anticipated from ongoing CERCLA/Tri-Party Agreement (Ecology et al., 1989a) response actions as part of the cumulative impact analysis in the *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (DOE/EIS-0391), which includes a sitewide cumulative impact groundwater analysis. That EIS is focused on the long term active management of mixed waste in the Tank Farms, which are Treatment, Storage and Disposal Units regulated under RCRA, which have been sources of the groundwater contamination which is being remediated through the Hanford Site CERCLA process.

10.5 Coordination of Interim and Final CERCLA Remedial Activities

A feature of each area is the ongoing implementation of interim action RODs, CERCLA removal actions, RCRA corrective actions, treatability tests, and other activities to remediate contaminated areas or to develop more effective methods that advance remediation, as discussed in preceding chapters.

Implementation of these interim action ROD activities is generating information that allows an improved understanding of site complexity, supports refinement of the CSM, and documents the effectiveness of the remedial actions.

Table 10-15. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
Transportation	Considers impacts of the proposed action on local traffic (that is, traffic at the Hanford Site) and traffic in the surrounding region.	Implementation of all action alternatives (except No Action) would be expected to produce short-term impacts on local traffic. A majority of the impact relates to increased truck traffic associated with the aforementioned alternatives: they would involve transport of contaminated soil moved from a waste site(s) to ERDF. Transportation impacts were considered in *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE/RL-93-99) as part of the evaluation of short-term effectiveness and implementability. NEPA values in the planning for ERDF operation were explained in detail in *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package* (DOE/RL-94-41). Transportation impacts associated with waste sites under Alternatives 2 and 3 are similar, though Alternative 2 impacts are somewhat smaller as a lower volume of soil would be excavated and transported to ERDF. The discussion of cumulative impacts provides a perspective of transportation to ERDF.
Water Quality	Considers potential water quality concerns associated with the groundwater below the site and the Columbia River.	Performance of excavation of waste sites requires the application of considerable quantities of water for dust control (for air quality). The application of this water may result in migration to groundwater. This impact would be similar for Alternatives 2 and 3 since the excavation footprint are anticipated to be nearly equivalent. Contaminants would be removed from groundwater in both alternatives, which would be expected to cause a net positive effect in water quality both for groundwater below the site and for the Columbia River. Spent ion exchange resin would be generated and managed as solid waste.
Air Quality	Considers potential air quality concerns associated with emissions generated during the proposed action.	Airborne releases associated with Alternatives 2 and 3 could occur due to dust generation during excavation. A maximum of approximately 3.7 million tons of contaminated soil would be removed (Alternative 3, over an expected duration of 8 years, or approximately 460,000 tons per year). Alternatives 2 and 3 would also release some carbon-14 to the atmosphere. Any potential of airborne release of contaminants during alternative remedial actions would be controlled in accordance with DOE radiation control and air pollution control standards to minimize emissions of air pollutants at the Hanford Site and protect all communities outside the site boundaries.
		Operation of trucks and other diesel-powered equipment for these alternatives would be expected to introduce quantities of carbon dioxide, sulfur dioxide, nitrogen dioxide, particulates, and other pollutants to the atmosphere. Alternative 3 is expected to have a slightly greater extent of these emissions since a larger quantity of soil would be excavated and transported. As applicable, vehicular and equipment emissions would be controlled and mitigated in compliance with the substantive standards for air quality protection that apply to the Hanford Site.

Table 10-15. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
Natural, Cultural, and Historical Resources	Considers impacts of the proposed action on wildlife, wildlife habitat, archeological sites and artifacts, and historically significant properties.	Impacts on ecological resources near the remedial actions could result from installation of groundwater wells and excavation of contaminated soil. Such impacts would be mitigated in accordance with *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32), *Biological Resources Mitigation Strategy* (DOE/RL-96-88), and applicable standards of all relevant biological species protection regulations. Alternative 3 could pose the greatest impact on cultural resources since it would require installation of wells in a potentially culturally sensitive area ("Protection of Historic Properties" [36 CFR 800], Section 106). However, because many of these sites have already been disturbed and only isolated artifacts would be expected to be encountered during project activities, implementation of the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10) and consultation with area Tribes would help ensure appropriate mitigation to avoid or minimize any adverse cultural or historical resource effects and address any relevant concerns. Impacts to other cultural values will be minimized through implementation of *Hanford Cultural Resources Management Plan* (DOE/RL-98-10), *Revised Mitigation Action Plan for the Environmental Restoration Disposal Facility* (DOE/RL-2005-27), and consultation with area Tribes, as needed. This will help ensure appropriate mitigation to avoid or minimize any adverse effects to natural and cultural resources and address any other relevant concerns. Contingent remedy may be applied, if appropriate, at culturally sensitive areas. Potential impacts to cultural and historical resources that may be encountered during short-term construction activities associated with implementing the action would be mitigated through compliance with the appropriate substantive requirements of the *National Historic Preservation Act of 1966* and other ARARs related to cultural preservation.
Socioeconomic Impacts	Considers impacts pertaining to employment, income, other services (for example, water and power utilities), and the effect of implementation of the proposed action on the availability of services and materials.	The proposed action is within the scope of current DOE-RL environmental restoration activities and would have minimal impact on the current availability of services and materials. This work would be expected to be accomplished largely using employees from the existing contractor workforce. Even if the remedial activities create additional service sector jobs, the total expected increase in employment would be expected to be less than 1 percent of the current employment levels. The socioeconomic impact of the project would contribute to the continuing overall positive employment and economic impacts on eastern Washington communities from Hanford Site cleanup operations.

Table 10-15. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
Environmental Justice	Considers whether the proposed response actions would have inappropriately or disproportionately high and adverse human health and the environment effects on minority or low income populations.	Per *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (Executive Order 12898), DOE seeks to ensure that no group of people bears a disproportionate share of negative environmental consequences resulting from proposed federal actions. There are no impacts associated with proposed activities associated with 100-BC that could reasonably be determined to affect any member of the public; therefore, they would not have the potential for high and disproportional adverse impacts on minority or low income groups.
Cumulative Impacts (Direct and Indirect)	Considers whether the proposed action could have cumulative impacts on human health and the environment when considered together with other activities locally, at the Hanford Site, or in the region.	The environmental concern of 100-BC is associated directly with the targeted area. Because of the temporary nature of the activities and their remote location, cumulative impacts on air quality or noise with other Hanford Site or regional construction and cleanup projects would be minimal. When soil at a site in this area is found to be contaminated with hazardous substances in concentrations presenting a material threat to human health and the environment, that threat would be mitigated. The net anticipated effect could be a positive contribution to cumulative environmental effects at the Hanford Site through RTD of such hazardous substances and COCs into a facility that has been designed and legally authorized to contain such contaminants safely, like ERDF. Contaminated soil removed under any alternative would meet the ERDF waste acceptable criteria described in *Environmental Restoration Disposal Facility Waste Acceptance Criteria* (WCH-191). As noted earlier, the maximum volume of soil that could be generated for disposal during implementation of the remedial action is approximately 3.7 million tons over the expected duration of this action (implementation of Alternative 3 is anticipated to occur over an 8-year period, resulting in 460,000 tons per year [and attendant transportation requirements]). Alternative 2 would result in approximately 860,000 tons per year (for 4 years).
		Wastes generated during implementation of the proposed alternatives would be manageable within the capacities of existing facilities. For perspective, ERDF received more than 700,000 tons of waste in 2008 and more than 430,000 tons in 2007. Radiological contamination is expected to be minimal; by definition, these are waste sites that are believed to be shallow in nature, do not impact groundwater, and have relatively small inventories. ERDF received approximately 22,500 Ci in 2008 and approximately 13,000 Ci in 2007.

Table 10-15. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
Mitigation	Considers that, if adverse impacts cannot be avoided, response action planning should minimize them to the extent practicable. This value identifies required mitigation activities.	Compliance with the substantive requirements of the ARARs would mitigate potential environmental impacts on the natural environment, including migratory birds and endangered species. DOE has established policies and procedures for the management of ecological and cultural resources when actions might affect such resources (*Hanford Site Biological Resources Management Plan* [DOE/RL-96-32], *Biological Resources Mitigation Strategy* [DOE/RL-96-88], and *Hanford Cultural Resources Management Plan* [DOE/RL-98-10]). Cultural resource and biological species reviews/surveys are undertaken that also provide suggested mitigation activities to ensure that adverse effects associated with implementing the actions are minimized or avoided. Health and safety methods, documented in the HSPs established by site contractors, would mitigate risks to workers from the remedial activities.
Irreversible and Irretrievable Commitment of Resources	Considers the use of nonrenewable resources for the proposed response actions and the effects that resource consumption would have on future generations. When a resource (for example, energy minerals, water, and wetland) is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.	Materials that would be used to backfill waste sites, removed under an alternative, could be taken, from the surrounding area, if needed, to contour the backfill to match the surrounding area. For Alternatives 2 and 3, normal usage of resources during construction activities, such as fuel and water, would be irreversibly used. Potential impacts would be expected to be greater for Alternative 3, due to the slightly larger extent of RTD and duration of operation. Restoration of formerly disturbed areas to a more natural state would be expected to result in a net benefit to the ecological and visual resources within the region.

* Includes the evaluation for each alternative.

Cleanup of waste sites in accordance with the interim action RODs and focused FSs is ongoing and expected to continue until final action RODs are in place. As remedial actions under interim action RODs are completed, verification sampling and laboratory analyses are performed to document the extent to which RAGs established under the interim action RODs have been met. This information will be essential to supporting final action RODs.

Many buildings and structures are present in the 100 Area. The buildings and structures are evaluated for removal, usually using a CERCLA removal action. Once these structures are demolished and decommissioned under CERCLA non-time-critical removal actions, samples of the residual soil may be collected for analysis. If the analytical results indicate that the area is contaminated, the area is considered a potential waste site. The area is then evaluated, and a remedy is selected in accordance with the interim action ROD.

Characterization data and information developed through implementation of remedial actions under interim action RODs and this work plan will be coordinated and evaluated in support of reaching a final action ROD. To support a final action remedy at each OU, the current remedial actions under interim action RODs for the 100 Area OUs will continue until issuance of the final action ROD. While these remedial actions are underway, data will be generated to support final action decision making through the CERCLA process. The 100 Area integrated RI/FS process will be concluded with a data summary for all media (i.e., surface soil, vadose zone, groundwater, and surface water), as documented in Chapters 1 through 7 of the RI report, and evaluated through remedial alternatives analyses in the FS (Chapters 8 through 10). The final action remedy selection completes the RI/FS process and will be presented in the Proposed Plan. Under CERCLA, 5-year reviews continue to be required to evaluate the implementation and effectiveness of remedial actions.

There will be a period of time between when the final action ROD is approved and when the required RD/RAWP is prepared and issued. During this time period, DOE-RL plans to continue remedial activities, such as waste site RTD and groundwater pump-and-treat. In order for these actions to be consistent with the final action remedy selection, the current interim action RD/RAWPs will be modified using the TPA (Ecology et al., 1989a) change notice process to include the final cleanup levels specified in the final action ROD.

10.6 CERCLA and RCRA Corrective Action

The Tri-Party Agreement (Ecology et al., 1989a) states the intent of the Parties that CERCLA remediation at the Hanford Site will also fulfill the corrective action requirements for the Hanford Site as a facility containing permitted temporary storage and disposal (TSD) units. The Tri-Party Agreement (Ecology et al., 1989a) guides integration and coordination of CERCLA and RCRA at the Hanford Site. The following articles explain the relations of CERCLA remedial actions and RCRA corrective actions:

- Article IV, Paragraph 17, which cites the Tri-Parties' intent "to integrate DOE's CERCLA response obligations and RCRA corrective action obligations that relate to the release(s) of hazardous substances, hazardous wastes, pollutants and contaminants" covered by the Tri-Party Agreement (Ecology et al., 1989a)
- Article XIV, which applies to the performance of both CERCLA remedial action and RCRA corrective action

- Article XXIII, which acknowledges the potential for overlap between CERCLA and RCRA cleanup
- Article XXIV, which specifies the approach for regulatory oversight

Section 5.4 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b) addresses the rationale and approach for past practice cleanup. Two key objectives are to "ensure that only one past practice program will be applied at each operable unit," and that "the process selected be sufficiently comprehensive to satisfy the technical requirements of both statutory authorities and the respective regulations."

DOE's corrective action obligation on the Hanford Site is addressed in the RCRA Hanford Facility Permit *(Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* [WA7890008967]), Condition II.Y.2.a, which provides that DOE corrective action obligations are met through adherence to the Tri-Party Agreement (Ecology et al., 1989a). In particular, MTCA "Overview of Cleanup Standards" (WAC 173-340-700) through "Sediment Cleanup Standards" (WAC 173-340–760) function as ARAR standards for CERCLA remedial actions on the Hanford Site. Strontium-90

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