ECF-100NR2-12-0060
Revision 2

COST ESTIMATE INPUT FOR THE 100-NR-1/100-NR-2 REMEDIAL INVESTIGATION/FEASIBILITY REPORT

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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ENVIRONMENTAL CALCULATION COVER PAGE

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Terms

ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
COPC	contaminant of potential concern
ECF	environmental calculation file
ERDF	Environmental Restoration Disposal Facility
FS	feasibility study
IC	institutional control
ISS	interim safe storage
MNA	monitored natural attenuation
OU	operable unit
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PRZ	periodically rewetted zone
RAO	remedial action objective
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RTD	removal, treatment, and disposal
TPH	total petroleum hydrocarbons
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

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1 Purpose

The purpose of this environmental calculation (ECF) brief is to describe the key assumptions and quantity inputs that support development of remedial action alternative cost estimates for DOE/RL-2012-15, *Remedial Investigation/Feasibility Study (RI/FS) for the 100-NR-1 and 100-NR-2 Operable Units* (hereinafter referred to as the 100-N remedial investigation [RI]/feasibility study [FS]). The FS cost estimate quantity inputs are derived from site features, physical parameters, and characteristics of the 100-NR-1 Source and 100-NR-2 Groundwater Operable Units (OUs), as well as the remedial action alternative descriptions presented in Chapter 9 of the 100-N RI/FS. The FS cost estimates are prepared to an accuracy range of +50% to -30% and are used to support the detailed and comparative analysis of remedial alternatives, as described in 40 CFR 300.430, "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy the National Contingency Plan" (hereinafter referred to as the National Contingency Plan).

2 Background

This ECF supports development of remedial action alternative cost estimates for the identified 100-NR-1 OU waste site (source) and 100-NR-2 OU contaminant plumes (i.e., the remedial action target areas). A range of alternatives was developed in the 100-N RI/FS (DOE/RL-2012-15) for each target area based on the nature of the threat posed by each waste site. The potential threats and exposure pathways include human health direct contact risk in the top 4.6 m (15 ft) of soil, groundwater and/or surface water quality protection, and exceedance of a contaminant of concern (COC) applicable, relevant, or appropriate requirement (ARAR) for groundwater or surface water quality.

2.1 Waste Sites Carried into the Feasibility Study

A total of 23 waste sites (including 15 previously remediated waste sites and 8 waste sites remaining for remediation) require further action based on the identified risks and the known COCs or suspected contaminants of potential concern (COPCs) present. These wastes sites are addressed in the remedial action alternatives presented in the 100-N RI/FS (DOE/RL-2012-15). The 15 previously remediated waste sites (100-N-60, 100-N-63:2, 100-N-79, 100-N-83, 116-N-1, 116-N-2, 116-N-3, 116-N-4, UPR-100-N-13, UPR-100-N-25, UPR-100-N-26, UPR-100-N-31, UPR-100-N-4, UPR-100-N-5, and UPR-100-N-8) were carried forward to the FS based on the presence of one or more of the following:

- Shallow (e.g., <4.6 m [15 ft] below ground surface [bgs]) direct contact risk exceeding the upper bound of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) 10^{-4} to 10^{-6} risk range
- Potential to impact groundwater quality above a groundwater or surface water quality ARAR value based on comparison of soil COC concentrations to soil screening levels or preliminary remediation goals (PRGs)

Six of these waste sites also contain residual radionuclide contamination at depths >4.6 m (15 ft) bgs and present a potential risk from inadvertent exposure through deep excavation activities.

The eight waste sites remaining for remediation (100-N-107/100-N-84:10,[1] 100-N-66/UPR-100-N-35,[2] 2607-FSM, 600-339, 600-348, and UPR-100-N-17) have known or suspected shallow or deep soil contamination. Table 1 provides a brief description of these waste sites.

Table 1. Waste Sites Remaining for Remedial Action Evaluated in the FS – Presumed Basis for Action

Waste Site and WIDS Site Type	Waste Site Description	Presumed Basis for Action			Known or Suspected Contaminants by Media
		Human Health	Ecological	GWP/SWP	
100-N-107 Unplanned release	Accepted site. Includes two separate but proximal areas of contaminated soils adjacent to the bioventing wells installed to address UPR-100-N-17. One area is the miscellaneous pipelines located in the area referred to as the bioventing well island. The second area is located adjacent to well 199-N-172. Remedial action will be removal, treatment, and disposal when the wells are taken out of service.	X	X		Shallow soil: radionuclides, TPH, and PAH
100-N-84:10 Radioactive process sewer	Accepted site. Consolidated with waste site 100-N-107.	X	X		Shallow soil: radionuclides, TPH, and PAH
100-N-66 Reactor	Accepted site. Contaminated soil associated with the former N Reactor building and the 109N heat exchanger building. Contaminated soils are primarily located on the northwest side of the facility, >4.6 m (15 ft) below grade. Several locations beneath former reactor facilities were deferred to 100-N-66 following removal and remedial action because further soil removal could potentially affect ISS conditions and the structural integrity of the reactor (D4-100N-0046). Contaminated soil will be remediated in accordance with the CERCLA process after the ISS period has ended and the reactor is removed in accordance with the Tri-Party Agreement (Ecology et al., 1989) Milestone M-093-00 schedule			X	Deep soil: radionuclides and metals
UPR-100-N-35 Unplanned release	Accepted site. Consolidated with waste site 100-N-66.			X	Deep soil: radionuclides and metals

[1] Waste sites 100-N-107/100-N-84:10 are consolidated administratively but are shown separately in the RI/FS report (DOE/RL-2012-15) for waste site tracking purposes.

[2] Waste sites 100-N-66/UPR-100-N-35 are consolidated administratively but are shown separately in the RI/FS report (DOE/RL-2012-15) for waste site tracking purposes

Table 1. Waste Sites Remaining for Remedial Action Evaluated in the FS – Presumed Basis for Action

Waste Site and WIDS Site Type	Waste Site Description	Presumed Basis for Action			Known or Suspected Contaminants by Media
		Human Health	Ecological	GWP/SWP	
2607-FSM Septic tank	Accepted site. Single-chamber, reinforced-concrete septic tank and a drain field. The 2607-FSM septic system receives sanitary wastewater at a rate of approximately 2,082 L (550 gal) per week. The system will remain in use until the fire station is decommissioned in 2020 (DOE/RL-2011-42).	X	X		Shallow soil: septic waste
600-339 French drain	Accepted site. Consists of a 1.83 m (6 ft) diameter dry well and associated inlet piping (part of the original construction), located west of the 609 Building. The dry well was designed to collect rainwater draining from the roof, as well as floor drain waste from the entire building. All liquid waste originating from the routine use and maintenance of the fire station vehicles was flushed to this dry well. Because of the drywell's proximity to the fire station building, it cannot be remediated until after the building is demolished.	X	X		Shallow soil: TPH
600-348 Storage tank	Accepted site. Site contained four USTs: a 1,893 L (500 gal) gas tank from the original 1960 construction; a 7,571 L (2,000 gal) diesel fuel oil tank for the boiler; and two 1,893 L (500 gal) gas tanks (unleaded and diesel) added in 1979. The USTs are no longer in service. The first orphan site is the original 1,893 L (500 gal) tank that was removed in 1987 (CCN 141240); however, closure information was not found. Therefore, the underlying soils have been identified as an orphan site. Geophysics conducted for this tank found no features characteristic of a buried tank, confirming that the tank was removed. Based on field observations, the 7,571 L (2,000 gal) diesel tank is still present and has been identified as an orphan site. The two 1,893 L (500 gal) fuel tanks added in 1979 (and associated pump island) were removed from service September 18, 1991, were permanently closed in April 1992, and are not considered to be orphan sites. The waste site will be remediated after the fire station building is demolished.	X	X		Shallow soil: TPH, PAHs

Table 1. Waste Sites Remaining for Remedial Action Evaluated in the FS – Presumed Basis for Action

Waste Site and WIDS Site Type	Waste Site Description	Presumed Basis for Action			Known or Suspected Contaminants by Media
		Human Health	Ecological	GWP/SWP	
UPR-100-N-17 Unplanned release	An unplanned release that occurred at the 166-N Tank Farm. External corrosion of a 10.2 cm (4 in.) diesel oil supply line (between the oil storage tank and the west dike) caused the line to leak and release diesel oil to the vadose zone in August 1966. In 2011, the pipelines associated with the tank farm were removed and the contaminated vadose zone was excavated. A Phase I bioremediation pilot system was installed during fiscal year 2009 to address petroleum contamination in the vadose zone at this waste site. A full-scale bioventing system was installed and initiated in December 2012 at UPR-100-N-17 under the interim Record of Decision (EPA/ROD/R10-99/112).			X	Deep soil: TPH

References: CCN 141240, "Additional Information to the DRD UST Update" (interoffice memorandum from Y. Chien to S.K. Omberg).

DOE/RL-2011-42, *Hanford Ten-Year Site Plan For the Fiscal Period 2012-2021*, Volume I.

EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
GWP = groundwater protection
ISS = interim safe storage
PAH = polycyclic aromatic hydrocarbons
SWP = surface water protection
TPH = total petroleum hydrocarbons
Tri-Party Agreement = *Hanford Federal Facility Agreementand Consent Order*
UST = underground storage tank
WIDS = Waste Information Data System

Remedial action for the 2607-FSM, 600-339, 600-348 waste sites is deferred under all remedial action alternatives, except Alternative 1 (No Further Action), until the fire station is decommissioned. Contaminated soil at reactor waste sites 100-N-66/UPR-100-N-35 will be remediated in accordance with the CERCLA process after the interim safe storage (ISS) period has ended and the reactor is removed in accordance with the schedule for Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-093-00. No remedial alternatives, including cost estimates, were developed for the two reactor waste sites.

Twelve waste sites (100-N-31, 100-N-32, 100-N-38, 100-N-61:3, 100-N-64:3, 100-N-68, 118-N-1, UPR-100-N-10, UPR-100-N-12, UPR-100-N-3, UPR-100-N-39, and UPR-100-N-7) were carried forward to the FS based on potential direct contact risk for deep radionuclide contamination only, which will be addressed through a deep excavation restriction institutional control (IC). Except for 118-N-1, these waste sites are collectively referred to as the waste sites west of N Reactor/109-N heat exchanger building. Interim remedial action for these sites included removing contaminated soil to depths up to 9.5 m (31 ft) bgs. This ECF provides information to develop a rough order of magnitude cost for

excavating radiologically contaminated soil at the 12 deep radionuclide and 118-N-1 waste sites. The IC costs are included in the FS alternative cost estimates, whereas the rough order of magnitude cost is presented in the 100-N RI/FS (DOE/RL-2012-15) for informational purposes only and is not included in the FS remedial action alternative cost estimates.

2.2 Groundwater Plumes

The groundwater target areas include COC plumes for nitrate, strontium-90, total petroleum hydrocarbons (TPH)-diesel/TPH-oil, and tritium. The inferred target areas for continuing vadose zone/periodically rewetted zone (PRZ) sources include strontium-90 (Areas 3 and 5 [Appendix B, Figure B-1]).

2.3 Remedial Action Alternative Descriptions

The 100-N RI/FS (DOE/RL-2012-15) provides a range of alternatives for remediating contaminated soil, groundwater, and continuing sources. Evaluation of these alternatives, including a detailed and comparative analysis, is required by the CERCLA process. These alternatives blend an array of technologies to achieve the remedial action objectives (RAOs) for the 100-N Area COCs and COPCs. Chapter 9 of the 100-N RI/FS provides additional information on the alternatives and the technologies that comprise them. Table 2 presents a summary of the alternatives and the key components for each.

Table 2. Summary of Alternative Components

Components	Alternatives				
	2[a]	3[b]	4[c]	5[d]	6[e]
Waste Site Components					
ICs (including excavation and irrigation restrictions)	X	X	X	X	X
Natural attenuation (biodegradation)	X	X	X	X	X
Shallow RTD	X	X	X	X	X
Deep RTD			X	X	
In situ biological treatment (bioventing)		X	X		X
Continuing Vadose Zone/Periodically Rewetted Zone Source Components of Strontium-90 (Areas 3 and 5 [Appendix B, Figure B-1])					
Institutional controls (irrigation restrictions)	X	X	X	X	X
Deep RTD				X	
Groundwater Components					
MNA and ICs	X All COCs	X Sr-90, nitrate, tritium	X Sr-90, nitrate, tritium	X Sr-90, nitrate, tritium	X Nitrate, tritium
Nonaqueous-phase liquid recovery (removal of floating free petroleum product) from wells	X				
Biosparging (TPH plume)		X	X	X	X
Apatite PRB for shoreline Sr-90 (saturated zone)	X	X	X	X	X
Apatite treatment (stabilization/sequestration) for upland Sr-90 – saturated zone					X

Table 2. Summary of Alternative Components

Components	Alternatives				
	2[a]	3[b]	4[c]	5[d]	6[e]
Monitoring for infrequently detected contaminants of potential concern[f]	X	X	X	X	X

Note: "X" denotes that component applies to the listed alternative.

a. Alternative 2 – ICs and Shallow RTD for Waste Sites; with MNA and ICs (Nitrate, TPH, Tritium) and Apatite PRB (Strontium-90) for Groundwater.

b. Alternative 3 – ICs, Shallow RTD and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater.

c. Alternative 4 – ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater.

d. Alternative 5 – ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater.

e. Alternative 6 – ICs, Shallow RTD. and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater.

f. Contaminants of potential concern include arsenic, benzo(a)pyrene, cadmium, manganese, and nickel.

COC	=	contaminant of concern	PRB	=	permeable reactive barrier
IC	=	institutional control	RTD	=	removal, treatment, and disposal
MNA	=	monitored natural attenuation	TPH	=	total petroleum hydrocarbons

2.3.1 Alternative 1 – No Action

The National Contingency Plan (40 CFR 300.430(e)(6)) requires consideration of a no action alternative. This alternative would take no further action and would terminate the ICs and the bioventing and apatite permeable reactive barrier (PRB) interim actions underway in the 100-N Area. Conceptual designs or cost estimates are not prepared for Alternative 1 because no actions are proposed.

2.3.2 Alternative 2 – ICs, and Shallow RTD for Waste Sites; with MNA and ICs (Nitrate, TPH, and Tritium) and Apatite PRB (Strontium-90) for Groundwater

Alternative 2 (shown in Table 3) includes the following primary components:

- Remove, treat, and dispose (RTD) to address shallow soil direct contact exposure at post-Record of Decision (ROD) waste sites with presumed shallow soil exceeding human health direct contact PRGs
- ICs restricting excavation at waste sites with residual radionuclide contamination present at depths >4.6 m (15 ft) that pose a potential risk from inadvertent exposure through deep excavation activities
- Irrigation ICs for continuing PRZ sources to groundwater
- Extension of the existing apatite PRB from 305 to 670 m (1,000 to 2,200 ft) to sequester strontium-90 along the shoreline where concentrations exceed the 278 pCi/L riparian animal bioconcentration guide
- Monitored natural attenuation (MNA) with ICs restricting groundwater use until groundwater PRGs are met for strontium-90, nitrate, tritium, and TPH
- Groundwater monitoring for COPCs

Table 3. Description of Alternative Components for Alternative 2: ICs and Shallow RTD for Waste Sites; with MNA and ICs (Nitrate, TPH, Tritium) and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	ICs	ICs to be implemented during remediation within the 100-N Area for land-use management and waste site information management include the following: • Excavation permits are required to dig on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land-use and real property controls (e.g., proprietary controls including easements and covenants) ensure that land use is in accordance with Hanford Site plans and CERCLA decision documents. • Warning notices providing visual identification and warning of hazardous or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit human access to hazardous or sensitive areas. • Administrative mechanisms (e.g., WIDS database) to maintain and provide access to information on the location and nature of contamination. • Irrigation restrictions for sites exceeding surface/groundwater protection criteria.
Waste site component	Excavation ICs and Irrigation ICs (combined with radioactive decay)	Shallow excavation ICs, combined with radioactive decay, to minimize the potential for direct contact exposure for waste sites with potential shallow human health direct contact risk (100-N-60, UPR-100-N-13, UPR-100-N-26, 100-N-63:2, 100-N-79, 100-N-83, and 116-N-4) up to year 2079. Irrigation ICs, combined with radioactive decay, at waste sites with exceedances of groundwater protection SSLs* and PRGs* (116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 2140. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at waste sites carried forward to the FS due to additional factors (waste sites 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 72904. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at 12 waste sites carried forward to the FS for deep excavation ICs only, for up to 294 years (2311).
Waste site component	Irrigation ICs and Natural Attenuation by Biodegradation	Irrigation ICs at waste sites with exceedances of groundwater protection SSLs* and PRGs* for TPH (UPR-100-N-17 and previously remediated sites 116-N-2, UPR-100-N-5, and UPR-100-N-25). Biodegradation of TPH in soil is measured indirectly through groundwater plume monitoring for up to 100 years (2117). Monitoring plans will be developed as part of the RD/RAWP. For cost estimating, assumes one monitoring well will be installed downgradient from the 116-N-2 well group to measure TPH for up to 50 years (one-half the model-projected timeframe for groundwater concentrations to fall below the PRG for TPH).

Table 3. Description of Alternative Components for Alternative 2: ICs and Shallow RTD for Waste Sites; with MNA and ICs (Nitrate, TPH, Tritium) and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	RTD	Shallow excavation using standard excavation methods at post-ROD sites where contaminant concentrations are presumed to exceed direct contact PRGs. • For all contaminants of concern to depths up to 4.6 m (15 ft). • RTD for previously remediated waste sites 100-N-107/100-N-84:10 deferred until after bioventing system operations have been completed (assumes year 2020). • RTD for waste sites 2607-FSM, 600-339, and 600-348 deferred until after the fire station is decommissioned (assumes year 2020). Determining the extent of excavation uses an observational approach. Removal action process knowledge and field measurements will be used to guide day-to-day excavation. • Excavation using best practices, including appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of stockpiled materials in accordance with Occupational Safety and Health Administration standards. • Sampling and field screening during excavation. • Dust suppression during excavation to ensure that contaminants are not spread by wind. • Disposal of excavated material to ERDF as long as the material meets disposal criteria (ERDF-00011); waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
Continuing source components	Irrigation ICs	Irrigation ICs, combined with radioactive decay of continuing vadose zone/PRZ sources of Sr-90 to upland groundwater (includes Areas 3 and 5, located downgradient of waste site 116-N-1 [see Figure B-1 in Appendix B]).
Groundwater component	ICs	• Maintain existing sitewide ICs (including groundwater use restrictions) in place in accordance with DOE/RL-2001-41, with modifications to include area-specific supplemental controls. • Groundwater use at the 100-N Area is restricted except for monitoring and treatment, as approved by EPA. • Land-use and real property controls ensure that the use of groundwater is in accordance with Hanford Site plans and CERCLA decision documents. • Excavation permits are required to prevent uncontrolled drilling of new groundwater wells in the existing plumes or their paths on the Hanford Site. • ICs are maintained for each plume for the time required to reach PRGs.
Groundwater component	MNA	• Monitoring Sr-90, nitrate, TPH, and tritium to track attenuation processes by periodically sampling the groundwater monitoring well network for up to 290 years. • Monitoring network is assumed to include 59 monitoring wells and aquifer tubes, and installation of up to 8 new monitoring wells to supplement the existing monitoring network. • Monitoring plans will be developed as part of the RD/RAWP.
Groundwater component	NAPL recovery	NAPL recovery, which assumes Soakease™ (or similar) used at two monitoring wells. Sorbant is removed/disposed/replaced six times per year.
Groundwater component	In situ treatment – apatite injections – PRB saturated zone	To sequester Sr-90 in groundwater along the shoreline where concentrations exceed 278 pCi/L: • Expand apatite PRB from 274 to 670 m (900 to 2,200 ft).

Table 3. Description of Alternative Components for Alternative 2: ICs and Shallow RTD for Waste Sites; with MNA and ICs (Nitrate, TPH, Tritium) and Apatite PRB (Strontium-90) for Groundwater

Component		Description
		• Injection wells were installed in 2009. Assumes no additional injection wells needed. • Injections in year 1 and year 5. • Year 1 injection of 10% apatite along total PRB length, resulting in 20% apatite concentration in existing segment (274 m [900 ft]) and 10% apatite concentration in new segment (396 m [1,300 ft], 227,125 L [60,000 gal] per well). • Year 5 reinjection of 10% apatite into PRB extension (396 m [1,300 ft], 227,125 L [60,000 gal] per well), resulting in 20% apatite concentration in new segment. • Apatite emplaced at 3 to 7.3 m (10 to 24 ft) bgs. • Emplaced into deeper wells during low river stage and shallower wells during high river stage. • PRB thickness is 9.8 m (32 ft). • Injection rate to achieve 1.92 mg apatite per gram of sediment to allow sufficient capacity for long-term treatment. • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.
Groundwater component	Groundwater remedial action timeframe (with PRZ source contributions)	• Nitrate based on 45,000 µg/L DWS – Cmax: 40 years in aquifer. • Strontium-90 based on 8 pCi/L DWS – Cmax: 290 years in aquifer. • Strontium-90 based on 278 pCi/L aquatic benchmark – Cmax: 40 years at shoreline. • Tritium based on 20,000 pCi/L DWS – Cmax: 15 years in aquifer. • TPH based on 500 µg/L MTCA groundwater cleanup level – Cmax: 100 years in aquifer.
	Compliance monitoring requirements	Semiannual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met.

References: DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*.

Note: Soakease™ is a trademark of Durham Geo Slope Indicator, Stone Mountain, Georgia.

*For groundwater protection, the term "SSL" refers to a PRG value calculated for an irrigation land-use scenario, used to represent residential use. The term "PRG" refers to a PRG value calculated for conservation with native vegetation land use.

bgs = below ground surface
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cmax = peak concentration
DWS = drinking water standard
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
FS = feasibility study
IC = institutional control
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act (WAC 173-340, "Model Toxics Control Act—Cleanup")
NAPL = nonaqueous-phase liquid
PRB = permeable reactive barrier
PRG = preliminary remediation goal
PRZ = periodically rewetted zone
RD/RAWP = remedial design/remedial action work plan
ROD = Record of Decision
RTD = removal, treatment, and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons
WIDS = Waste Information Data System

2.3.3 Alternative 3 – ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Alternative 3 uses in situ bioventing and biosparging treatment to address TPH in soil and groundwater and shallow RTD for radiologically contaminated waste sites with >30 years decay timeframes. Table 4 provides a summary of the remedy components for Alternative 3.

Table 4. Description of Alternative Components for Alternative 3: ICs, Shallow RTD and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	ICs	ICs to be implemented during remediation within the 100-N Area for land-use management and waste site information management include the following: • Excavation permits are required to dig on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land-use and real property controls (e.g., 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 or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit human access to hazardous or sensitive areas. • Administrative mechanisms (e.g., WIDS database) to maintain and provide access to information on the location and nature of contamination. • Irrigation restrictions for sites exceeding surface/groundwater protection criteria.
Waste site component	Excavation ICs and Irrigation ICs (combined with radioactive decay)	Shallow excavation ICs, combined with radioactive decay, to minimize the potential for direct contact exposure for waste sites with potential shallow human health direct contact risk (100-N-63:2, 100-N-79, and 116-N-4) up to year 2038. Irrigation ICs, combined with radioactive decay, at waste sites with exceedances of groundwater protection SSLs* and PRGs* (116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 2140. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at waste sites carried forward to the FS due to additional factors (waste sites 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 72904. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at 12 waste sites carried forward to the FS for deep excavation ICs only, up to year 2311.
Waste site component	Irrigation ICs and Natural Attenuation by Biodegradation	Irrigation ICs at waste sites with exceedances of groundwater protection SSLs* and PRGs* for TPH (116-N-2, UPR-100-N-5, and UPR-100-N-25). Biodegradation of TPH in soil is measured indirectly through groundwater plume monitoring for up to 30 years (2047). Monitoring plans will be developed as part of the RD/RAWP. For cost estimating, assumes that one downgradient monitoring well will be installed to measure TPH for up to 15 years (one-half the projected timeframe for groundwater concentrations to fall below the PRG for TPH).

Table 4. Description of Alternative Components for Alternative 3: ICs, Shallow RTD and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	In situ biological treatment – bioventing	Aerobic degradation of TPH using bioventing at one waste site with exceedances of groundwater protection SSLs* and PRGs* (UPR-100-N-17): • For TPH at depths >4.6 m (15 ft) bgs. • Costs for bioventing system include installation and also operations and maintenance. • Expand existing bioventing system by adding two injection wells to treat vadose zone contamination below 5.5 m (18 ft) bgs and adding two air monitoring wells. • Assumes 25 years of operation. • Assumes three post-remediation confirmation boreholes to 36.6 m (120 ft) bgs. • Monitoring plans will be developed as part of the RD/RAWP.
Waste site component	RTD	Shallow excavation using standard excavation methods at previously remediated and post-ROD sites where contaminant concentrations are known or presumed to exceed direct contact PRGs. For all COCs to depths up to 4.6 m (15 ft): • RTD for previously remediated waste sites with decay timeframe >30 years (100-N-60, UPR-100-N-13, UPR-100-N-26, and 100-N-83). • RTD for waste sites 100-N-107/100-N-84:10 deferred until after bioventing system operations have been completed (assumes year 2042). • RTD for waste sites 2607-FSM, 600-339, and 600-348 deferred until after fire station is decommissioned (assumes year 2020). Determining the extent of excavation uses an observational approach. Removal actions process knowledge and field measurements will be used to guide day-to-day excavation. • Excavation using best practices, including appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of stockpiled materials in accordance with Occupational Safety and Health Administration standards. • Sampling and field screening during excavation. • Dust suppression during excavation to ensure that contaminants are not spread by wind. • Disposal of excavated material to ERDF as long as the material meets disposal criteria (ERDF-00011). Waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
Continuing source components	Irrigation ICs	Irrigation ICs, combined with radioactive decay of continuing vadose zone/PRZ sources of Sr-90 to upland groundwater (includes Areas 3 and 5, located downgradient of waste site 116-N-1 [see Figure B-1 in Appendix B]).
Groundwater component	ICs	• Maintain existing sitewide ICs (including groundwater use restrictions) in place in accordance with DOE/RL-2001-41, with modifications to include area-specific supplemental controls. • Groundwater use at the 100-N Area is restricted except for monitoring and treatment, as approved by EPA. • Land-use and real property controls ensure that the use of groundwater is in accordance with Hanford Site plans and CERCLA decision documents. • Excavation permits are required to prevent uncontrolled drilling of new groundwater wells in the existing plumes or their paths on the Hanford Site. • ICs are maintained for each plume for the time required to reach PRGs.

Table 4. Description of Alternative Components for Alternative 3: ICs, Shallow RTD and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Groundwater component	MNA and performance monitoring	• Monitoring nitrate and tritium to track attenuation processes by periodically sampling the monitoring well network for up to 40 years. • Monitoring Sr-90 for 290 years. • Monitoring TPH for 25 years. • Monitoring network assumed to include 59 monitoring wells and aquifer tubes, and installation of up to eight new monitoring wells to supplement the existing monitoring network. • Monitoring plans will be developed as part of the RD/RAWP.
Groundwater component	In situ treatment – apatite injections – PRB saturated zone component	To sequester Sr-90 in groundwater along the shoreline where concentrations exceed 278 pCi/L: • Expand apatite PRB from 274 to 670 m (900 to 2,200 ft). • Injection wells were installed in 2009. Assumes no additional injection wells are needed. • Injections in year 1 and year 5. • Year 1 injection of 10% apatite along total PRB length, resulting in 20% apatite concentration in existing segment (274 m [900 ft]) and 10% apatite concentration in new segment (396 m [1,300 ft], 227,125 L [60,000 gal] per well). • Year 5 reinjection of 10% apatite into PRB extension (396 m [1,300 ft], 227,125 L [60,000 gal] per well), resulting in 20% apatite concentration in new segment. • Apatite emplaced at 3 to 7.3 m (10 to 24 ft) bgs. • Emplaced into deeper wells during low river stage and shallower wells during high river stage. • PRB thickness is 9.8 m (32 ft). • Injection rate to achieve 1.92 mg apatite per gram of sediment to allow sufficient capacity for long-term treatment. • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.
Groundwater component	In situ treatment – biological	Biosparging for TPH in groundwater: • Target area is TPH-diesel plume >500 µg/L. • Introduce oxygen from ambient air to enhance aerobic bioremediation (assumes TPH degradation rate of $k = 0.1\ day^{-1}$). • Install seven rows of injection wells across 10,800 m^2 (116,250 ft^2) treatment area. Assumes 43 wells total. • Groundwater monitoring until cleanup confirmed.
Groundwater component	Groundwater remedial action timeframe (with PRZ source contributions)	• Nitrate based on 45,000 µg/L DWS – Cmax: 40 years in aquifer. • Sr-90 based on 8 pCi/L DWS – Cmax: 290 years in aquifer. • Sr-90 based on 278 pCi/L aquatic benchmark – Cmax: 40 years at shoreline. • Tritium based on 20,000 pCi/L DWS – Cmax: 15 years in aquifer. • TPH based on 500 µg/L MTCA groundwater cleanup level – Cmax: 25 years in aquifer.
Groundwater component	Compliance monitoring requirements	Semiannual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met.

Table 4. Description of Alternative Components for Alternative 3: ICs, Shallow RTD and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component	Description

References: DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*.

*For groundwater protection, the term "SSL" refers to a PRG value calculated for an irrigation land-use scenario, used to represent residential use. The term "PRG" refers to a PRG value calculated for conservation with native vegetation land use.

bgs = below ground surface
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cmax = peak concentration
DWS = drinking water standard
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
FS = feasibility study
IC = institutional control
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act (WAC 173-340, "Model Toxics Control Act—Cleanup")
PRB = permeable reactive barrier
PRG = preliminary remediation goal
PRZ = periodically rewetted zone
RD/RAWP = remedial design/remedial action work plan
ROD = Record of Decision
RTD = removal, treatment, and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons
WIDS = Waste Information Data System

2.3.4 Alternative 4 – ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Alternative 4 includes the same remedy components as described above for Alternative 3 but uses deep RTD for waste sites with groundwater protection PRG exceedances for strontium-90. Table 5 provides a summary of the remedy components for Alternative 4.

Table 5. Description of Alternative Components for Alternative 4: ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	ICs	ICs to be implemented during remediation within the 100-N Area for land-use management and waste site information management include the following: • Excavation permits are required to dig on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land-use and real property controls (e.g., 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 or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit human access to particular hazardous or sensitive areas. • Administrative mechanisms (e.g., WIDS database) to maintain and provide access to information on the location and nature of contamination. • Irrigation restrictions for sites exceeding surface/groundwater protection criteria.

Table 5. Description of Alternative Components for Alternative 4: ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	Excavation ICs and Irrigation ICs (combined with radioactive decay)	Shallow excavation ICs, combined with radioactive decay, to minimize the potential for direct contact exposure for waste sites with potential shallow human health direct contact risk (100-N-63:2, 100-N-79, and 116-N-4) up to year 2038. Irrigation ICs, combined with radioactive decay, at waste sites with exceedances of groundwater protection SSLs* and PRGs* (116-N-3 Trench) up to year 2072. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at waste sites carried forward to the FS due to additional factors for waste sites 100-N-63:2 and 116-N-3 trench (Area 2 [Figure B-1 of Appendix B]) up to year 2340. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at 12 waste sites carried forward to the FS for deep excavation ICs only, up to year 2311.
Waste site component	Irrigation ICs and Natural Attenuation by Biodegradation	Irrigation ICs at waste sites with exceedances of groundwater protection SSLs* and PRGs* for TPH (116-N-2, UPR-100-N-5, and UPR-100-N-25). Biodegradation of TPH in soil is measured indirectly through groundwater plume monitoring for up to 30 years (2047). Monitoring plans will be developed as part of the RD/RAWP For cost estimating, assumes one downgradient monitoring well will be installed to measure TPH for up to 15 years (one-half the projected timeframe for groundwater concentrations to fall below the PRG for TPH).
Waste site component	In situ biological treatment - bioventing	Aerobic degradation of TPH using bioventing at one waste site with exceedances of groundwater protection SSLs* and PRGs* (UPR-100-N-17): • For TPH at depths >4.6 m (15 ft) bgs. • Costs for bioventing system include installation, as well as operations and maintenance. • Expand existing bioventing system by adding two injection wells to treat vadose zone contamination below 5.5 m (18 ft) bgs and adding two air monitoring wells. • Assumes 25 years of operation. • Assumes three post-remediation confirmation boreholes to 36.6 m (120 ft) bgs. • Monitoring plans will be developed as part of the RD/RAWP.

Table 5. Description of Alternative Components for Alternative 4: ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	RTD	Shallow excavation using standard excavation methods at previously remediated and post-ROD sites where contaminant concentrations are known or presumed to exceed direct contact PRGs. For all COCs to depths up to 4.6 m (15 ft): • RTD for previously remediated waste sites with decay timeframe >30 years (100-N-60, UPR-100-N-13, UPR-100-N-26, and 100-N-83). • RTD for waste sites 100-N-107/100-N-84:10 deferred until after bioventing system operations have been completed (assumes year 2042). • RTD for waste sites 2607-FSM, 600-339, and 600-348 deferred until after the fire station is decommissioned (assumes year 2020). Deep excavation using deep excavation methods at previously remediated waste sites with exceedances of groundwater protection SSLs* and PRGs*: • Waste sites 116-N-1 Crib and Trench (includes Area 1 and one-half of Area 4 [see Figure B-1 in Appendix B]), 116-N-3 Crib (includes Area 0 [Figure B-1 in Appendix B]), UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8 for Sr-90 at depths >4.6 m (15 ft) bgs. Determining the extent of excavation uses an observational approach. Removal actions process knowledge and field measurements will be used to guide day-to-day excavation. • Excavation using best practices, including appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of stockpiled materials in accordance with Occupational Safety and Health Administration standards. • Sampling and field screening during excavation. • Dust suppression during excavation to ensure that contaminants are not spread by wind. • Disposal of excavated material to ERDF as long as the material meets disposal criteria (ERDF-00011). Waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
Continuing Source components	Irrigation ICs	Irrigation ICs, combined with radioactive decay, for continuing vadose zone/PRZ sources of Sr-90 to upland groundwater (includes Areas 3 and 5 located downgradient of waste site 116-N-1 [see Figure B-1 in Appendix B]).
Groundwater components	ICs	• Maintain existing sitewide ICs (including groundwater use restrictions) in place in accordance with DOE/RL-2001-41, with modifications to include area-specific supplemental controls. • Groundwater use at the 100-N Area is restricted except for monitoring and treatment, as approved by EPA. • Land-use and real property controls ensure that the use of groundwater is in accordance with Hanford Site plans and CERCLA decision documents. • Excavation permits are required to prevent uncontrolled drilling of new groundwater wells in the existing plumes or their paths on the Hanford Site. • ICs are maintained for each plume for the time required to reach PRGs.

Table 5. Description of Alternative Components for Alternative 4: ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Groundwater component	MNA and performance monitoring	• Monitoring nitrate and tritium to track attenuation processes by periodically sampling the monitoring well network for up to 40 years. • Monitoring Sr-90 for 290 years. • Monitoring TPH for 25 years. • Monitoring network is assumed to include 59 monitoring wells and aquifer tubes, and installation of up to 8 new monitoring wells to supplement the existing monitoring network. • Monitoring plans will be developed as part of the RD/RAWP.
Groundwater component	In situ treatment – apatite injections – PRB saturated zone	To sequester Sr-90 in groundwater along the shoreline where concentrations exceed 278 pCi/L: • Expand apatite PRB from 274 to 670 m (900 to 2,200 ft). • Injection wells were installed in 2009. Assumes no additional injection wells needed. • Injections in year 1 and year 5. • Year 1 injection of 10% apatite along total PRB length, resulting in 20% apatite concentration in existing segment (274 m [900 ft]) and 10% apatite concentration in new segment (396 m [1,300 ft], 227,125 L [60,000 gal] per well). • Year 5 reinjection of 10% apatite into PRB extension (396 m [1,300 ft], 227,125 L [60,000 gal] per well), resulting in 20% apatite concentration in new segment. • Apatite emplaced at 3 to 7.3 m (10 to 24 ft) bgs. • Emplaced into deeper wells during low river stage and shallower wells during high river stage. • PRB thickness is 9.8 m (32 ft). • Injection rate to achieve 1.92 mg apatite per gram of sediment to allow sufficient capacity for long-term treatment. • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.
Groundwater component	In situ treatment – biological	Biosparging for TPH in groundwater: • Target area is TPH-diesel plume >500 µg/L. • Introduce oxygen from ambient air to enhance aerobic bioremediation (assumes TPH degradation rate of $k = 0.1\ day^{-1}$). • Install seven rows of injection wells across 10,800 m^2 (116,250 ft^2) treatment area. Assumes 43 wells total. • Groundwater monitoring until cleanup confirmed.
Groundwater component	Groundwater remedial action timeframe (with PRZ source contributions)	• Nitrate based on 45,000 µg/L DWS – Cmax: 30 years in aquifer. • Sr-90 based on 8 pCi/L DWS – Cmax: 290 years in aquifer. • Sr-90 based on 278 pCi/L aquatic benchmark – Cmax: 40 years at shoreline. • Tritium based on 20,000 pCi/L DWS – Cmax: 15 years in aquifer. • TPH based on 500 µg/L MTCA groundwater cleanup level – Cmax: 25 years in aquifer.

Table 5. Description of Alternative Components for Alternative 4: ICs, Shallow/Deep RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Groundwater component	Compliance monitoring requirements	Semiannual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met.

References: DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*.

*For groundwater protection, the term "SSL" refers to a PRG value calculated for an irrigation land-use scenario, used to represent residential use. The term "PRG" refers to a PRG value calculated for conservation with native vegetation land use.

bgs = below ground surface
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cmax = peak concentration
DWS = drinking water standard
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
FS = feasibility study
IC = institutional control
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act (WAC 173-340, "Model Toxics Control Act—Cleanup")
PRB = permeable reactive barrier
PRG = preliminary remediation goal
PRZ = periodically rewetted zone
RD/RAWP = remedial design/remedial action work plan
ROD = Record of Decision
RTD = removal, treatment, and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons
WIDS = Waste Information Data System

2.3.5 Alternative 5 – ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Alternative 5 uses deep RTD for waste sites with groundwater protection PRG exceedances and vadose zone and PRZ continuing sources of TPH and strontium-90. Table 6 provides a summary of the remedy components for Alternative 5.

Table 6. Description of Alternative Components for Alternative 5: ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Waste site component	ICs	ICs to be implemented during remediation within the 100-N Area for land-use management and waste site information management include the following: • Excavation permits are required to dig on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land-use and real property controls (e.g., 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 or sensitive areas.

Table 6. Description of Alternative Components for Alternative 5: ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
		• Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit human access to particular hazardous or sensitive areas. • Administrative mechanisms (e.g., WIDS database) to maintain and provide access to information on the location and nature of contamination. • Irrigation restrictions for sites exceeding surface/groundwater protection criteria.
Waste site component	Excavation ICs and Irrigation ICs (combined with radioactive decay)	Shallow excavation ICs, combined with radioactive decay, to minimize the potential for direct contact exposure for waste sites with potential shallow human health direct contact risk (100-N-63:2, 100-N-79, and 116-N-4) up to year 2038. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at waste sites carried forward to the FS due to additional factors (waste site 100-N-63:2) up to year 2038. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at 12 waste sites carried forward to the FS for deep excavation ICs only, up to year 2311.
Waste site component	Irrigation ICs and Natural Attenuation by Biodegradation	Irrigation ICs at waste sites with exceedances of groundwater protection SSLs* and PRGs* for TPH (116-N-2, UPR-100-N-5, and UPR-100-N-25). Biodegradation of TPH in soil is measured indirectly through groundwater plume monitoring for up to 30 years (2047). Monitoring plans will be developed as part of the RD/RAWP. For cost estimating, assumes that one downgradient monitoring well will be installed to measure TPH for up to 15 years (one-half the projected timeframe for groundwater concentrations to fall below the PRG for TPH).
Waste site component	Aggressive RTD	Shallow excavation using standard excavation methods at previously remediated and post-ROD sites where contaminant concentrations are known or presumed to exceed direct contact PRGs. For all COCs to depths up to 4.6 m (15 ft): • RTD for previously remediated waste sites with decay timeframe >30 years (100-N-60, UPR-100-N-13, UPR-100-N-26, and 100-N-83). • RTD for waste sites 100-N-107/100-N-84:10 deferred until after bioventing system operations have been completed (assumes year 2020). • RTD for waste sites 2607-FSM, 600-339, and 600-348 deferred until after the fire station is decommissioned (assumes year 2020). Deep excavation using deep excavation methods at previously remediated waste sites with exceedances of groundwater protection SSLs* and PRGs*: • Waste sites 116-N-1 Crib and Trench (includes Areas 1 and 4 [see Figure B-1 in Appendix B]), 116-N-3 crib and trench (includes Areas 0 and 2 [Figure B-1 in Appendix B), UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8 for radionuclides at depths >4.6 m (15 ft) bgs. Determining the extent of excavation uses an observational approach. Removal actions process knowledge and field measurements will be used to guide day-to-day excavation: • Excavation using best practices, including appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of stockpiled materials in accordance with Occupational Safety and Health Administration standards. • Sampling and field screening during excavation.

Table 6. Description of Alternative Components for Alternative 5: ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
		• Dust suppression during excavation to ensure that contaminants are not spread by wind. • Disposal of excavated material to ERDF as long as the material meets disposal criteria (ERDF-00011). Waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
Continuing source component	Irrigation ICs	Irrigation ICs, combined with radioactive decay, for continuing vadose zone/PRZ sources of Sr-90 to upland groundwater (includes Areas 3 and 5 located downgradient of waste site 116-N-1 [see Figure B-1 in Appendix B]).
Groundwater components	ICs	• Maintain existing sitewide ICs (including groundwater use restrictions) in place in accordance with DOE/RL-2001-41, with modifications to include area-specific supplemental controls. • Groundwater use at the 100-N Area is restricted except for monitoring and treatment, as approved by EPA. • Land-use and real property controls ensure that the use of groundwater is in accordance with Hanford Site plans and CERCLA decision documents. • Excavation permits are required to prevent uncontrolled drilling of new groundwater wells in the existing plumes or their paths on the Hanford Site. • ICs are maintained for each plume for the time required to reach PRGs.
Groundwater component	MNA and performance monitoring	• Monitoring nitrate and tritium to track attenuation processes by periodically sampling the monitoring well network for up to 30 years. • Monitoring Sr-90 for up to 290 years. • Monitoring TPH for 25 years. • Monitoring network is assumed to include 59 monitoring wells and aquifer tubes, and installation of up to 8 new monitoring wells to supplement the existing monitoring network. • Monitoring plans will be developed as part of the RD/RAWP.
Groundwater component	In situ treatment – apatite injections – PRB saturated zone	To sequester Sr-90 in groundwater along the shoreline where concentrations exceed 278 pCi/L: • Expand apatite PRB from 274 to 670 m (900 to 2,200 ft). • Injection wells were installed in 2009. Assumes no additional injection wells needed. • Injections in year 1 and year 5. • Year 1 injection of 10% apatite along total PRB length, resulting in 20% apatite concentration in existing segment (274 m [900 ft]) and 10% apatite concentration in new segment (396 m [1,300 ft], 227,125 L [60,000 gal] per well). • Year 5 reinjection of 10% apatite into PRB extension (396 m [1,300 ft], 227,125 L [60,000 gal] per well), resulting in 20% apatite concentration in new segment. • Apatite emplaced at 3 to 7.3 m (10 to 24 ft) bgs. • Emplaced into deeper wells during low river stage and shallower wells during high river stage. • PRB thickness is 9.8 m (32 ft). • Injection rate to achieve 1.92 mg apatite per gram of sediment to allow sufficient capacity for long-term treatment. • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.

Table 6. Description of Alternative Components for Alternative 5: ICs and Aggressive RTD for Waste Sites and Continuing Sources; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB (Strontium-90) for Groundwater

Component		Description
Groundwater component	In situ treatment – biological	Biosparging for TPH in groundwater: • Target area is TPH-diesel plume >500 µg/L. • Introduce oxygen from ambient air to enhance aerobic bioremediation (assumes TPH degradation rate of k = 0.1 day^{-1}). • Install seven rows of injection wells across 10,800 m^2 (116,250 ft^2) treatment area. Assumes 43 wells total. • Groundwater monitoring until cleanup confirmed.
Groundwater component	Groundwater remedial action timeframe (with PRZ source contributions)	• Nitrate based on 45,000 µg/L DWS – Cmax: 30 years in aquifer. • Sr-90 based on 8 pCi/L DWS – Cmax: 290 years in aquifer. • Sr-90 based on 278 pCi/L aquatic benchmark – Cmax: 40 years at shoreline. • Tritium based on 20,000 pCi/L DWS – Cmax: 15 years in aquifer. • TPH based on 500 µg/L MTCA groundwater cleanup level – Cmax: 25 years in aquifer.
Groundwater component	Compliance monitoring requirements	Semiannual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met.

References: DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*.

*For groundwater protection, the term "SSL" refers to a PRG value calculated for an irrigation land-use scenario, used to represent residential use. The term "PRG" refers to a PRG value calculated for conservation with native vegetation land use.

bgs = below ground surface
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cmax = peak concentration
DWS = drinking water standard
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
FS = feasibility study
IC = institutional control
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act (WAC 173-340, "Model Toxics Control Act—Cleanup")
PRB = permeable reactive barrier
PRG = preliminary remediation goal
PRZ = periodically rewetted zone
RD/RAWP = remedial design/remedial action work plan
ROD = Record of Decision
RTD = removal, treatment, and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons
WIDS = Waste Information Data System

2.3.6 Alternative 6 – ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (nitrate, tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater

Alternative 6 is similar to Alternative 3 but uses plume wide treatment of strontium-90 in upland groundwater, through apatite injection, within the area exceeding the 80 pCi/L isopleth. Table 7 provides a summary of the remedy components for Alternative 6.

Table 7. Description of Alternative Components for Alternative 6: ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater

Component		Description
Waste site component	ICs	ICs to be implemented during remediation within the 100-N Area for land-use management and waste site information management include the following: • Excavation permits are required to dig on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land-use and real property controls (e.g., 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 or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to provide entry restrictions to prevent or limit human access to particular hazardous or sensitive areas. • Administrative mechanisms (e.g., WIDS database) to maintain and provide access to information on the location and nature of contamination. • Irrigation restrictions for sites exceeding surface/groundwater protection criteria.
Waste site component	Excavation ICs and Irrigation ICs (combined with radioactive decay)	Shallow excavation ICs, combined with radioactive decay, to minimize the potential for direct contact exposure for waste sites with potential shallow human health direct contact risk (100-N-63:2, 100-N-79, and 116-N-4) up to year 2038. Irrigation ICs, combined with radioactive decay, at waste sites with exceedances of groundwater protection SSLs* and PRGs* (116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 2140. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at waste sites carried forward to the FS due to additional factors (waste sites 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-31, UPR-100-N-4, and UPR-100-N-8) up to year 72904. Deep excavation ICs, combined with radioactive decay, to minimize the potential for inadvertent exposure through deep excavation activities at 12 waste sites carried forward to the FS for deep excavation ICs only, up to year 2311.
Waste site component	Irrigation ICs and Natural Attenuation by Biodegradation	Irrigation ICs, at waste sites with exceedances of groundwater protection SSLs* and PRGs* for TPH (116-N-2, UPR-100-N-5, and UPR-100-N-25). Biodegradation of TPH in soil is measured indirectly through groundwater plume monitoring for up to 30 years (2047). Monitoring plans will be developed as part of the RD/RAWP. For cost estimating, assumes that one downgradient monitoring well will be installed to measure TPH for up to 15 years (one-half the projected timeframe for groundwater concentrations to fall below the PRG for TPH).
Waste site component	In situ biological treatment – bioventing	Aerobic degradation of TPH using bioventing at one waste site with exceedances of groundwater protection SSLs* and PRGs* (UPR-100-N-17): • For TPH at depths >4.6 m (15 ft) bgs. • Costs for bioventing system include installation, as well as operations and maintenance. • Expand existing bioventing system by adding two injection wells to treat vadose zone contamination below 5.5 m (18 ft) bgs and adding two air monitoring wells. • Assumes 25 years of operation. • Assumes three post-remediation confirmation boreholes to 36.6 m (120 ft) bgs. • Monitoring plans will be developed as part of the RD/RAWP.

Table 7. Description of Alternative Components for Alternative 6: ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater

Component		Description
Waste site component	RTD	Shallow excavation using standard excavation methods at previously remediated and post-ROD sites where contaminant concentrations are known or presumed to exceed direct contact PRGs. For all COCs to depths up to 4.6 m (15 ft): • RTD for previously remediated waste sites with decay timeframe >30 years (100-N-60, UPR-100-N-13, UPR-100-N-26, and 100-N-83). • RTD for waste sites 100-N-107/100-N-84:10 deferred until after bioventing system operations have been completed (assumes year 2042). • RTD for waste sites 2607-FSM, 600-339, and 600-348 deferred until after fire station is decommissioned (assumes year 2020). • Excavation using best practices, including appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of stockpiled materials in accordance with Occupational Safety and Health Administration standards. • Sampling and field screening during excavation. • Dust suppression during excavation to ensure that contaminants are not spread by wind. • Disposal of excavated material to ERDF as long as the material meets disposal criteria (ERDF-00011). Waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
Continuing source components	Irrigation ICs	Irrigation ICs, combined with radioactive decay, for continuing vadose zone/PRZ sources of Sr-90 to upland groundwater (includes Areas 3 and 5 located downgradient of waste site 116-N-1 [see Figure B-1 in Appendix B]).
Groundwater component	ICs	• Maintain existing sitewide ICs (including groundwater use restrictions) in place in accordance with DOE/RL-2001-41, with modifications to include area-specific supplemental controls. • Groundwater use at the 100-N Area is restricted except for monitoring and treatment, as approved by EPA. • Land-use and real property controls ensure that the use of groundwater is in accordance with Hanford Site plans and CERCLA decision documents. • Excavation permits are required to prevent uncontrolled drilling of new groundwater wells in the existing plumes or their paths on the Hanford Site. • ICs are maintained for each plume for the time required to reach PRGs.
Groundwater component	MNA and performance monitoring	• Monitoring nitrate and tritium to track attenuation processes by periodically sampling the monitoring well network for up to 30 years. • Monitoring Sr-90 for up to 190 years. • Monitoring TPH for 25 years. • Monitoring network assumed to include 59 monitoring wells and aquifer tubes, and installation of up to 8 new monitoring wells to supplement the existing monitoring network. • Monitoring plans will be developed as part of the RD/RAWP.

Table 7. Description of Alternative Components for Alternative 6: ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater

Component		Description
Groundwater component	In situ treatment – apatite injections – PRB saturated zone component	To sequester Sr-90 in groundwater along the shoreline where concentrations exceed 278 pCi/L: • Complete expansion of apatite PRB from 274 to 670 m (900 to 2,200 ft). • Injection wells were installed in 2009. Assumes no additional injection wells are needed. • Injection of 10% apatite along total PRB length, resulting in 20% apatite concentration in existing segment (274 m [900 ft]) and 10% apatite concentration in new segment (396 m [1,300 ft], 227,125 L [60,000 gal] per well). • Apatite emplaced at 3 to 7.3 m (10 to 24 ft) bgs. • PRB thickness is 9.8 m (32 ft). • Injection rate to achieve 1.92 mg apatite per gram of sediment to allow sufficient capacity for long-term treatment. • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.
Groundwater component	In situ treatment – apatite injections – upland saturated zone component	To sequester Sr-90 in upland groundwater where concentrations exceed 8 pCi/L: • Treatment of 42 ha (104 ac) groundwater plume containing Sr-90 concentrations >80 pCi/L. • Assumes 2,300 injection wells 23 to 27.4 m (75 to 90 ft) bgs, each with a radius of influence of 7.6 m (25 ft). • Assumes injection of 10% apatite (227,125 L [60,000 gal] per well). • Monitor to evaluate effectiveness at reducing Sr-90 concentrations.
Groundwater component	In situ treatment – biological	Biosparging for TPH in groundwater: • Target area is TPH-diesel plume >500 µg/L. • Introduce oxygen from ambient air to enhance aerobic bioremediation (assumes TPH degradation rate of $k = 0.1\ day^{-1}$). • Install seven rows of injection wells across 10,800 m^2 (116,250 ft^2) treatment area. Assumes 43 wells total. • Groundwater monitoring until cleanup confirmed.
Groundwater component	Groundwater remedial action time frame (with PRZ source contributions)	• Nitrate based on 45,000 µg/L DWS – Cmax: 40 years in aquifer. • Sr-90 based on 8 pCi/L DWS – Cmax: 190 years in aquifer. • Sr-90 based on 278 pCi/L aquatic benchmark – Cmax: 45 years at shoreline. • Tritium based on 20,000 pCi/L DWS – Cmax: 15 years in aquifer. • TPH based on 500 µg/L MTCA groundwater cleanup level – Cmax: 25 years in aquifer.
Groundwater component	Compliance monitoring requirements	Semiannual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met.

Table 7. Description of Alternative Components for Alternative 6: ICs, Shallow RTD, and Bioventing for Waste Sites; with MNA and ICs (Nitrate, Tritium), Biosparging (TPH), and Apatite PRB and In Situ Treatment (Strontium-90) for Groundwater

Component	Description

References: DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*.

*For groundwater protection, the term "SSL" refers to a PRG value calculated for an irrigation land-use scenario, used to represent residential use. The term "PRG" refers to a PRG value calculated for conservation with native vegetation land use.

bgs	=	below ground surface	PRB	=	permeable reactive barrier
CERCLA	=	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*	PRG	=	preliminary remediation goal
			PRZ	=	periodically rewetted zone
Cmax	=	peak concentration	RD/RAWP	=	remedial design/remedial action work plan
DWS	=	drinking water standard	ROD	=	Record of Decision
EPA	=	U.S. Environmental Protection Agency	RTD	=	removal, treatment, and disposal
ERDF	=	Environmental Restoration Disposal Facility	SSL	=	soil screening level
FS	=	feasibility study	TPH	=	total petroleum hydrocarbons
IC	=	institutional control	WIDS	=	Waste Information Data System
MNA	=	monitored natural attenuation			
MTCA	=	Model Toxics Control Act (WAC 173-340, "Model Toxics Control Act—Cleanup")			

2.4 Remedial Action Timeframes

The remedial action alternatives achieve PRGs at the individual waste sites and groundwater COC plumes over a range of timeframes. With respect to the groundwater plumes, the upper range of the remediation timeframe was defined through numerical modeling based on the time required for the peak (Cmax) concentration, within the model domain, to decline to the PRG. For the purposes of defining remedial action durations for cost estimating purposes, the average Cmax timeframe is used (based on best-estimate initial concentrations).

3 Methodology

To develop cost inputs for the 100-N Area remedial action alternatives, simple calculations are generally performed using Microsoft® Excel® spreadsheets. Examples of the types of calculations included in this calculation brief are as follows:

- Total number of groundwater samples = Number of groundwater samples per well × number of wells
- Total apatite injection volume (gal) = Apatite injection volume per well (gal) × total number of wells

Due to the basic nature of these calculations, developing a detailed methodology for each calculation is not necessary. Section 4 provides the key inputs and assumptions that support each calculation, and Section 6 provides a summary of the spreadsheet calculations.

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4 Assumptions and Inputs

This section describes the overall assumptions applicable to the 100-N Area remedial action alternatives. The assumptions associated with the cost calculations were grouped into the following categories:

- ICs
- Vadose zone components (waste sites)
- Continuing source components (strontium-90 and nitrate)
- Groundwater components

4.1 Institutional Controls

While remediation is underway, ICs will be put in place to control access and prevent exposure to contamination. The ICs for the 100-N Area are expected to be implemented independently for each waste site or groundwater plume. In accordance with DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*, ICs are currently in place to protect workers and control site access and will be continued during the period of remedial actions. ICs that are in place to prevent exposure to contamination will remain in place until waste sites or groundwater plumes are remediated.

When remediation is complete, ICs will be put in place to address waste site contamination using excavation and irrigation restrictions. Additional waste sites may be added through closure reclassifications.

Programs are in place to control access to and specific uses of the Hanford Site (in addition to preserving the Hanford Reach National Monument and providing security and safety) that also serve to protect human health and the environment by limiting potential exposure to hazardous substances. Many of these multipurpose or programmatic controls are typically required ICs by each CERCLA ROD for the Hanford Site. Programmatic controls include the following:

- Hanford Site access controls
- Personnel badging
- Real estate and deeds
- Warning signs along the Columbia River bank and other access points
- Current Sitewide IC plan (DOE/RL-2001-41)
- Controls for excavating soil, accessing and using groundwater, and irrigation restrictions

While these controls transcend any specific CERCLA ROD or the overall CERCLA cleanup, the U.S. Department of Energy and the U.S. Environmental Protection Agency recognize the importance of maintaining these controls until unrestricted use (related to the protection of human health and the environment) is permitted.

The eight waste sites remaining for remediation (100-N-107/100-N-84:10, 100-N-66/UPR-100-N-35, 2607-FSM, 600-339, 600-348, and UPR-100-N-17) have known or suspected shallow or deep soil contamination. Remedial action has been delayed due to the presence of overlying structures:

- Waste sites 2607-FSM, 600-339, and 600-348 have known or suspected shallow soil contamination. These sites will be remediated using RTD after the overlying fire station is decommissioned in 2020.

- Waste sites 100-N-107/100-N-84:10 have known shallow soil radiological contamination that was left in place because the waste sites are adjacent to the bioventing system wells. These sites will be remediated using RTD after the bioventing wells are decommissioned. The bioventing system is remediating TPH-contaminated deep soil (waste site UPR-100-N-17). Alternatives 2 through 6 include MNA, RTD, or bioventing components to address contaminated soil at waste site UPR-100-N-17.
- Contaminated soil at reactor waste sites 100-N-66/UPR-100-N-35 will be remediated in accordance with the CERCLA process after the ISS period has ended and the reactor is removed in accordance with the schedule Tri-Party Agreement Milestone M-093-00. Cost estimates were not developed for the reactor waste sites.

ICs will prevent unauthorized access until remedial actions are completed. It is assumed that RAOs will be met and post-remedial action ICs will not be needed.

4.1.1 ICs for Waste Sites

The quantities for ICs are determined on a per waste site basis and include a quantity input on the number of years the IC restricting excavation in shallow or deep soil or prohibiting irrigation needs to be maintained. Table A-1 in Appendix A (columns 3 through 7) lists the waste sites requiring ICs and the type of IC required for each FS alternative. Table A-1 (column 2) shows the year until which the specific IC needs to be maintained for each waste site.

Twelve waste sites were carried forward into the FS with direct contact risk for deep radionuclide contamination only. Table A-1 in Appendix A (row 1, column 2) shows the years until which ICs restricting deep excavation need to be maintained for these waste sites under all alternatives (Alternatives 2 through 6).

Fifteen previously remediated waste sites carried forward to the FS will require post-remediation ICs restricting shallow excavation, restricting deep excavation, and/or prohibiting irrigation combined with radioactive decay or biodegradation. Table A-1 in Appendix A (rows 2, 3, and 4) shows the ICs types required based on the identified risk identified for each of the 23 waste sites. Column 2 in Table A-1 shows the years until which the specific IC type needs to be maintained for the IC and waste sites identified in columns 3 through 7.

Radioactive decay will not require monitoring. Natural attenuation of TPH through biodegradation will be monitored indirectly by monitoring the groundwater for TPH for a maximum of 50 years (based on one-half the time to achieve cleanup level for TPH in the upland area under Alternative 2 shown in Table 8.

Table 8. Timeframe to Meet Shoreline and Upland Groundwater PRGs for the FS Alternatives

COC	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Upland Area (Year Concentration Falls Below DWS)						
Sr-90	290 years (2307)	290 years (2307)	290 years (2307)	290 years (2307)	290 years (2307)	190 years (2227)
Nitrate	40 years (2057)	40 years (2057)	40 years (2057)	30 years (2057)	30 years (2047)	40 years (2057)
TPH	100 years (2117)	100 years (2117)	25 years (2042)	25 years (2042)	25 years (2042)	25 years (2042)
Tritium	15 years (2032)	15 years (2032)	15 years (2032)	15 years (2032)	15 years (2032)	15 years (2032)
Shoreline (Year Concentration Falls Below Bioconcentration Guide)						
Sr-90	55 years (2072)	40 years (2057)	40 years (2057)	40 years (2057)	40 years (2057)	45 years (2062)
Nitrate	N/A	N/A	N/A	N/A	N/A	N/A
TPH	N/A	N/A	N/A	N/A	N/A	N/A
Tritium	N/A	N/A	N/A	N/A	N/A	N/A

Note: Groundwater fate and transport model results between 11 and 50 years are rounded up to the nearest 5 years, and those >50 years are rounded up to the nearest 10 years to account for model uncertainty.

COC = contaminant of concern
DWS = drinking water standard
N/A = not applicable
TPH = total petroleum hydrocarbon

4.1.2 Monitored Natural Attenuation with ICs for Groundwater

The duration for ICs will primarily be controlled by the period required to achieve groundwater cleanup PRGs. Table 8 summarizes the expected time to achieve groundwater PRGs by COC for each alternative based on peak concentrations. These timeframes are the average time for concentrations to fall below cleanup levels for all simulated scenarios using the best-estimate concentration initial conditions from Table 7.3 in ECF-100NR2-15-0128, *Simulation of Contaminant Migration for the 100-N Feasibility Study*. The overall duration of the ICs period is controlled by the time to achieve the strontium-90 PRG in the upland area. A 5-year compliance monitoring period (10 sampling events) is assumed to demonstrate that the remedy has achieved the cleanup goals for each COC. It is assumed that ICs will be maintained for 5 years beyond the time that the cleanup goals are initially achieved. Therefore, the maximum groundwater ICs duration for each alternative is assumed to be as follows:

- **Alternative 1 – 295 years:** Based on the 290-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.
- **Alternative 2 – 295 years:** Based on the 290-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.
- **Alternative 3 – 295 years:** Based on the 290-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.

- **Alternative 4 – 295 years:** Based on the 290-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.
- **Alternative 5 – 295 years:** Based on the 290-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.
- **Alternative 6 – 195 years:** Based on the 190-year time period to achieve cleanup level for strontium-90 in the upland area, plus 5-year compliance monitoring period.

4.2 Vadose Zone Components

Table A-2 in Appendix A summarizes the cost basis for each waste site by alternative. This section describes the waste site remedies that are included in the six alternatives.

4.2.1 Removal, Treatment, and Disposal at Waste Sites

Shallow RTD (up 4.6 m [15 ft] bgs) is a component of Alternatives 2 through 6. Deep RTD (>4.6 m [15 ft] bgs) is a component of Alternatives 4 and 5 for waste sites.

The quantities for RTD related activities (e.g., excavation, sampling and analysis, Environmental Restoration Disposal Facility [ERDF] disposal, and backfill) are all based on the volumes of contaminated soil and noncontaminated soil. The information required for calculating soil volumes is provided for waste sites where RTD is being performed under Alternatives 2 through 6 is included in Table A-2. The contaminated and noncontaminated soil quantities are based on the waste site-specific area of contamination and depths listed in Table A-2. The assumed footprint requiring remediation is provided in Table A-2 (column 3). The contaminated interval (column 4) is the depth range of contamination and is calculated from the maximum contamination depth minus the top of contamination. The assumed interval of clean soil overlying the contaminated interval is also listed in column 4. The contaminated and noncontaminated soil quantities will be determined by the cost estimator.

In accordance with EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, RTD for the 100-NR-1 OU waste sites includes the following activities:

1. All work required under this approved remedial action must be performed in accordance with approved plans and ARARs.
2. Prior to beginning remedial action or excavation, a cultural and natural resources review will be conducted.
3. Any uncontaminated overburden will be removed and stockpiled if needed to gain access to contaminated soils and, to the extent practicable, this overburden will be used to backfill excavated areas.
4. To stabilize side slopes, excavation at each waste site will include a layback with a slope of 1.5:1.
5. The extent of remediation of the waste sites will be as follows:
    a. For remediation of the top 4.6 m (15 ft) below surrounding grade or the bottom of the engineering structure, whichever is deeper, remove until contaminant levels meet RAOs.

b. For sites where the engineered structure and/or contaminated soil and debris begins <4.6 m (15 ft) bgs and extends to deeper than 4.6 m (15 ft) bgs, the engineered structure (at a minimum) will be remediated so the contaminant levels meet RAOs. Where residual contamination exceeds cleanup standards in the soil column deeper than 4.6 m (15 ft) bgs, the extent of remediation must ensure that contaminant levels remaining in the soil are protective of groundwater and the Columbia River.

6. The measurement of contaminant levels during remediation will rely on field screening methods. Appropriate confirmation sampling of field screen measurements will be obtained to correlate and validate the field screening. After field screening activities have indicated that cleanup levels have been achieved, more extensive confirmation sampling will be performed that routinely achieves higher levels of quality assurance and quality control to support issuance of an interim remedy CERCLA closeout report for the waste site.

7. After a site has been demonstrated to achieve cleanup levels and RAOs, the site will be backfilled and revegetated. To the extent practicable, removed and stockpiled uncontaminated overburden will be used to backfill excavated areas. Revegetation plans will be developed as part of remedial design activities.

8. Pipelines associated with the units will be removed and disposed or sampled to determine if they meet RAOs and can be left in place.

9. Treatment of excavated soils will be conducted before disposal, as required, to meet *Resource Conservation and Recovery Act of 1976* land disposal restrictions and ERDF waste acceptance criteria (ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria, formerly WCH-191 Rev 4*).

10. Excavated contaminated soils, structures, and pipelines will be transported to ERDF for disposal. Excavation activities will follow all appropriate construction practices for excavation and transportation of hazardous materials and will follow as low as reasonably achievable practices for remediation workers. Dust suppression during excavation, transportation, and disposal will be implemented as necessary.

11. Post-remediation monitoring of the vadose zone and groundwater will be performed to confirm the effectiveness of remediation efforts and the accuracy of modeling predictions associated with the selected remedy.

A rough order of magnitude cost to excavate and remove the contaminants at waste site 118-N-1, with direct contact risk for deep radionuclide contamination only, is calculated for informational purposes. This rough order of magnitude cost is not included in the alternative cost estimates (although excavation ICs for this site are included). Table A-3 in Appendix A lists the soil contamination intervals and footprints for this waste site.

4.2.2 In Situ Aerobic Bioremediation – Bioventing

In situ bioremediation is an alternative component (Alternatives 3, 4 and 6) for treating one waste site (UPR-100-N-17) contaminated with residual TPH in the vadose zone.

In situ bioremediation of TPH in the deep vadose zone (bioventing) is underway at the UPR-100-N-17 waste site. Seven bioremediation wells were completed between January and March 2009, and pilot testing was conducted between February 2010 and May 2011 (Figure 1). The pilot testing results indicated that deep vadose zone hydrocarbon-impacted soils are amenable to enhanced in situ bioremediation (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). The results also

indicated that the radius of influence for the deep injection wells is about 60 m (200 ft). The design for the Phase II in situ bioremediation system was completed in 2012, and the system was started in December 2012. In August 2016, a borehole was completed to a depth of about 36.6 m (120 ft) bgs for the installation of monitoring well 199-N-377. The TPH-impacted soil was encountered at depths ranging from 5.5 to 13.7 m (18 to 45 ft) bgs, with the top of the Ringold Formation potentially acting as a barrier to further downward migration. Groundwater and soil gas TPH results, as well as respirometry testing results, suggest a potential residual source area remaining upgradient of the main area of groundwater contamination, possibly near the former 166-N Tank Farm; and residual hydrocarbon contamination within a "smear" zone resulting from groundwater elevation fluctuations (DOE/RL-2017-29, *Annual Operations and Monitoring Report for UPR-100-N-17, March 2016 – February 2017*).

The current system consists of two deep (22.9 m [75 ft] bgs) injection wells and five monitoring wells. Three blowers supply air to the two injection wells. Each blower is a 7.5-horsepower, 208–230/480-volt alternating-current regenerative blower. Each blower is connected to a header pipeline that connects to a main airline leading to each of the treatment wells (199-N-167 and 199-N-172). The bioventing component of Alternatives 3, 4, and 6 includes expanding the current system to target contamination detected above the 2,000 mg/kg PRG in soil deeper than 5.5 m (18 ft) bgs. Table 9 lists the cost input quantities for the bioventing at waste site UPR-100-N-17. The estimate includes costs for decommissioning eight shallow wells to 10.7 m (35 ft), and five deep wells to 24.4 m (80 ft) after remedy completion.

4.3 Continuing Vadose Zone/Periodically Rewetted Zone Source Components

Assumptions and input for the PRZ sources include the following:

- Maps provided in Appendix B show the continuing source footprint areas (strontium-90 in Areas 0 through 5, nitrate, and TPH).
- Table A-4 in Appendix A describes each source area and the remedial action technologies applied under Alternatives 2 through 6.
- Table A-4 in Appendix A lists the areas and COC depth intervals for each of the presumed PRZ sources.
- Where PRZ source areas overlap with waste sites, the RTD footprints listed in Table A-2 in Appendix A are used to prevent duplication.

4.3.1 Removal, Treatment, and Disposal – Source Areas

Deep RTD (>4.6 m [15 ft] bgs) of continuing strontium-90 and nitrate sources is a component of Alternative 5.

The quantities for RTD-related activities (e.g., excavation, sampling and analysis, ERDF disposal, and backfill) are all based on the volumes of contaminated soil and noncontaminated soil. The information required for calculating soil volumes is provided for the waste sites where RTD is being performed under Alternative 5 (Table A-4 in Appendix A). The contaminated and noncontaminated soil quantities are based on the waste site-specific area of contamination and depths shown in Table A-4. The assumed footprint requiring remediation is provided in Table A-4 (column 3). The contaminated interval (column 4) is the depth range of contamination and is calculated from the maximum contamination depth minus the top of contamination. The assumed interval of clean soil overlying the contaminated interval is also provided in column 4 of Table A-4. The contaminated and noncontaminated soil quantities will be determined by the cost estimator.

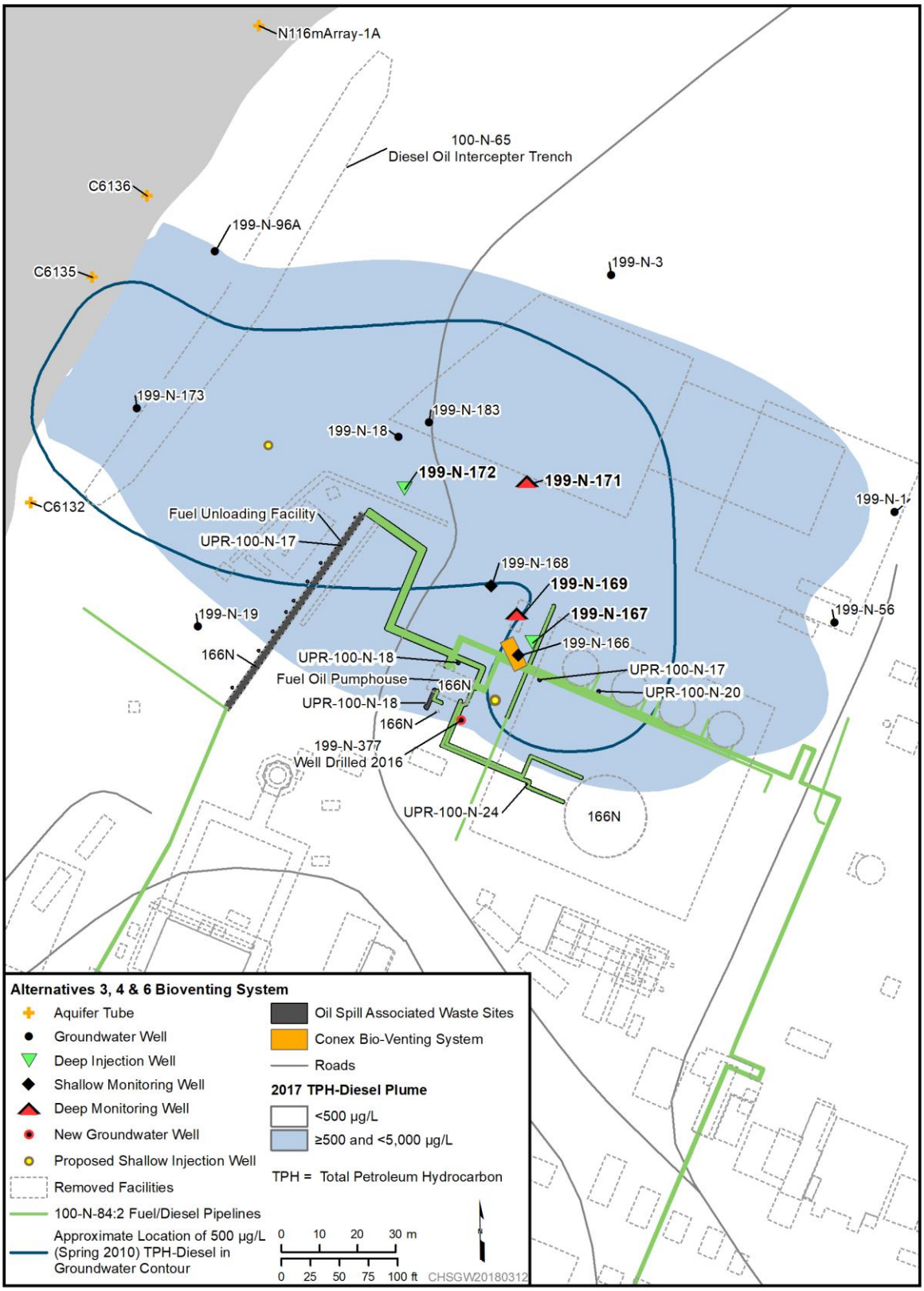

Figure 1. Bioremediation Layout for Deep Vadose Zone Petroleum Contamination at UPR-100-N-17

Table 9. Bioventing Cost Input Parameters – Waste Site UPR-100-N-17

Input Parameter	Quantity	Units	Comments
Injection wells radius of influence	200	ft	DOE/RL-2017-29
Number of new injection wells	2	each	—
Injection well depth	35	ft bgs	DOE/RL-2017-29
Screen interval	15 to 35	ft bgs	Based on depth of contamination (18 to 45 ft bgs) at well 199-N-377
Injection well diameter	4	in.	—
Number of new vapor monitoring wells	2	each	—
Monitoring well depth	35	ft bgs	DOE/RL-2017-29
Screen interval	15 to 35	ft bgs	DOE/RL-2017-29
Monitoring well diameter	4	in.	DOE/RL-2017-29
Blower	1	unit	Rotron® Model DR808AY72MX
Miscellaneous mechanical/electrical/ instrumentation and controls	1	LS	Assumes 50% of capital costs
Header pipe	300	ft	Estimate
Number of confirmation boreholes (post-remediation)	3	each	To confirm shallow and deep total petroleum hydrocarbons concentrations
Boring depth	120	ft bgs	Based on depth of well 199-N-377
Assumed remediation timeframe	25	years	ECF-100NR2-2015-0128
Annual bioventing operations and maintenance costs	25	years	$20,000/yr (DOE/RL-2017-29)
Annual performance monitoring	25	years	$159,000/yr; assumes 50% of 2016 costs (DOE/RL-2017-29)

References: DOE/RL-2017-29, *Annual Operations and Monitoring Report for UPR-100-N-17, March 2016 – February 2017*.
ECF-100NR2-2015-0128, *Simulation of Contaminant Migration for the 100-N Feasibility Study*.
Note: Rotron® is a registered trademark of Ametek, Inc., Berwyn, Pennsylvania.
bgs = below ground surface
LS = lump sum

4.4 Groundwater Components

This section summarizes the key groundwater remedy cost input parameters for each component and remedial technology carried forward into the remedial alternatives, including the following:

- Groundwater monitoring
- Free product removal from monitoring wells
- Extension of the apatite PRB (saturated zone)
- Biosparging for TPH
- Apatite treatment for upland strontium-90 (saturated zone)

Figure 2 shows the strontium-90 plume and existing PRB location, the proposed PRB extension based on the 278 pCi/L concentration contour, and the upland apatite treatment area based on the 80 pCi/L concentration contour.

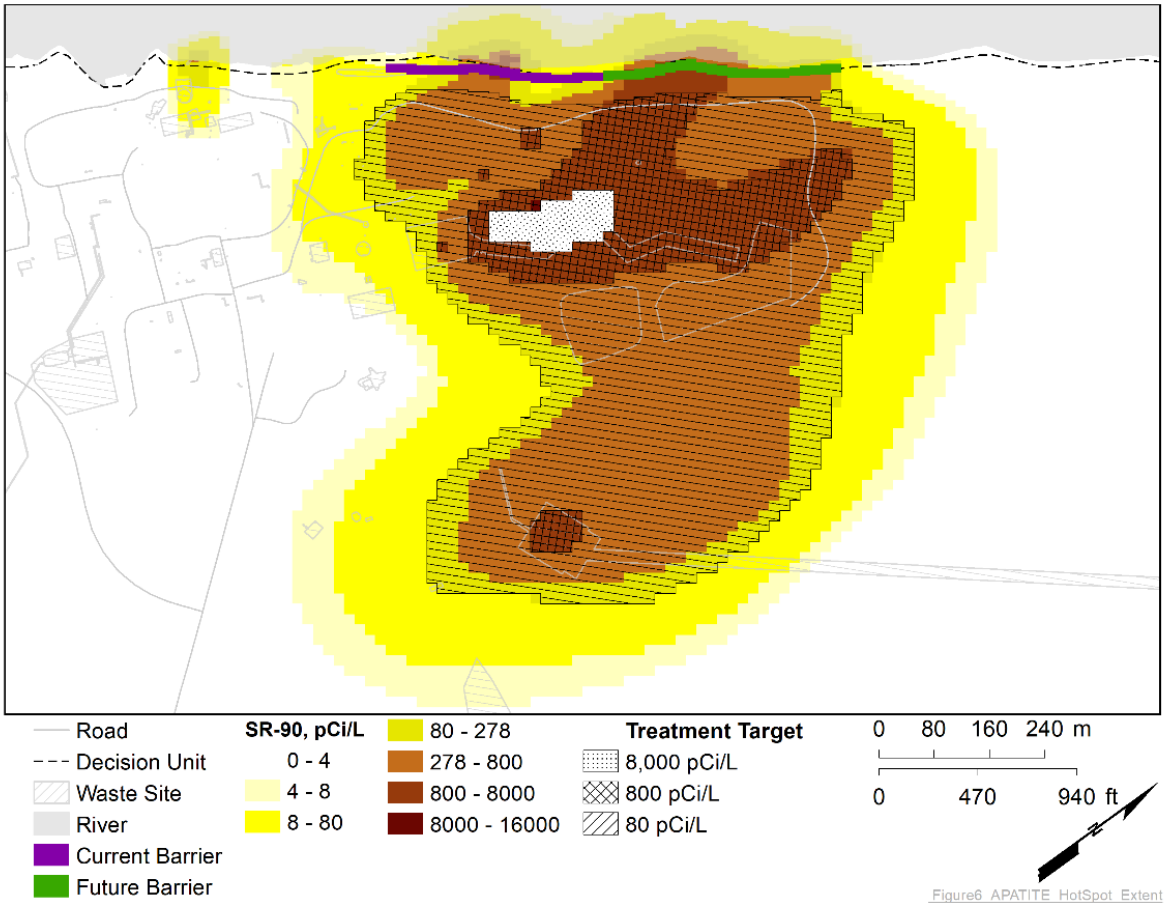

Figure 2. Strontium-90 Shoreline PRB and Upland Treatment Areas

4.4.1 Groundwater Monitoring

The basis for cost estimate inputs for sampling soil and groundwater monitoring wells during and following installation includes the following:

- Number of new monitoring wells installed
- Number of groundwater samples per well for each type of well
- Number of soil samples per new well borehole

The monitoring well network at the 100-N Area currently consists of 99 monitoring wells (including 29 wells installed to monitor downgradient from the PRB), plus 26 aquifer tubes along the shoreline. Of the 99 wells in the monitoring network, 59 wells will be sampled during each sampling event, as outlined in Table 10. Sampling activities for groundwater monitoring include the following key assumptions:

- The temporal effects will have already been established. The sampling program outlined in Table 10 includes MNA, groundwater monitoring, and performance monitoring. The costs for additional performance monitoring associated with PRB installation (Tables 11 and 12 and Section 4.4.3) are included with PRB costs and are excluded from annual groundwater costs.

Table 10. Annual Groundwater Sampling Wells

COC[a]	Basis	Quantity	Units
Sr-90 upland	Number of wells	16	each
Sr-90 shoreline	Number of wells	20	each
Nitrate	Number of wells	6	each
TPH-diesel and TPH-oil	Number of wells	8	each
Tritium	Number of wells	3	each
Other contaminants of potential concern[b]	Number of wells	6	each

a. Sampling durations are listed in Table A-5 in Appendix A for each COC and alternative. Compliance monitoring (semiannually for 5 years) is assumed to begin at the end of the timeframes shown in Table A-5 for each COC.

b. Includes compliance monitoring only (semiannual sampling for 5 years beginning at year 0) for arsenic, benzo(a)pyrene, cadmium, manganese, and nickel.

COC = contaminant of concern

TPH = total petroleum hydrocarbons

Table 11. Key Apatite PRB Cost Input Parameters for Alternatives 2 Through 5

Input Parameter	Quantity	Units	Comments
Length of existing (treated) PRB	900	ft	900 ft / 64 wells
Length of PRB extension	1,300	ft	1,300 ft / 80 wells
Radius of influence per well	25	ft	DOE/RL-2010-29
Number of new injection wells	0	each	No new wells; 64 wells in the existing PRB and 80 wells needed for PRB extension were previously installed (DOE/RL-2011-25)
Year 1 injection: number of wells to be injected	144	each	Injection into entire 2,200 ft PRB (including existing 900 ft, plus 1,300 ft extension)
Year 1 injection: calcium-citrate-phosphate concentrate volume	7.2×10^5	gal	Assumes 18,927 L (5,000 gal) of calcium-citrate-phosphate concentrate × 144 wells
Year 1 injection: injection volume per well (dilute solution) for 10% target	60,000	gal	Calcium-citrate-phosphate dilute solution injected into each well. (Ratio river water to solution provided by truck 12:1 (SGW-47614)
Year 1 injection: total injection volume	8.6×10^6	gal	227,124 L (60,000 gal) calcium-citrate-phosphate dilute solution × 144 wells
Year 1 injection: performance monitoring and sampling	See Table 13 for sample requirements during the year 1 injection and during the following year.		
Reinjection frequency	5	years	Assumes one reinjection in PRB extension only
Year 5 reinjection: number of wells to be reinjected	80	#	Injection into 1,300 ft PRB extension only

Table 11. Key Apatite PRB Cost Input Parameters for Alternatives 2 Through 5

Input Parameter	Quantity	Units	Comments
Year 5 reinjection: calcium-citrate-phosphate concentrate volume	4.0×10^5	gal	Assumes 18,927 L (5,000 gal) of calcium-citrate-phosphate concentrate × 80 wells
Year 5 reinjection: injection volume per well (dilute solution) for 10% target	60,000	gal	Calcium-citrate-phosphate dilute solution injected into each well (ratio river water to solution provided by truck 12:1) (SGW-47614)
Year 5 reinjection: total reinjection volume	4.8×10^6	gal	227,124 L (60,000 gal) calcium-citrate-phosphate dilute solution × 80 wells
Year 5 reinjection: performance monitoring and sampling	See Table 14 for sample requirements during the year 5 reinjection and during the following year.		

References:

DOE/RL-2010-29, 2010, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*.

DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*.

SGW-47614, *Field Test Instruction 100-NR-2 Operable Unit Design Optimization Study for Sequestration of SR-90 Saturated Zone Apatite Permeable Reactive Barrier Extension*.

PRB = permeable reactive barrier

Table 12. Key Apatite PRB Cost Input Parameters for Alternative 6

Input Parameter	Quantity	Units	Comments
Length of existing (treated) PRB	900	ft	900 ft / 64 wells
Length of PRB extension	1,300	ft	1,300 ft / 80 wells
Radius of influence per well	25	ft	DOE/RL-2010-29
Number of new injection wells	0	each	No new wells; 64 wells in the existing PRB and 80 wells needed for PRB extension were previously installed (DOE/RL-2011-25)
Number of wells to be injected	144	each	Injection into entire 2,200 ft PRB (including existing 900 ft, plus 1,300 ft extension)
Calcium-citrate-phosphate concentrate volume	7.2×10^5	gal	Assumes 18,927 L (5,000 gal) of calcium-citrate-phosphate concentrate × 144 wells
Injection volume/well (dilute solution) for 10% target	60,000	gal	Calcium-citrate-phosphate solution injected into each well (ratio river water to solution provided by truck 12:1) (SGW-47614)
Total injection volume	8.6×10^6	gal	227,124 L (60,000 gal) calcium-citrate-phosphate dilute solution × 144 wells
Reinjection frequency	0	years	Assumes one injection in entire 2,200 ft (144 wells) only
Injection performance monitoring and sampling	See Table 13 for sample requirements during the injection and following year.		

Table 12. Key Apatite PRB Cost Input Parameters for Alternative 6

Input Parameter	Quantity	Units	Comments

References: DOE/RL-2010-29, 2010, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*.

DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*.

SGW-47614, *Field Test Instruction 100-NR-2 Operable Unit Design Optimization Study for Sequestration of SR-90 Saturated Zone Apatite Permeable Reactive Barrier Extension*.

PRB = permeable reactive barrier

- After a plume for a given COC has been remediated, sampling of associated wells will be terminated. The number of monitoring wells will decrease over time, depending upon the alternative. Table A-5 in Appendix A shows how the sampling regime changes over time for each alternative.
- A 5-year compliance monitoring period is assumed after operations conclude for each alternative. Groundwater monitoring will be conducted on a semiannual basis during this period.
- Other COPCs for compliance monitoring only (Table 10) include arsenic, benzo(a)pyrene, cadmium, manganese, and nickel.

Key assumptions for well installation, sampling, and monitoring are as follows:

- Assumes that eight new monitoring wells will be added to complete the coverage needed to monitor COPCs at the 100-NR-2 OU.
- Monitoring wells are assumed to be 4 in. diameter and 30.5 m (100 ft) deep, with 7.6 m (25 ft) long screens.
- Five groundwater samples will be collected at various depths to vertically profile COC distribution within the aquifer and determine the appropriate screen interval for each monitoring well, extraction well, and injection well.
- Five soil samples will be collected to determine soil type and particle-size gradation to support design of the extraction and injection well screen slot size and filter pack gradation. One soil sample will be obtained from the surface of the water table for monitoring wells.
- Monitoring wells are assumed to have a design life of 30 years.

4.4.2 Free Product Removal from Monitoring Wells

Removal of free product from wells 199-N-18 and 199-N-183 is conducted in accordance with the interim action ROD (EPA/ROD/R10-99/112). Diesel is removed using a polymer “smart sponge” that selectively absorbs petroleum products from the surface of the water in the well. About every 2 months, two sponges are lowered into well 199-N-18 and left to soak up the diesel. The sponges are weighed prior to placement and again after removal. The weight difference is the amount of diesel removed from the well. In 2016, 950 g of diesel were removed from well 199-N-18. Sponges are also used at well 199-N-183, where a sheen has been detected. Removal of diesel from wells 199-N-18 and 199-N-183 is assumed for the cost estimate for Alternative 2.

Monitoring of free product within the monitoring wells will be included as part of the groundwater monitoring program and, as such, does not represent an additional cost. Product recovery cost allowance for recovery of <1 gal/well/yr for wells 199-N-18 and 199-N-183 for 5 years has been assumed for cost estimating for Alternative 2. It is assumed product recovery will not be required for alternatives using biosparging to treat the TPH plume (Alternatives 3 through 6).

4.4.3 Rejuvenation and Extension of the Apatite PRB

A total of 162 PRB injection wells have been installed in accordance with the interim action ROD (EPA/ROD/R10-99/112). Injection to a target apatite content of 10% in 64 of the 162 wells was previously completed to construct the existing 275 m (900 ft) PRB. The interim action ROD specified the PRB should be completed to a length of 760 m (2,500 ft), which is the length of the shoreline where groundwater concentrations exceed the 8 pCi/L strontium-90 PRG. Costs for completing treatment of the remaining 487.7 m (1,600 ft) of PRB included a single injection into 98 wells (DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations and 100-NR-2 Groundwater Remediation*). However, costs for the FS assume a total PRB length of 670 m (2,200 ft), which is the approximate length of shoreline where groundwater concentrations exceed the strontium-90 bioconcentration guide of 278 pCi/L. PNNL-23367, *Hanford Apatite Treatability Test Report Errata: Apatite Mass Loading Calculation*, indicates that a target apatite injection of 0.96 mg of apatite per gram of sediment will occupy 10% of the pore space. It is assumed additional treatment is required in the existing portion of the PRB to address observed strontium-90 breakthrough. The FS cost estimate assumes that only 80 of the remaining 98 wells will be used to extend the PRB to 670 m (2,200 ft).

Alternatives 2 through 5 include the following:

- Year 1 injection into 144 injection wells (includes 64 previously treated wells [existing barrier] plus 80 untreated wells [PRB extension])
- Year 5 reinjection into 80 wells that comprise the PRB extension

Alternatives 2 through 5 assume that the year 1 treatment across the full PRB plus the year 5 reinjection across the extension will result in apatite content of 20% (1.9 mg apatite per gram of sediment) across the full PRB.

Alternatives 2 through 5 will require initial injection in year 1 and reinjection in year 5:

- **Year 1:** All 144 injection wells within the 670 m (2,200 ft) PRB will be injected (includes the existing barrier and the PRB extension). It is assumed that the year 1 injection will result in an apatite content of 20% (1.9 mg apatite per gram of sediment) in the existing portion of the barrier and 10% (0.96 mg apatite per gram of sediment) in the barrier extension. Injection will be performed in two phases, one during high river and one during low river, taking about 5 months each to complete (10 months total). The shallower wells will be injected during high river stage, and the deeper wells will be injected during low river stage.
- **Year 5:** For cost-estimating purposes, 80 injection wells (the 396 m [1,300 ft] PRB extension) will be reinjected after the initial injection and 5 years of monitoring. It is assumed the reinjection will result in an apatite content of 20% (1.9 mg apatite per gram of sediment) in the barrier extension. Injection will be performed in two phases, one during high river and one during low river, taking about 3 months each to complete (6 months total). The shallower wells will be injected during high river stage, and the deeper wells will be injected during low river stage.

The apatite PRB is installed by injecting a calcium-citrate-phosphate solution into injection wells. The specific steps for injection and sequestration are as follows:

1. River water is mixed with concentrated calcium-citrate-phosphate (12:1 dilution).
2. Diluted calcium-citrate-phosphate solution is injected.
3. In situ biodegradation of citrate results in apatite precipitation.
4. The apatite surface adsorbs strontium-90 (new strontium-90 migrating into the treated zone from upgradient sources).
5. Apatite recrystallization occurs with strontium-90 substitution for calcium (permanent); radioactive decay of strontium-90 to yttrium-90 and zirconium-90.

Alternative 6 includes the year 1 injection described for Alternatives 2 through 5 (the year 5 reinjection is excluded). Alternative 6 will require one 10% injection along the entire 670 m (2,200 ft) PRB, including the current 275 m and 396 m (900 ft and 1,300 ft) extension. It is assumed that injection is required in the existing portion to address breakthrough that has occurred. It is assumed only one 10% injection is needed in the extension if it is properly placed in phases (one during high river stage and one during low river stage, taking about 5 months each to complete [10 months total]) because strontium-90 flux through the PRB is reduced by the upland apatite treatment component of Alternative 6 (described in Section 4.4.5).

4.4.3.1 Cost Input Parameters

Key cost input parameters for completing the apatite PRB are summarized in Table 11 for Alternatives 2 through 5 and in Table 12 for Alternative 6. Implementation of this remedy component is further reviewed in the following discussion.

Site utility requirements for the apatite injection include a generator and water supply. Columbia River water will be used to dilute the high-concentration calcium-citrate-phosphate solution at a ratio of 12:1. A diesel generator will be used to operate the site facilities, the injection/monitoring equipment, and ancillary equipment.

Calcium-citrate-phosphate injections will be made using two existing injection skids (Figure 3) to mix a dilute solution of river water and concentrated chemicals for injection. For each injection event, volumes of 227,125 to 454,249 L (60,000 to 120,000 gal) of dilute calcium-citrate-phosphate solution will be injected into each well. The injection system is capable of injecting chemical solution at a flow rate from 37 to 189 L/min (10 to 50 gal/min) per well, with a total capacity for each injection skid of up to 1,135 L/min (300 gal/min). Each injection skid can inject chemicals into six wells simultaneously.

Each treatment skid is capable of pumping chemicals from tanker trucks or tanks and river water to form an injection solution for distribution to well heads (dilution rate of 12:1). Flow meters and sample ports are provided on each injection skid to monitor and collect samples of pre-mixed chemical solution. Submersible pumps in the Columbia River will extract and transfer river water to the injection skid where it will be filtered prior to mixing with the chemical in a static in-line mixing chamber. Following mixing, a 2 in. transfer hose will distribute the dilute chemical solution to a manifold for distribution at up to six individual wells. A sample port is provided for sample collection of the dilute chemical prior to the manifold.

Sampling and analysis requirements for the high-concentration calcium-citrate-phosphate solution injections include chemical make-up sampling, injection flow rate and volume monitoring, groundwater

and aquifer tube sampling, and potential soil sampling after injections are complete. Tables 13 and 14 summarize the sampling requirements.

Groundwater samples will be collected from wells located within the potential area of injection influence. Groundwater samples will be collected using either a peristaltic pump or 12-volt electric submersible pump. Field parameters will be measured for each sample using portable field instruments. Specific conductance, oxidation-reduction potential, temperature, dissolved oxygen, turbidity, and pH will all be measured in the field. Aqueous samples for analyses of other parameters will be collected. Samples will also be collected from aquifer tubes located within the potential area of injection influence.

4.4.4 Biosparging

Biosparging is a component of Alternatives 3 through 6. Biosparging involves injecting air to stimulate biological activity and treat petroleum contamination in the groundwater, aquifer materials, and the capillary fringe. Dissolved oxygen is used by aerobic microorganisms to degrade the TPH. Following injection, dissolved oxygen is transported downgradient by advection with the groundwater flow. (Note: The target vadose zone treatment area overlaps the target biosparging treatment area; therefore, biosparging implementation would require coordination with in situ treatment components for the vadose zone [bioventing for Alternatives 3, 4, and 6, and RTD for Alternative 5].)

The 100-N Area TPH plume area is approximately 16,000 m^2 (172,000 ft^2). The TPH treatment will target the plume where concentrations are consistently above the PRG of 500 µg/L, except for the shoreline area below the bluff. The estimated treatment area is approximately 120 m×90 m = 10,800 m^2 (394 ft×295 ft = 116,250 ft^2), as shown in Figure 4. A total of 43 wells aligned in seven rows will be used to inject air into the saturated zone and increase the dissolved oxygen within the injection zone. Testing will be performed during the remedial action to adjust (as needed) the initial assumptions on the radius of influence, potential nutrient limitations, and rate of degradation of the hydrocarbons present in the plume. The estimate includes costs for decommissioning the 43 biosparging wells after remedy completion.

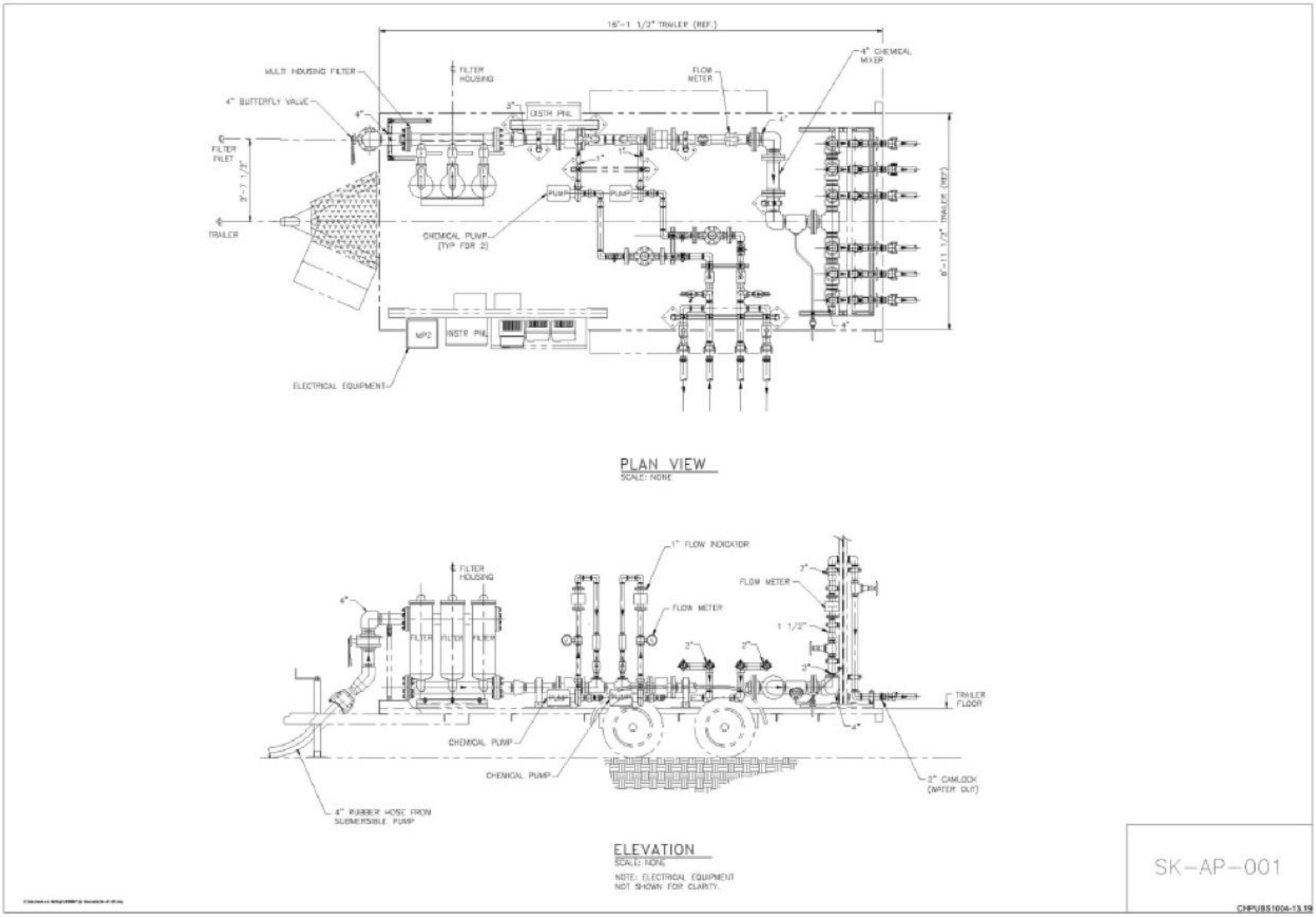

Figure 3. Generalized Injection Skid Schematic

Table 13. PRB Injection and Performance Monitoring: Approximate Sampling Locations and Frequency – Year 1 (Alternatives 2 Through 6)

Sample Purpose	Sampling Locations	Approximate Sampling Frequency	Analytes	Number of Wells/Samples
Pre-injection monitoring (baseline sampling)	Nearby monitoring wells/aquifer tubes downgradient of wells to be injected	One time immediately prior to injections	Cations, anions, Sr-90, gross beta, TPH-diesel,[b] and field parameters[c]	Baseline sampling already being performed. Cost estimate assumes no new sampling needed for this activity.
Injection monitoring	Injection stream from injection skid	Field parameters every 4 hours, aqueous samples (for laboratory analysis) daily	Cations, anions, and field parameters[c]	Total of 720 samples for field parameters only and 144 samples for laboratory analysis. Field sample assumptions: • 3 samples per skid every 4 hours for duration of continuous injection period • 40 hours to inject 60,000 gal per well at 25 gal/min (1,500 gal/hr), (60,000 gal ÷ 1,500 gal/hr = 40 hrs) • 30 field samples per injection campaign[d] based on 40 hrs ÷ 4 hrs × 3 samples = 30 samples • 24 injection campaigns (144 injection wells ÷ 6 wells per campaign = 24) each × 30 field samples = 720 total field samples Aqueous sample assumptions: • Assumes 144
Injection arrival monitoring[a]	Downgradient monitoring wells/ aquifer tubes	Field parameters continuously in situ from wells, aqueous samples at the end of injection from both wells and aquifer tubes	Cations, anions, Sr-90, gross beta, TPH-diesel,[b] and field parameters	Field parameters through monitoring equipment. 10 wells and 4 aquifer tube samples per injection campaign × 24 campaigns = 336 samples.

Table 13. PRB Injection and Performance Monitoring: Approximate Sampling Locations and Frequency – Year 1 (Alternatives 2 Through 6)

Sample Purpose	Sampling Locations	Approximate Sampling Frequency	Analytes	Number of Wells/Samples
Short-term performance monitoring	51 nearby monitoring wells/aquifer tubes	Two and four weeks after the injection, then quarterly for the first year (then as per Table 10)	Cations, anions, gross beta, Sr-90, TPH-diesel, and field parameters[c]	Total of 255 samples. Assumes 29 monitoring wells and 22 aquifer tubes sampled 5 times during the first year (51 wells × 5 times = 255 samples).

a. For injection and arrival monitoring, probes will be placed in two wells during injection. Probes will be placed in one downriver well to monitor performance.

b. This cost estimate assumes all samples analyzed for TPH-diesel. However, TPH-diesel range organic analysis conducted will be performed for a subset of monitoring wells based on location relative to TPH plume.

c. Field parameters include specific conductance, temperature, pH, oxidation-reduction potential, and dissolved oxygen.

d. Campaign = Six wells at 60,000 gal per well.

TPH = total petroleum hydrocarbons

Table 14. PRB Reinjection and Performance Monitoring: Approximate Sampling Locations and Frequency – Year 5 (Alternatives 2 Through 5)

Sample Purpose	Sampling Locations	Approximate Sampling Frequency	Analytes	Number of Wells/Samples
Pre-injection monitoring (baseline sampling)	Nearby monitoring wells/aquifer tubes downgradient of wells to be injected	One time immediately prior to injections	Cations, anions, Sr-90, gross beta, TPH-diesel,[b] and field parameters[c]	Baseline sampling already being performed. Cost estimate assumes no new sampling needed for this activity.
Injection monitoring	Injection stream from injection skid	Field parameters every 4 hours, aqueous samples (for laboratory analysis) daily	Cations, anions, and field parameters[c]	Total of 390 samples for field parameters only and 80 samples for laboratory analysis. Field sample assumptions: • 3 samples per skid every 4 hours for duration of continuous injection period • 40 hours to inject 60,000 gal per well at 25 gal/min (1,500 gal/hr), (60,000 gal ÷ 1,500 gal/hr = 40 hrs) • 30 field samples per injection campaign[d] based on 40 hrs ÷ 4 hrs × 3 samples = 30 samples

Table 14. PRB Reinjection and Performance Monitoring: Approximate Sampling Locations and Frequency – Year 5 (Alternatives 2 Through 5)

Sample Purpose	Sampling Locations	Approximate Sampling Frequency	Analytes	Number of Wells/Samples
				• 13 injection campaigns (80 injection wells ÷ 6 wells per campaign = 13) each × 30 field samples = 390 total field samples Aqueous sample assumptions: • Assumes 80
Injection arrival monitoring[a]	Downgradient monitoring wells/ aquifer tubes	Field parameters continuously in situ from wells, aqueous samples at the end of injection from both wells and aquifer tubes	Cations, anions, Sr-90, gross beta, TPH-diesel,[b] and field parameters	Field parameters through monitoring equipment. 10 wells and 4 aquifer tube samples per injection campaign × 13 campaigns = 182 samples.
Short-term performance monitoring	28 nearby monitoring wells/aquifer tubes	Two and four weeks after the injection, then quarterly for the first year (then as per Table 10)	Cations, anions, gross beta, Sr-90, TPH-diesel, and field parameters[c]	Total of 140 samples. Assumes 16 monitoring wells and 12 aquifer tubes sample 5 times during the first year (28 wells × 5 times = 140 samples).

a. For injection and arrival monitoring, probes will be placed in four wells during injection. Probes will be placed in two wells to monitor performance.

b. This cost estimate assumes all samples analyzed for TPH-diesel. However, TPH-diesel range organic analysis conducted will be performed for a subset of monitoring wells based on location relative to TPH plume.

c. Field parameters include specific conductance, temperature, pH, oxidation-reduction potential, and dissolved oxygen.

d. Campaign = Six wells at 60,000 gal per well.

TPH = total petroleum hydrocarbons

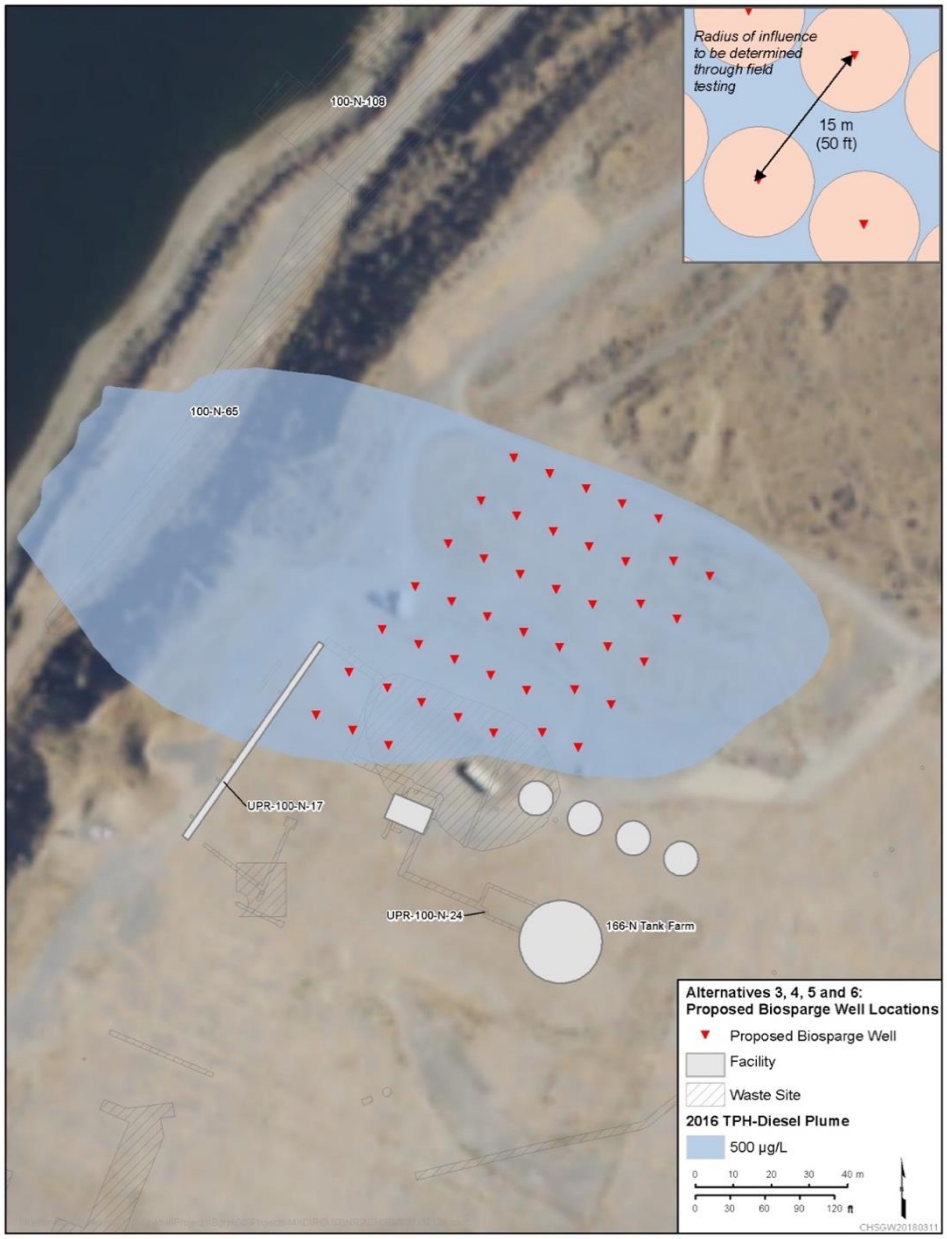

Figure 4. Proposed Injection Well Locations for Biosparging TPH

Key biosparging input parameters are summarized in Table 15.

Table 15. Key Biosparging Cost Input Parameters

Input Parameter	Quantity	Units	Comments
Plume area Treatment area	172,000 116,250	ft^2	See Figure 4.
Radius of influence	25	ft	Typical range: 5 to 25 ft (EM-1110-1-4005).
Number of sparging wells	43	#	Assumes seven rows of wells.
Total well depth	100	ft	
Well spacing	50	ft	
Screen interval	90 to 100	ft bgs	Typical range: 0.5 to 10 ft (EM-1110-1-4005)
Depth to water table	85	ft bgs	DOE/RL-2011-25
Well diameter	4	in.	Typical range: 1 to 4 in. (EM-1110-1-4005).
Air flow rate per well	20	scfm	Typical range: 1.3 to 40 scfm (EM-1110-1-4005).
Total injection flow rate	150	scfm	Assumes pulse operation of six zones of seven wells operating at a time, controlled with a solenoid valve controlling each zone, and separate header pipe to each zone. Assumes manual throttling valves at each injection well.
Compressor	150	scfm	Air flow rate per well × 7 wells per zone × 6 zones. Assumes 30-horsepower rotary screw air compressor rated at 150 scfm, 460-volt, three-phase.
Miscellaneous mechanical/ electrical/instrumentation and controls	1	LS	Assumes 50% of capital costs.
Operational frequency (pulse operation)	4	hr/d	Assumes each zone will be pulsed to operate 4 hr/d.
Piping – 4 in. HDPE (above grade)	500	ft	Estimate
Piping – 2 in. HDPE	1,000	ft	Estimate
Compressor enclosure	150	sf	Assumes 150 sf prefabricated metal building, slab on grade foundation to house compressor, electrical panel, controls and solenoid valves. Assumes programmable logic controller with local control of solenoid valves within the enclosure.
Operational duration	25 years (Alternatives 3 through 6)	years	See Table 8.
Annual biosparging operations and maintenance costs	25	years	Assumes 20% of capital costs per year (estimate).
Annual performance monitoring	25	years	Included in groundwater monitoring costs.

References: DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation.*

EM-1110-1-4005, 2002, *Engineering and Design: Soil Vapor Extraction and Bioventing*.

bgs = below ground surface
HDPE = high-density polyethylene
LS = lump sum
scfm = standard cubic feet per minute

4.4.5 Apatite Treatment for Upland Strontium-90 – Saturated Zone

Apatite treatment is used to treat the strontium-90 in the upland aquifer and reduce the timeframe to achieve drinking water standards beneath the 100-N Area. Using technology similar to that used to install the apatite PRB (Section 4.4.3), sufficient apatite to immobilize all of the strontium-90 within the 42 ha (104 ac) plume that exceeds 80 pCi/L would be emplaced in the upland aquifer by aqueous injection. Figure 5 shows the layout of the treatment, and Table 16 provides the cost parameter assumptions. The estimate includes the cost for abandoning 2,300 injection wells. Section 4.4.1 discusses the groundwater monitoring cost assumptions.

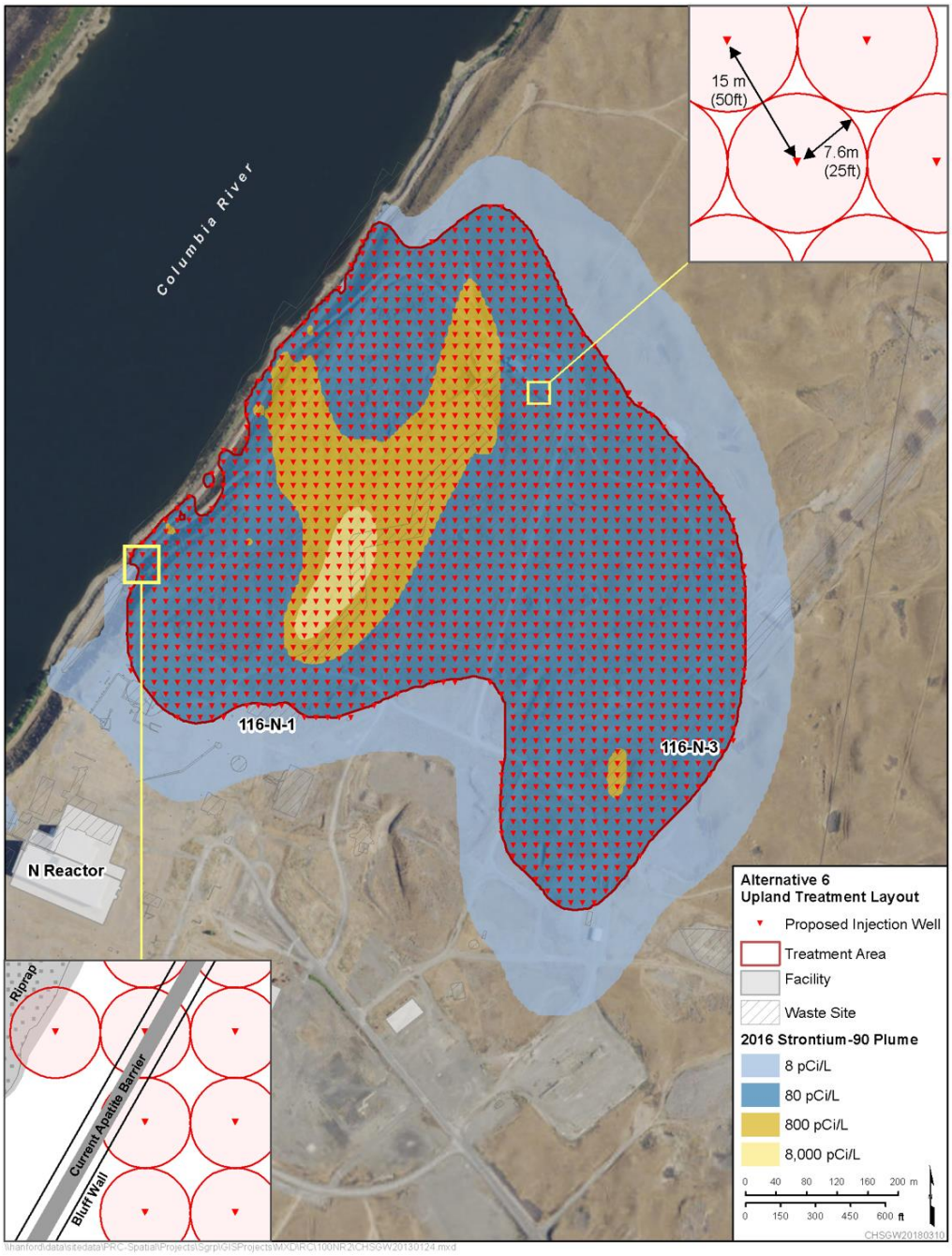

Figure 5. Apatite Treatment for Upland Strontium-90 Layout

Table 16. Key Apatite Treatment for Upland Strontium-90 Injection Cost Input Parameters

Input Parameter	Quantity	Units	Comments
Treatment area	100	ac	Area of plume >80 pCi/L.
Radius of influence per well	25	ft	DOE/RL-2010-29
Well spacing	50	ft	
Number of new injection wells	2,300	#	Based on a 15 m (50 ft) well spacing.
Total well depth	90	ft bgs	
Screen interval	75 to 90	ft bgs	
Well diameter	6	in.	10 in. diameter temporary casing installed prior to installation of 6 in. diameter well.
Calcium-citrate-phosphate volume (concentrate)	11.5×10^6	gal	Assumes 18,927 L (5,000 gal) of calcium-citrate-phosphate concentrate × 2,300 wells.
Injection volume (assumes 12:1 dilution with river water)	138×10^6	gal	Assumes maximum of 227,124 L (60,000 gal) of calcium-citrate-phosphate dilute solution injected into each well × 2,300 wells.
Operational duration	210	years	See Table 15.
Reinjection frequency	0	years	Assumes no reinjections.

Reference: DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*.

bgs = below ground surface

Table 16 provides the key cost estimate input parameters for the apatite source treatment injections.

5 Software Applications

Microsoft Excel was used to perform the calculations. Microsoft Excel is site-licensed client software and is exempt from formal control requirements of PRC-PRO-IRM-309, *Controlled Software Management*.

6 Calculation

As previously discussed, the development of the cost inputs for the 100-N Area remedial action alternatives generally requires very simple calculations performed by hand or using Microsoft Excel spreadsheets.

Appendix A provides the calculations for the waste site remedy components. The calculations for groundwater remedy components are noted in the key cost input tables presented in Section 4.

7 Results/Conclusions

The cost inputs, assumptions, and calculations presented in this ECF were used to develop conceptual-level cost estimate input quantities for waste site and groundwater remedy components, which are documented in Section 4 and Appendix A.

8 References

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Appendix A

Feasibility Study Alternatives Matrices for 100-N Area Waste Sites, Sources, and Plumes

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Table A-1. Institutional Controls Implemented at Waste Sites Post-Remediation by Alternative

Risk Driver	Waste Site[a] – Year when EPC < PRG	Institutional Controls by Alternative				
		Alternative 2 Waste Sites	Alternative 3 Waste Sites	Alternative 4 Waste Sites	Alternative 5 Waste Sites	Alternative 6 Waste Sites
Waste sites with residual radiological contamination at depths >4.6 m (15 ft) bgs and present a potential risk from inadvertent exposure through deep excavation activities	100-N-31 – 2241 100-N-32 – 2241 100-N-38 – 2241 100-N-61:3 – 2241 100-N-64:3 – 2241 100-N-68 – 2241 118-N-1 – 2311 UPR-100-N-3 – 2241 UPR-100-N-7 – 2241 UPR-100-N-10 – 2241 UPR-100-N-12 – 2241 UPR-100-N-39 – 2037	Deep excavation restrictions for all 12 waste sites	Deep excavation restrictions for all 12 waste sites	Deep excavation restrictions for all 12 waste sites	Deep excavation restrictions for all 12 waste sites	Deep excavation restrictions for all 12 waste sites
Waste sites carried forward into the FS with shallow contamination (<4.6 m [15 ft] bgs) that may pose an unacceptable level of risk if excavated	100-N-60 – 2079 100-N-63:2 – 2032 100-N-79 – 2038 100-N-83 – 2073 116-N-4 – 2023 UPR-100-N-13 – 2079 UPR-100-N-26 – 2079	Shallow excavation restrictions for 100-N-60, 100-N-63:2, 100-N-79, 100-N-83, 116-N-4, UPR-100-N-13, and UPR-100-N-26	Shallow excavation restrictions for 100-N-63:2, 100-N-79, and 116-N-4	Shallow excavation restrictions for 100-N-63:2, 100-N-79, and 116-N-4	Shallow excavation restrictions for 100-N-63:2, 100-N-79, and 116-N-4	Shallow excavation restrictions for 100-N-63:2, 100-N-79, and 116-N-4
Waste sites carried forward into the FS with groundwater/ surface water protection risk if irrigation were applied (vadose soil contaminant concentrations exceed soil screening level)	116-N-1 – 2139 116-N-3 – 2140 or 2072[b] UPR-100-N-4 – 2117 UPR-100-N-8 – 2117 UPR-100-N-31 – 2117 116-N-2 – 2067[c] or 2032[d] UPR-100-N-5 – 2067[c] or 2032[d] UPR-100-N-25 – 2067[c] or 2032[d] UPR-100-N-17 – 2067[c]	Prohibit irrigation for 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, UPR-100-N-31, 116-N-2,[c] UPR-100-N-5,[c] UPR-100-N-25,[c] and UPR-100-N-17[c]	Prohibit irrigation for 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, UPR-100-N-31, 116-N-2,[d] UPR-100-N-5,[d] and UPR-100-N-25[d]	Prohibit irrigation for 116-N-3,[b] 116-N-2,[d] UPR-100-N-5,[d] and UPR-100-N-25[d]	Prohibit irrigation for 116-N-2,[d] UPR-100-N-5,[d] and UPR-100-N-25[d]	Prohibit irrigation for 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, UPR-100-N-31, 116-N-2,[d] UPR-100-N-5,[d] and UPR-100-N-25[d]

Table A-1. Institutional Controls Implemented at Waste Sites Post-Remediation by Alternative

Risk Driver	Waste Site[a] – Year when EPC < PRG	Institutional Controls by Alternative				
		Alternative 2 Waste Sites	Alternative 3 Waste Sites	Alternative 4 Waste Sites	Alternative 5 Waste Sites	Alternative 6 Waste Sites
Waste sites with residual radiological contamination at depths >4.6 m (15 ft) bgs and present a potential risk from inadvertent exposure through deep excavation activities that were carried forward into the FS due to additional factors	100-N-63:2 – 2038 116-N-1 – 45043 116-N-3 – 72904 or 2340[b] UPR-100-N-4 – 2418 UPR-100-N-8 – 2418 UPR-100-N-31 – 2418	Deep excavation restrictions for 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, and UPR-100-N-31	Deep excavation restrictions for 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, and UPR-100-N-31	Deep excavation restrictions for 100-N-63:2 and 116-N-3[b]	Deep excavation restrictions for 100-N-63:2	Deep excavation restrictions for 100-N-63:2, 116-N-1, 116-N-3, UPR-100-N-4, UPR-100-N-8, and UPR-100-N-31

a. Additional waste sites may be added through closure reclassifications.

b. Removal, treatment, and disposal of crib results in lower decay date for Alternative 4 compared with Alternatives 2, 3, and 6.

c. Year 2067, estimated based on one-half the groundwater remediation timeframe for total petroleum hydrocarbons.

d. Year 2032, estimated based on one-half the groundwater remediation timeframe for total petroleum hydrocarbons.

bgs = below ground surface
EPC = exposure point concentration
FS = feasibility study
PRG = preliminary remediation goal

Table A-2. Summary of the Cost Basis for Each Waste Site by Alternative

Site Code	Waste Site	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Decision Unit and COPCs Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
100-N-60	French drain (1314-N drywell)	373 m^2 (4,018 ft^2) Dimensions 15 m by 25 m (49 ft by 82 ft) Includes area at sample locations EXC-3, EXC-4, and EXC-5 (Figures 4 and 5 of RSVP attachment to WSRF 2012-084) where concentrations exceed PRGs Footprint includes UPR-100-N-13 and UPR-100-N-26.	4.6 m (15 ft) Contaminated interval: 4.4 m to 5.5 m (14.5 to 18 ft) bgs Assumes RTD to 5.5 m (18 ft) bgs Assumes 4.4 m (14.5 ft) of clean backfill	Shallow: Co-60, Ni-63, Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2079)	(1) Shallow RTD area of 373 m^2 (4,018 ft^2) to 5.5 m (18 ft) bgs (2) Disposal at ERDF	(1) Shallow RTD area of 373 m^2 (4,018 ft^2) to 5.5 m (18 ft) bgs (2) Disposal at ERDF	(1) Shallow RTD area of 373 m^2 (4,018 ft^2) to 5.5 m (18 ft) bgs (2) Disposal at ERDF	(1) Shallow RTD area of 373 m^2 (4,018 ft^2) to 5.5 m (18 ft) bgs (2) Disposal at ERDF
UPR-100-N-13	Unplanned release	Included with 100-N-60	Included with 100-N-60	Shallow: Co-60, Ni-63, Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2079)	Included with 100-N-60	Included with 100-N-60	Included with 100-N-60	Included with 100-N-60
UPR-100-N-26	Unplanned release	Included with 100-N-60	Included with 100-N-60	Shallow: Co-60, Ni-63, Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2079)	Included with 100-N-60	Included with 100-N-60	Included with 100-N-60	Included with 100-N-60
100-N-63:2	Radioactive process sewer	5,000 m^2 (53,800 ft^2) West pipeline leg of excavation: 100 m by 50 m (328 ft by 164 ft) based on Figure 12 in CVP-2013-00001	Contaminated interval: 1.5 to 4.6 m (5 to 15 ft) bgs Assumes 1.5 m (5 ft) of clean backfill	Shallow_Focused 1: Cs-137 and Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2032)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2032)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2032)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2032)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2032)
		2,500 m^2 (26,900 ft^2) 50 m by 50 m (164 ft by 164 ft) at sample location S-21	Contaminated interval: 4.6 to 13.7 m (15 to 45 ft) bgs based on exceedance at 11 m (36 ft) bgs for 116-N-2 in the same excavation area	Deep_Focused 2: Co-60 and Sr-90	ICs: Deep excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	ICs: Deep excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	ICs: Deep excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	ICs: Deep excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	ICs: Deep excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)
100-N-79	Outfall	150 m^2 (1,615 ft^2) 10 m by 15 m (33 ft by 49 ft) based on PRG exceedance for one location only (EXC-11 in Figure 6 of RSVP attachment to WSRF 2013-130)	Contaminated interval: 1.5 to 4.6 m (5 to 15 ft) bgs Assumes 1.5 m (5 ft) of clean backfill Floor and wall height of removed spillway varied from 1.5 to 2.1 m (5 to 7 ft).	Shallow: Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2038)

Table A-2. Summary of the Cost Basis for Each Waste Site by Alternative

Site Code	Waste Site	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Decision Unit and COPCs Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
100-N-83	Unplanned release	North area: 12,000 m^2 (129,170 ft^2) South area: 2,500 m^2 (26,910 ft^2) North area: 240 m by 50 m (787 ft by 164 ft) based on Figure 8 of RSVP attachment to WSRF 2016-006 South area: 50 m by 50 m (164 ft by 164 ft) based on Figure 8 of RSVP attachment to WSRF 2016-006	Contaminated interval: 0.15 to 1.5 m (0.5 to 5 ft) bgs, assumed based on depth of southern area that had nondetects Assumes 15 cm (6 in.) of clean backfill	Shallow: Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2073)	(1) Shallow RTD area of 14,500 m^2 (156,080 ft^2) to 1.5 m (5 ft) bgs (2) Disposal at ERDF	(1) Shallow RTD area of 14,500 m^2 (156,080 ft^2) to 1.5 m (5 ft) bgs (2) Disposal at ERDF	(1) Shallow RTD area of 14,500 m^2 (156,080 ft^2) to 1.5 m (5 ft) bgs (2) Disposal at ERDF Note: May be within layback area for 116-N-1 Trench (Area 4) excavation.	(1) Shallow RTD area of 14,500 m^2 (156,080 ft^2) to 1.5 m (5 ft) bgs (2) Disposal at ERDF
116-N-4	Retention basin	160 m^2 (1,722 ft^2) 16 m by 10 m (52.5 ft by 32.8 ft) based on Figure 12 of RSVP attachment to WSRF 2013-01	Contaminated interval: 1.5 to 4.6 m (5 to 15 ft) bgs Assumes 1.5 m (5 ft) of clean backfill	Shallow: Sr-90	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2023)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2023)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2023)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2023)	Radioactive decay ICs: Shallow excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2023)
116-N-1	Crib	Footprint >151 pCi/g groundwater protection PRG as provided from vadose zone source model: • Crib (Area 1): 10,125 m^2 (108,985 ft^2) • Trench (Area 4), Alternative 5: 39,600 m^2 (426,251 ft^2) • Trench (Area 4), Alternative 4: 19,800 m^2 (213,125 ft^2) (half of footprint provided from vadose zone model, based on professional judgment)	Contaminated interval: • Crib: 4.6 to 15.2 m (15 to 50 ft) bgs based on soil results for borehole 199-N-186 • Trench: 6.4 to 21 m (21 to 69 ft) bgs based on soil results for borehole 199-N-187 Assumes 4.6 m (15 ft) clean backfill for the crib and 6.4 m (21 ft) of clean backfill for the trench	Deep soil exceeds groundwater/surface water protection SSLs and PRGs: • Deep_3, Deep_4, Deep_Focused: Sr−90 Deep soil exceeds human health direct contact PRGs: • Deep_3 (crib): Co-60, Cs-137, Eu-154, Sr-90 • Deep_4 (trench): Co-60, Cs-137, Eu-154, Ni-63, Sr-90 • Deep_Focused (trench): Am-241, Co-60, Cs-137, Eu-154, Ni-63, Pu-239/240, Sr-90	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ [year 2139] (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 45043)	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2139) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 45043)	(1) Deep RTD of crib (10,125 m^2 [108,985 ft^2] to 15.2 m [50 ft] bgs) and deep RTD of trench (19,800 m^2 [213,125 ft^2] to 21 m [69 ft] bgs) (2) Disposal at ERDF	(1) Deep RTD of crib (10,125 m^2 [108,985 ft^2] to 15.2 m [50 ft] bgs) and deep RTD of full trench / source (39,600 m^2 [426,251 ft^2] to 21 m (69 ft) bgs (2) Disposal at ERDF	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2139) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 45043)

Table A-2. Summary of the Cost Basis for Each Waste Site by Alternative

Site Code	Waste Site	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Decision Unit and COPCs Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
116-N-3	Crib	Footprint >15 pCi/g groundwater protection PRG as provided from vadose zone source model: • Crib (Area 0): 20,475 m^2 (220,391 ft^2) • Trench (Area 2), Alternative 5: 5,175 m^2 (55,703 ft^2) • Trench not included in Alternative 4 RTD	Contaminated interval: • Crib: 5.8 to 10.7 m (19 to 35 ft) bgs based on soil results for borehole 199-N-188 • Trench: 5.8 to 10.7 m (19 to 35 ft) bgs Assumes 5.8 m (19 ft) clean backfill for the crib and trench	Deep soil exceeds groundwater/surface water protection SSLs and PRGs: • Deep_3, Deep 5, Deep_6: Sr−90 Deep soil exceeds human health direct contact PRGs: • Deep_3 (trench): Co-60, Cs-137, Ni-63, Sr-90 • Deep_5 (trench): Sr-90 • Deep_6 (crib): Am-241, Co-60, Cs-137, Eu-154, Ni-63, Pu-239/240, Sr-90	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ [year 2140] (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 72904)	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2140) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 72904)	(1) Deep RTD of crib (20,475 m^2 {220,391 ft^2] to approximately 10.7 m [35 ft] bgs) (2) Disposal at ERDF (3) Radioactive decay with irrigation ICs for trench until cumulative risk $\leq 1\times10^{-4}$ (year 2072) (1) Radioactive decay with excavation ICs for trench until cumulative risk $\leq 1\times10^{-4}$ (year 2340)	(1) Deep RTD of crib and trench (total area of 25,650 m^2 (276,094 ft^2) to approximately 10.7 m (35 ft) bgs (2) Disposal at ERDF	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2140) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 72904)
UPR-100-N-31	Unplanned release	900 m^2 (9,688 ft^2) 30 m by 30 m (98.4 ft by 98.4 ft) based on Figure 5 of RSVP-2013-036 Assumes UPR-100-N-8 and UPR-100-N-4 are clean because verification samples exceeding criteria were in area of UPR-100-N-31 Note: UPR-100-N-31, UPR-100-N-8, and UPR-100-N-4 are grouped as one excavation. Note: This area is contiguous with excavation footprint for 116-N-1 Crib (Area 1).	Contaminated interval: 4.6 m to groundwater at 22.6 m (74 ft) bgs (15 to 74 ft) bgs Assumes 4.6 m (15 ft) of clean backfill	Deep soil exceeds groundwater/surface water protection SSLs and PRGs: • Deep, Deep_Focused: Sr-90 • Deep soil exceeds human health direct contact PRGs: • Deep: Co-60, Cs-137, Sr-90 • Deep_Focused: Co-60, Cs-137, Eu-154, Sr-90	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2117) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2418)	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2117) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2418)	(1) Deep RTD area of 900 m^2 (9,688 ft^2) to approximately 22.6 m (74 ft) bgs (2) Disposal at ERDF Note: This area is contiguous with excavation footprint for 116-N-1 Crib (Area 1).	(1) Deep RTD area of 900 m^2 (9,688 ft^2) to approximately 22.6 m (74 ft) bgs (2) Disposal at ERDF Note: This area is contiguous with excavation footprint for 116-N-1 Crib (Area 1).	(1) Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2117) (2) Radioactive decay with excavation ICs until cumulative risk $\leq 1\times10^{-4}$ (year 2418)
UPR-100-N-4	Unplanned release	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31
UPR-100-N-8	Unplanned release	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31	Included with UPR-100-N-31

Table A-2. Summary of the Cost Basis for Each Waste Site by Alternative

Site Code	Waste Site	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Decision Unit and COPCs Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
116-N-2	Storage tank	100 m^2 (1,076 ft^2) 10 m by 10 m (32.8 ft by 32.8 ft) based on TPH verification sample location footprint in Figure 8 of RSVP attachment to WSRF 2013-015	Contaminated interval: 13.1 to 16.7 m (43 to 15 to 55 ft) bgs	Deep: TPH-oil	MNA (biodegradation) Includes one new groundwater monitoring well ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 50 years (year 2067), which is one-half the estimated groundwater cleanup timeframe	MNA (biodegradation) Includes one new groundwater monitoring well ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 15 years (year 2032), which is approximately one-half the estimated groundwater cleanup timeframe	MNA (biodegradation) Includes one new groundwater monitoring well ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 15 years (year 2032), which is approximately one-half the estimated groundwater cleanup timeframe	MNA (biodegradation) Includes one new groundwater monitoring well ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 15 years (year 2032), which is approximately one-half the estimated groundwater cleanup timeframe	MNA (biodegradation) Includes one new groundwater monitoring well ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 15 years (year 2032), which is approximately one-half the estimated groundwater cleanup timeframe
UPR-100-N-5.	Unplanned release	Included with 116-N-2	Included with 116-N-2	Deep: TPH-oil	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2
UPR-100-N-25	Unplanned release	Included with 116-N-2	Included with 116-N-2	Deep: TPH-oil	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2	Included with 116-N-2
100-N-66	Reactor	18,700 m^2 (201,285 ft^2)	To be determined	Not applicable	Waste site will be addressed through the NEPA process Assumes excavation and irrigation ICs in place until remediation is completed	Waste site will be addressed through the NEPA process Assumes excavation and irrigation ICs in place until remediation is completed	Waste site will be addressed through the NEPA process Assumes excavation and irrigation ICs in place until remediation is completed	Waste site will be addressed through the NEPA process Assumes excavation and irrigation ICs in place until remediation is completed	Waste site will be addressed through the NEPA process Assumes excavation and irrigation ICs in place until remediation is completed
UPR-100-N-35	Unplanned release	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66	Included with 100-N-66
100-N-107	Unplanned release	1,400 m^2 (15,160 ft^2) Note: This waste site overlies waste site UPR-100-N-17.	Surface to 4.6 m (15 ft)	Shallow soil and pipelines: radionuclides, TPH, PAH	(1) RTD area of 1,400 m^2 (15,160 ft^2) to 4.6 m (15 ft) bgs (after bioventing system discontinued; assumes year 2020) (2) Disposal at ERDF	(1) RTD area of 1,400 m^2 (15,160 ft^2) to 4.6 m (15 ft) bgs (after bioventing at UPR-100-N-17 discontinued; assumes year 2042) (2) Disposal at ERDF	(1) RTD area of 1,400 m^2 (15,160 ft^2) to 4.6 m (15 ft) bgs (after bioventing at UPR-100-N-17 discontinued; assumes year 2042) (2) Disposal at ERDF	(1) RTD area of 1,400 m^2 (15,160 ft^2) to 4.6 m (15 ft) bgs (2) Disposal at ERDF	(1) RTD area of 1,400 m^2 (15,160 ft^2) to 4.6 m (15 ft) bgs (after bioventing at UPR-100-N-17 discontinued; assumes year 2042) (2) Disposal at ERDF
100-N-84:10	Radioactive process sewer	Included with 100-N-107	Included with 100-N-107	Shallow soil and pipelines: radionuclides, TPH, PAH	Included with 100-N-107	Included with 100-N-107	Included with 100-N-107	Included with 100-N-107	Included with 100-N-107
2607-FSM	100-N Area fire station septic tank 2607-FSM Remediation will not occur until after fire station is decommissioned (scheduled for 2020)	Septic tank 7570 L (2000 gal) Drain field: 31.8 m (104 ft) long by 11.9 m (39 ft) wide	Surface to 4.6 m (15 ft)	Septic waste	(1) RTD area of 400 m^2 (4,300 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 400 m^2 (4300 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 400 m^2 (4,300 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 400 m^2 (4,300 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 400 m^2 (4,300 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF

Table A-2. Summary of the Cost Basis for Each Waste Site by Alternative

Site Code	Waste Site	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Decision Unit and COPCs Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
600-339	100-N Area fire station dry well Remediation will not occur until after the fire station is decommissioned (scheduled for 2020)	16 m^2 (172 ft^2)	Surface to 4.6 m (15 ft)	TPH-diesel	(1) RTD area of 16 m^2 (172 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 16 m^2 (172 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 16 m^2 (172 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 16 m^2 (172 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF	(1) RTD area of 16 m^2 (172 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Disposal at ERDF
600-348	100-N Area fire station underground storage tanks Remediation will not occur until after the fire station is decommissioned (scheduled for 2020)	31 m^2 (334 ft^2)	Surface to 4.6 m (15 ft) Potentially deeper	TPH-diesel	(1) RTD area of 31 m^2 (334 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Dispose at ERDF	(1) RTD area of 31 m^2 (334 ft^2) to 4.6 m (15 ft) bgs. (after 2020) (2) Dispose at ERDF	(1) RTD area of 31 m^2 (334 ft^2) to 4.6 m (15 ft) bgs (after 2020) (2) Dispose at ERDF	(1) RTD area of 31 m^2 (334 ft^2) to 4.6 m (15 ft) bgs. (after 2020) (2) Dispose at ERDF	(1) RTD area of 31 m^2 (334 ft^2) to 4.6 m (15 ft) bgs. (after 2020) (2) Dispose at ERDF
UPR-100-N-17	166-N diesel oil supply line leak	4,725 m^2 (50,860 ft^2) Note: This waste site underlies waste site 100-N-107.	Contaminated interval: • 4.6 to 16.7 m (15 to 75 ft) bgs • Most TPH between 60 and 75 ft bgs Assumes 4.6 m (15 ft) of clean backfill except for 1,400 m^2 (15,160 ft^2) area encompassing 100-N-107/ 100-N-84:10	TPH: Deep soil exceeds groundwater/ surface water protection SSLs and PRG	MNA (biodegradation) ICs: Irrigation ICs until TPH concentrations are <2,000 mg/kg Assumes 50 years (year 2067), which is one-half the estimated groundwater cleanup timeframe	Bioventing of shallow and deep vadose zone for 25 years (year 2042)	Bioventing of shallow and deep vadose zone for 25 years (year 2042)	(1) Deep RTD area of 4,725 m^2 (50,860 ft^2) to 16.7 m (75 ft) bgs minus the area encompassing 100-N-107 Note: Subtract the soil volume include for overlying waste 100-N-107. (2) Disposal at ERDF	Bioventing of shallow and deep vadose zone for 25 years (year 2042)

References: CVP-2013-00001, *Cleanup Verification Package for the 100-N-63:2, Pipelines Between 109N, 105N, 107N, 1310N, 1322N, 1926N, and 36" Process Drain to Outfall*.

WSRF 2012-084, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 100-N-60; 1314-N Drywell, Attachment, "Remaining Sites Verification Package for the 100-N-60, 1314-N Drywell; UPR-100-N-13, 1314-N Drywell Overflow, 1314-N Loading Station, UN-100-N-13; and UPR-100-N-26, Backflow of Radioactive Waste in 1314-N Facility, UN-100-N-26 Waste Sites."

WSRF 2013-01, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 116-N-4, Attachment, "Remaining Sites Verification Package for the 116-N-4, 1300-N Emergency Dump Basin Waste Site."

WSRF 2013-015, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 116-N-2, Attachment, "Remaining Sites Verification Package for the 116-N-2; 1310-N Chemical Waste Storage Tank; 1310-N Waste Storage Area; the Golf Ball, UPR-100-N-5; 116-N-2 Radioactive Chemical Waste Treatment Storage Facility; 1310-N Chemical Waste Storage Tank Leak; UN-100-N-5, UPR-100-N-25; UN-100-N-25; Uncontrolled Venting of 1310-N Tank Waste Sites."

WSRF 2013-130, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 100-N-79; 1908-N Spillway Waste Site, "Remaining Sites Verification Package for the 100-N-79, 1908-N Spillway Waste Site."

WSRF 2016-006, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 100-N-83, Attachment, "Remaining Sites Vitrification Package for the 100-N-83, Two Contamination Areas Found Near 116-N-1 Waste Site."

bgs = below ground surface
COPC = contaminant of potential concern
ERDF = Environmental Restoration Disposal Facility
FS = feasibility study
IC = institutional control
MNA = monitored natural attenuation
NEPA = *National Environmental Policy Act of 1970*
PAH = polycyclic aromatic hydrocarbons
PRG = preliminary remediation goal
RSVP = Remaining Sites Vitrification Package
RTD = removal, treatment and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons

Table A-3. Estimated Area and Depth of Contamination for Deep Waste Sites Identified for Excavation Restriction ICs Only

Site	Decision Units and COCs	Date when Radionuclide COC Concentration Declines to PRG (e.g., ELCR <10^{-4})	Area of Contamination	Assumed Depth Range of Contamination	Basis/Comment
118-N-1	Deep: Ni-63, Sr-90 Deep_Focused 1: Co-60, Cs-137, Sr-90 Deep_Focused 2: Co-60, Cs-137, Eu-154, Sr-90	Year 2032 Year 2061 **Year 2311**	1,000 m^2 [10,763 ft^2])	10.4 to 13.4 m [34 to 44 ft] bgs (overlain by clean fill material)	Source: WSRF 2013-076, RSVP attachment Figures 10 and 11. Area 50 m by 20 m (164 ft by 65.6 ft) based on location of contaminated samples (Figure 10). Upper boundary based on grade elevation (138.4 m [454.1 ft]), minus bottom of previous excavation (128 m [419.9 ft]) (Figure 11). Lower boundary is base of Sr-90 contamination in test pit (125 m [410.1 ft] elevation) (Figure 11).
100-N-31	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	3,300 m^2 [35,520 ft^2] (estimated area for all 11 sites west of N Reactor/ 109-N heat exchanger building)	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Source: WSRF 2013-065, RSVP attachment. Area for group of waste sites based on combined area for deep zone decision units DZ1 (500 m^2 [5,382 ft^2]) and DZ2 (2,800 m^2 [30,139 ft^2]) (RSVP, Figure 5). Upper boundary based on bottom of previous excavation 9.5 m (31 ft). Lower boundary is groundwater at 20 m (65.6 ft).
100-N-32	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31)	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
100-N-38	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
100-N-61:3	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
100-N-68	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
UPR-100-N-3	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
UPR-100-N-7	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
UPR-100-N-10	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 2 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
UPR-100-N-12	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90	Year 2102 **Year 2241**	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
100-N-64:3	Deep_1: Co-60, Cs-137, Sr-90 Deep_2: Sr-90 Deep_Focused: Co-60, Cs-137, Sr-90	Year 2102 **Year 2241** Year 2110	Included in area shown for 100-N-31	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Same as above.
UPR-100-N-39	Deep_Focused: Co-60, Cs-137, Sr-90	**Year 2037**	150 m^2 [1,614 ft^2]	9.5 to 20 m [31 to 65.6 ft] bgs (overlain by clean fill material)	Source: WSRF 2013-065, RSVP attachment. Area 19 m by 8 m (62.3 ft by 26.2 ft) based on deep zone decision unit DZ3 (RSVP, Figure 5). Upper boundary based on bottom of previous excavation 9.5 m (31 ft). Lower boundary is groundwater at 20 m (65.6 ft).

References: WSRF 2013-065, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 100-N-31, Attachment, "Remaining Sites Verification Package for the 100-N-31, 100-N-32, 100-N-38, 100-N-61:3, 100-N-64:3, 100-N-68, UPR-100-N-3, UPR-100-N-7, UPR-100-N-10, UPR-100-N-12, and UPR-100-N-39 Waste Sites.

WSRF 2013-076, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 118-N-1; 1303-N Spacer Silos, Attachment, "Remaining Sites Verification Package for the 118-N-1, 1303-N Spacer Silos Waste Site."

Note: **Bold** font indicates maximum year when radionuclide COC concentration declines to the PRG (e.g. ELCR <10^{-4}). Deep excavation ICs are needed until this date.

bgs = below ground surface
COC = contaminant of concern
ELCR = excess lifetime cancer risk
PRG = preliminary remediation goal
RSVP = Remaining Sites Verification Package

Table A-4. Summary of the Cost Basis for each Vadose Zone/PRZ Continuing Source by Alternative

Source	Target Area	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Source Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Strontium-90	3	3,150 m^2 (33,906 ft^2) Area where soil Sr-90 concentration downgradient of the 116-N-1 Crib is greater than the 151 mg/kg groundwater protection PRG, as provided from vadose zone source model.	Contaminated interval: 6.4 m (21 ft) bgs to groundwater at 21.9 m (72 ft)	Deep soil assumed to exceed groundwater/ surface water protection SSLs and PRG.	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)
Strontium-90	5	10,425 m^2 (112,214 ft^2) Area where soil Sr-90 concentration downgradient of the 116-N-1 Trench is greater than the 151 mg/kg groundwater protection PRG, as provided from vadose zone source model.	Contaminated interval: 6.4 m (21 ft) bgs to groundwater at 19.9 m (65.3 ft)	Deep soil assumed to exceed groundwater/ surface water protection SSLs and PRG.	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)	Radioactive decay with irrigation ICs until cumulative risk $\leq 1\times10^{-4}$ (assumes year 2139)
Strontium-90	Areas 1 and 4	Alternatives 2, 3, 5, and 6: Included in footprints for waste site 116-N-1 Crib and Trench, respectively (see Table A-2). Alternative 4: Included in the footprint for waste site 116-N-1, except for one-half of Area 4 (19,800 m^2 [213,125 ft^2], which is half of the footprint provided from vadose zone model.		Included in the footprints for waste site 116-N-1 Crib and Trench (see Table A-2), except as noted.			Radioactive decay for one-half of Area 4 (area outside RTD footprint for waste site 116-N-1 Trench described in Table A-2)		
Strontium-90	Areas 0 and 2	Included in footprints for waste site 116-N-3 Crib and Trench, respectively (see Table A-2).		No separate FS action. Areas are included in the footprints for waste site 116-N-3 Crib and Trench (see Table A-2).					
TPH	1	Area where soil TPH concentration is >2,000 mg/kg, as provided from vadose zone source model. Area is included in the footprint for waste site UPR-100-N-17 (see Table A-2).		No separate FS action. Area is included in the footprint for waste site UPR-100-N-17 (see Table A-2).					

Table A-4. Summary of the Cost Basis for each Vadose Zone/PRZ Continuing Source by Alternative

Source	Target Area	Assumed Areal Footprint Requiring Remediation	Assumed Depth of Contamination Requiring Remediation	Source Considered for the FS	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Nitrate	1	1,350 m^2 (14,530 ft^2) Area where soil nitrate concentration is >45 mg/kg as provided from vadose zone source model. Note: This area is encompassed in excavation footprint for 116-N-1 Crib (Area 1).	Contaminated interval: 6.4 m (21 ft) bgs to groundwater at 22.6 m (74 ft). Assumes 4.6 m (15 ft) clean backfill	Area is within footprint of Sr-90 target Area 1 and waste site 116-N-1 Crib (see Table A-2).	Irrigation ICs (area is within footprint of Sr-90 Area 1 (waste site 116-N-1 Crib).	Irrigation ICs (area is within footprint of Sr-90 Area 1 (waste site 116-N-1 Crib).	Area is within RTD footprint of Sr-90 Area 1 (waste site 116-N-1 Crib) (see Table A-2)	Area is within RTD footprint of Sr-90 Area 1 (waste site 116-N-1 Crib) (see Table A-2)	Irrigation ICs (area is within footprint of Sr-90 Area 1 (waste site 116-N-1 Crib).

bgs = below ground surface
FS = feasibility study
IC = institutional control
PRG = preliminary remediation goal
RTD = removal, treatment, and disposal
SSL = soil screening level
TPH = total petroleum hydrocarbons

Table A-5. Annual Groundwater Well Sampling Schedule by COC for the FS Alternatives

COC	Number of Wells					
Nitrate plume	6					
TPH plume	8					
Sr-90 shoreline	20					
Sr-90 upland	16					
Tritium	3					
Other COPCs*	6*					
Total	59					
*COPC monitoring includes 5 years of semiannual compliance monitoring only beginning in year 0.						
Alternative 2	**Years to Cleanup from Start Date**					
	0	**15**	**40**	**100**	**290**	
Other COPCs*						
NO_3			-6			
TPH				-8		
Sr-90 shoreline			-20			
Sr-90 upland					-16	
Tritium		-3				
Wells remaining	53	50	24	16	0	
Note: Add 5 years compliance monitoring (semiannual) for nitrate, TPH, Sr-90, and tritium after years to cleanup. *Monitoring for other COPCs assumes 5 years of semiannual compliance monitoring only at six wells, starting in year 0.						
Alternative 3	**Years to Cleanup from Start Date**					
	0	**15**	**25**	**40**	**290**	
Other COPCs*						
NO_3				-6		
TPH			-8			
Sr-90 shoreline				-20		
Sr-90 upland					-16	
Tritium		-3				
Wells remaining	53	50	42	16	0	
Note: Add 5 years compliance monitoring (semiannual) for nitrate, TPH, Sr-90, and tritium after years to cleanup. *Monitoring for other COPCs assumes 5 years of semiannual compliance monitoring only at six wells, starting in year 0.						

Table A-5. Annual Groundwater Well Sampling Schedule by COC for the FS Alternatives

Alternative 4	Years to Cleanup from Start Date					
	0	**15**	**25**	**30**	**40**	**290**
Other COPCs*						
NO_3				-6		
TPH			-8			
Sr-90 shoreline					-20	
Sr-90 upland						-16
Tritium		-3				
Wells remaining	53	50	42	36	16	0
Note: Add 5 years compliance monitoring (semiannual) for nitrate, TPH, Sr-90, and tritium after years to cleanup. *Monitoring for other COPCs assumes 5 years of semiannual compliance monitoring only at six wells, starting in year 0.						
Alternative 5	**Years to Cleanup from Start Date**					
	0	**15**	**25**	**30**	**40**	**290**
Other COPCs*						
NO_3				-6		
TPH			-8			
Sr-90 shoreline					-20	
Sr-90 upland						-16
Tritium		-3				
wells remaining	53	50	42	36	16	0
Note: Add 5 years compliance monitoring (semiannual) for nitrate, TPH, Sr-90, and tritium after years to cleanup. *Monitoring for other COPCs assumes 5 years of semiannual compliance monitoring only at six wells, starting in year 0.						
Alternative 6	**Years to Cleanup from Start Date**					
	0	**15**	**25**	**40**	**45**	**190**
Other COPCs						
NO_3				-6		
TPH			-8			
Sr-90 shoreline					-20	
Sr-90 upland						-16
Tritium		-3				
Wells remaining	53	50	42	36	16	0
Add 5 years compliance monitoring (semiannual) for nitrate, TPH, Sr-90, and tritium after years to cleanup. *Monitoring for other COPCs assumes 5 years of semiannual compliance monitoring only at six wells, starting in year 0.						

COC = contaminant of concern
COPC = contaminant of potential concern
TPH = total petroleum hydrocarbons

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Appendix B

Continuing Periodically Rewetted Zone Source Area Maps

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Figure B-3. Total Petroleum Hydrocarbons Continuing Source Area (Waste Site UPR-100-N-17 and Vicinity) B-3

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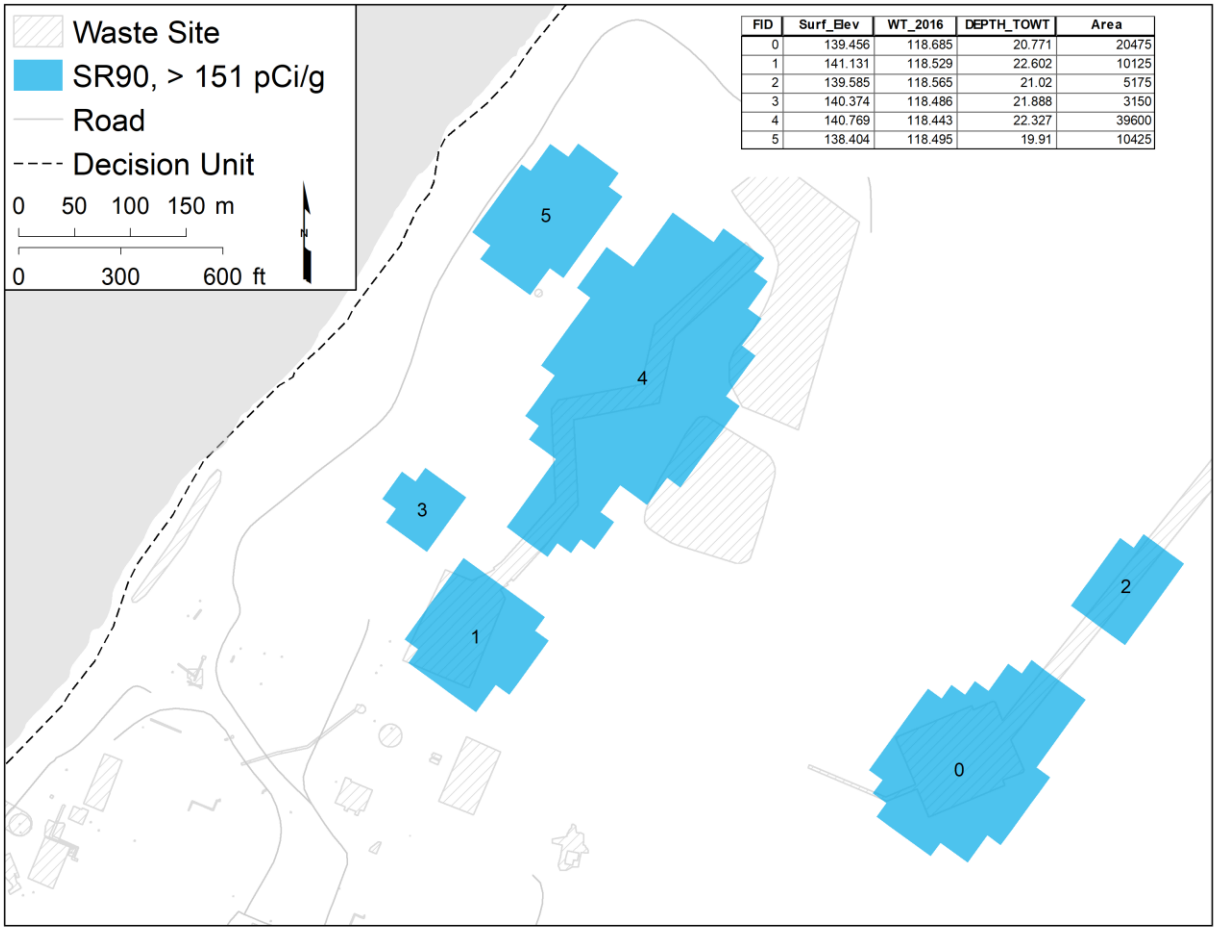
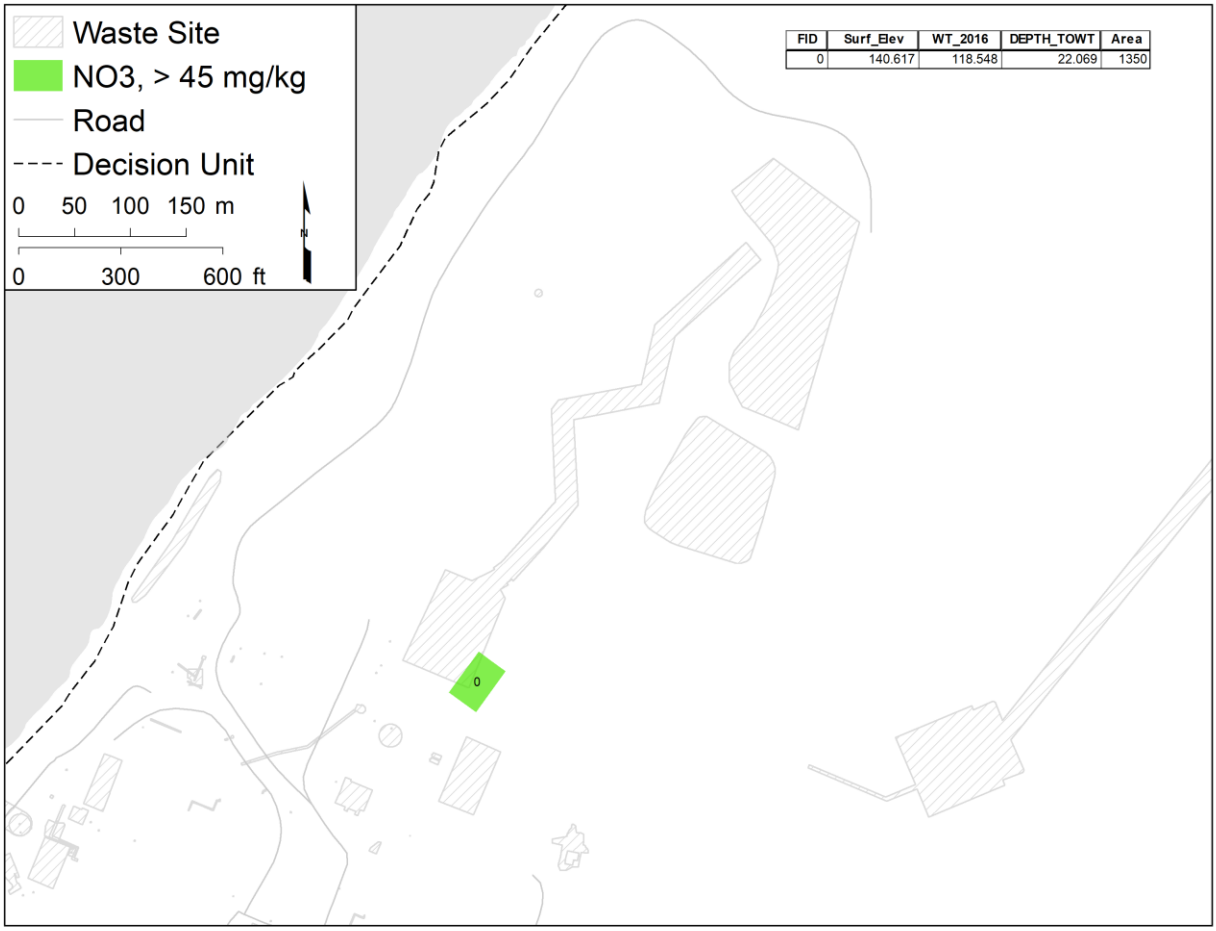


FID	Surf_Elev	WT_2016	DEPTH_TOWT	Area
0	139.456	118.685	20.771	20475
1	141.131	118.529	22.602	10125
2	139.585	118.565	21.02	5175
3	140.374	118.486	21.888	3150
4	140.769	118.443	22.327	39600
5	138.404	118.495	19.91	10425

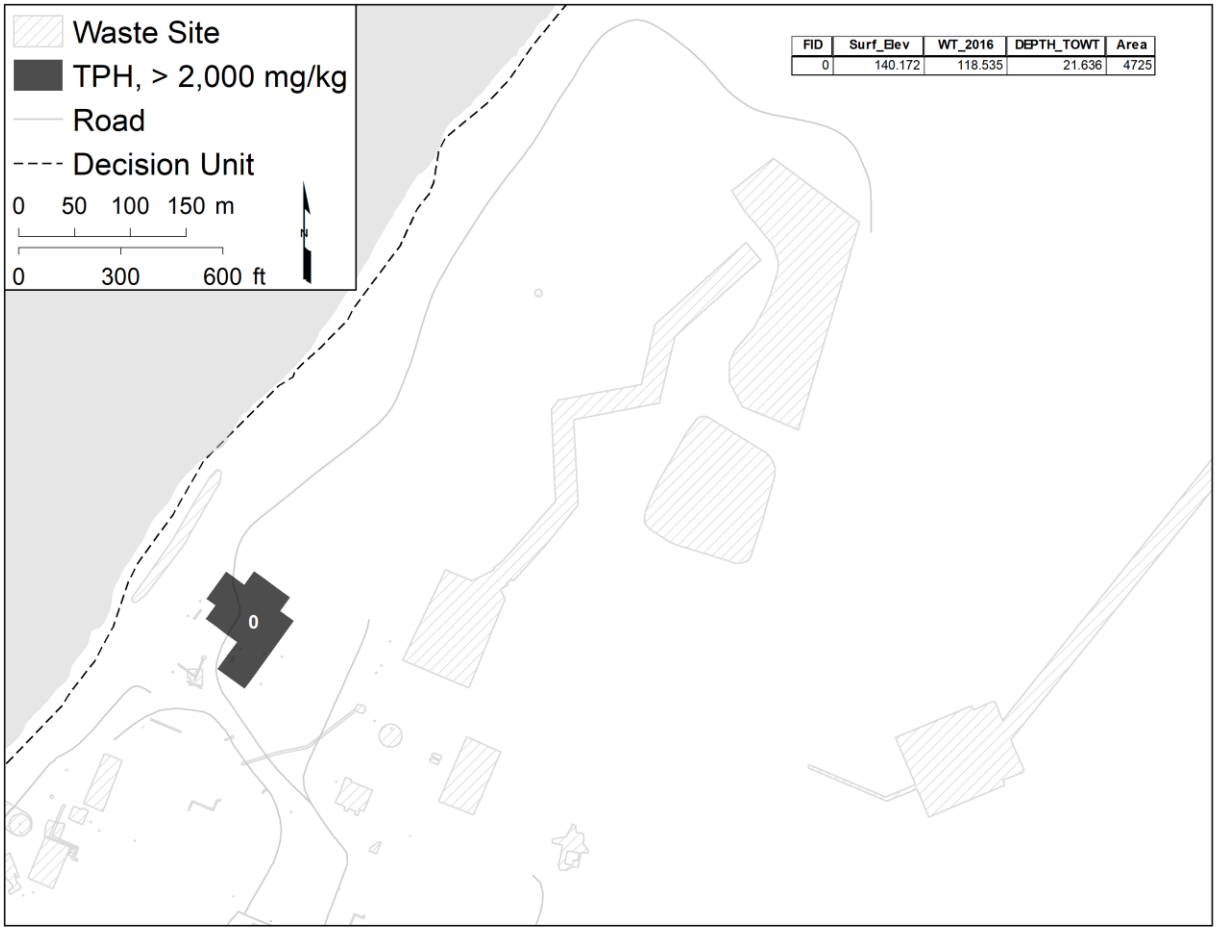
Note: Areas 3 and 5 are continuing sources of strontium-90. Areas 0 and 2 are the 116-N-3 Crib and Trench; Areas 1 and 4 are 116-N-1 Crib and Trench. Alternative 4 removal, treatment, and disposal assumes 50% of Area 4 footprint, whereas Alternative 5 assumes 100% of Area 4 footprint for removal, treatment, and disposal.

Figure B-1. Strontium-90 Continuing Source Areas and Overlap with Waste Sites 116-N-1 and 116-N-3



Note: Nitrate continuing source is located within the 116-N-1 Crib footprint (Area 1 in Figure B-1).

Figure B-2. Nitrate Continuing Source Area



Note: Total petroleum hydrocarbons continuing source footprint is assumed contamination footprint for waste site UPR-100-N-17.

Figure B-3. Total Petroleum Hydrocarbons Continuing Source Area (Waste Site UPR-100-N-17 and Vicinity)

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