Appendix B

Screening-Level Ecological Risk Assessment

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Terms

DOE	U.S. Department of Energy
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ERAGS	Ecological Risk Assessment Guidance for Superfund
OU	Operable Units
RECUPLEX	Recovery of Uranium and Plutonium by Extraction
SLERA	screening level ecological risk assessment
UPR	unplanned release
WAC	Washington Administrative Code
WIDS	Waste Information Data System database

Appendix B

Screening-Level Ecological Risk Assessment

B1.0 200-PW-1/3/6 Operable Units Ecological Risk Assessment

A screening level ecological risk assessment (SLERA) was performed for all 16 sites in the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units (OUs) following EPA 540-R-97-006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* (ERAGS) and the Terrestrial Ecological Evaluation (TEE) procedure presented in WAC 173-340-7490. Waste sites were considered with regard to exposure potential for plants and animals. The 16 waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs are listed in Table 1-1 of the main text and described further in Section B2.0.

The SLERA steps focus the assessment and determine whether the potential for exposure or risk to ecological receptors warrant further investigation. The most critical aspect of an ecological screen is problem formulation. This is the systematic planning incorporated into the beginning of the risk assessment process that identifies the major factors to be considered and is linked to the regulatory and policy contexts of the assessment.

Problem formulation involved reviewing relevant site records (e.g., Waste Information Data System [WIDS]) as a first step to assess existing data on waste site conditions pertinent to ecological exposure. This information was considered before the site visit was undertaken (ERAGS Step 1). As noted in ERAGS, a possible outcome of the site visit is a determination that present or future ecological impacts are negligible because complete exposure pathways do not exist. This is an important determination, and the guidance emphasizes all sites should be evaluated by qualified personnel to determine whether this conclusion is appropriate. In accordance with this guidance, the principal authors of the Central Plateau ecological DQOs (WMP-20570) and sampling and analysis plans (DOE/RL-2004-42) evaluated whether complete exposure pathways exist for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites.

Evaluating potential exposure pathways is one of the primary tasks of the screening-level characterization of a site. For an exposure pathway to be complete, a contaminant must be able to travel from the source to ecological receptors and be taken up by the receptors via one or more exposure routes. If an exposure pathway is not complete for a specific contaminant, the exposure pathway does not need to be evaluated further.

Information is provided in Table B-1 for the deeper-rooted plant species and deeper burrowing mammal and ant species occurring on the Hanford Site (PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport*; RHO-SA-211, *Intrusion of Radioactive Waste Burial Sites by the Great Basin Pocket Mouse* (*Perognathus parvus*). None of the maximum depths reported for plant or animal species were greater than 3 m (10 ft), above the 4.6 m (15-ft) interval defined for applicability of shallow-zone screening thresholds (WAC 173-340-7490[4][b]), which indicates the pathway from deep soil to ecological receptors is incomplete. The Hanford Site-specific data indicate the shallow-zone soil (<4.6 m [15 ft) bgs) is the primary contaminated medium of concern for ecological receptors. Waste sites were considered inaccessible to ecological receptors under either current or future conditions if the contamination was deeper than 4.6 m (15 ft) bgs.

Table B-1. Maximum Plant-Rooting and Burrowing Depth for the Hanford Site Receptors

Species	Maximum Depth		Reference
	(cm)	(ft)	
Plants			
Antelope bitterbrush	300	9.8	PNL-5247
Big sagebrush	200	6.6	PNL-5247
Spiny hopsage	195	6.4	PNL-5247
Russian thistle	172	5.6	PNL-5247
Mammals			
Great Basin pocket mouse	200	6.6	RHO-SA-211
Soil Biota			
Harvester ants	270	8.8	PNL-2774

Source:
PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport.*
PNL-5247, *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site.*
RHO-SA-211, *Intrusion of Radioactive Waste Burial Sites by the Great Basin Pocket Mouse (*Perognathus parvus*).*

In considering the subsurface extent of plant roots or animal burrows, it is important to realize that burrow and root density are not continuous from the soil surface to the maximum reported depths; biotic activity decreases with depth. The depths to which insects, animals (burrows), and plants (roots) are likely to occur define the biologically active zone. The working hypothesis for purposes of this screening ecological risk assessment is that biological activity at the 200-PW-1, 3 and 6 OUs is limited largely to the top 2.44 to 3.05 m (8 to 10 ft), and a conceptual model of belowground biotic activity is presented in Figure B-1.

Empirical data on arid-adapted species offer support for the conceptual model, showing the burrow fraction and percentage of root biomass is heavily weighted to shallow soils (Figure B-2). "Biotic Transport of Radionuclides From A Low-Level Radioactive Waste Site" (Kennedy et al., 1985), and "Vertical Distribution of Soil Removed by Four Species of Burrowing Rodents in Disturbed and Undisturbed Soils" (Reynolds and Laundré, 1988) offer data for pocket mice, kangaroo rats, pocket gophers, and ground squirrels to illustrate how burrow density is a function of depth. Except for the kangaroo rat, these arid-adapted mammals are all Hanford Site species (PNNL, 2008, *Hanford Site Ecological Monitoring & Compliance*). Similar to mammalian burrow density, the belowground mass of deeply rooting desert shrubs also is weighted toward greater density near the surface and, similar to mammalian burrow density, root mass declines with depth (Figure B-2). In Figure B-2, the different colors represent data on different species of plants and animals. The y-axis represents depth, and the x-axis is the fraction of burrow density or plant-root density above a given depth in the subsurface. For example, approximately 80 percent of the plant-root density is located above a depth of 30 cm (12 in.). Thus, while certain plants and animals have maximum rooting or burrowing depths many feet into the subsurface, it is clear most of the biotic activity for these species is in the top few feet of the soil column. The animal and plant data used to generate Figure B-2 have been published previously in WMP-20570, Appendix F.

Soil macroinvertebrates also burrow extensively in deserts. For example, some species of spiders (e.g., trap-door spiders) are known to burrow albeit shallowly (usually less than 15 cm [6 in.]), as do many species of arid-system beetles such as the ubiquitous *Eleodes* spp. and other darkling beetles. At the Hanford Site, harvester ants likely are the deepest burrowing animals occurring on the Central Plateau (PNL-2774). For this reason, harvester ants are actively managed for removal where they occur on waste sites. For example, alpha contamination was found on the soil surface at one of the sites (216-Z-9 Trench) that apparently had been brought to the surface by ants. The contamination was detected at the edge of the existing concrete pad through site surveillance. This contamination pathway was promptly mitigated by pesticide application and the installation of a biobarrier to circumvent this potential exposure pathway. These management practices serve to break potential exposure pathways created through biointrusion under current conditions at the Hanford Site. However, for the purposes of making a baseline assessment of ecological risks, it is necessary to take into consideration that biointrusion by harvester ants could potentially create exposure pathways. The potential exposure pathways that could exist include:

- Potential accumulation of radionuclides and inorganics by ants burrowing into contaminated soils (up to a depth of 8.8 feet, based on the data presented in Table B-1).
- Potential exposures to insectivorous or omnivorous birds and mammals from ingestion of ants that have accumulated radionuclides and inorganic contaminants.
- Potential exposures of wildlife from ingestion of radionuclides and inorganics in contaminated soil that has been exhumed and brought to the surface by ants.
- Potential accumulation by plants of contaminants in exhumed soils that are subsequently incorporated into surface soil through wind action and rainfall.

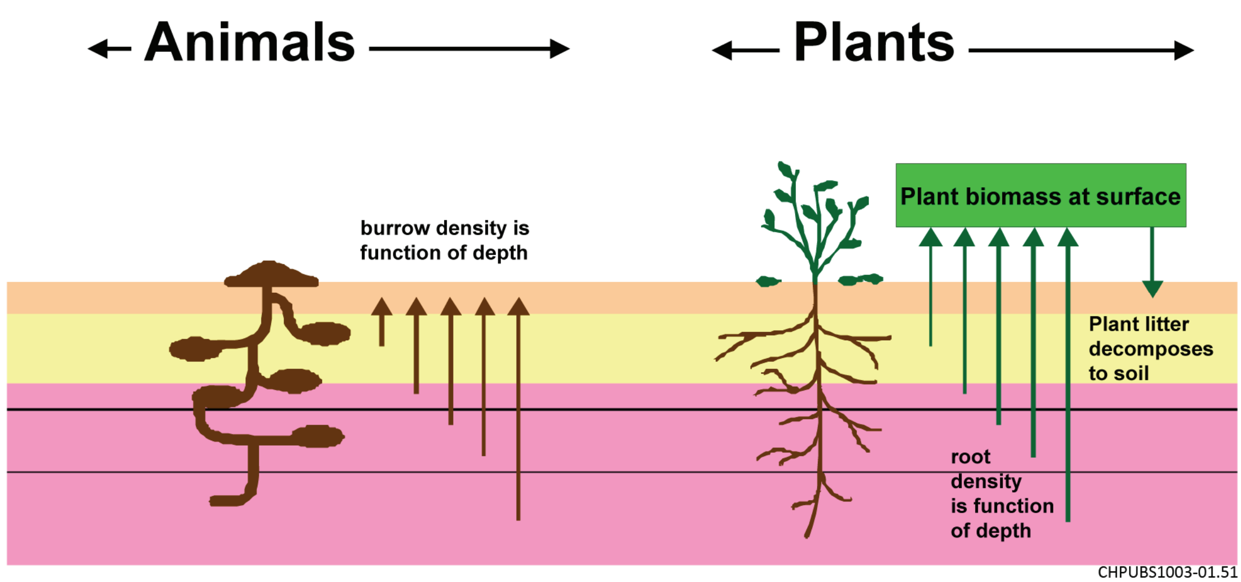
Plants rely on extensive belowground biomass to capture nutrients and water. The extent of the rooting systems for species in the 200 Areas was evaluated in PNL-5247, *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site*. This study concentrated on plant species suspected of having deep-root systems and those species reported in previous studies to contain radionuclides in aboveground parts. These maximum rooting depths listed in Table B-1 are consistent with the majority of plant species in a literature review of rooting depth by vegetation types ("Maximum Rooting Depth of Vegetation Types at the Global Scale" [Canadell et al., 1996]). This review indicates 194 of 253 species had maximum rooting depths of 2 m (6.6 ft) or less. Although root depth determines whether buried waste is accessible by plants, biologically mediated contaminant transport is a function of the biomass available for transport. Consequently, the relative density of roots is more important than the absolute depth attained. As shown in Figure B-2, only a minor percentage of roots ever reach depths greater than 1.5 m (5 ft) bgs. This is especially true for arid-adapted plants of the Central Plateau. In dry environments such as this where groundwater is inaccessible, plants must rely on meteoric water infiltration to survive, and plant roots tend to extend laterally (rather than vertically) to capture this infiltrating water.

It is important to recognize that biointrusion into subsurface sites requires aboveground conditions favoring burrowing animals and deep-rooted plants. These conditions are lacking for the majority of sites within the 200-PW-1, 200-PW-3, and 200-PW-6 OUs under current conditions because of the institutional controls in place to discourage biotic access to buried waste. These controls include: (1) at least an annual visual site inspection to look for evidence of subsidence or animal intrusion, (2) a surface radiological survey performed in any areas where radiation is detected, covered with soil, or posted for further action, (3) herbicide application performed several times a year to control any vegetation, and (4) pesticides applied as needed to control ants and termites.

Because of the active management practices and lack of biological activity at the 2.44 to 3.05 m (8 - 10 ft) bgs interval, exposure potential to ecological receptors is not of concern under current conditions for the remaining sites, because waste is buried deeper, and there are no aboveground receptors that could access the waste. These waste sites not of concern under current conditions include the following:

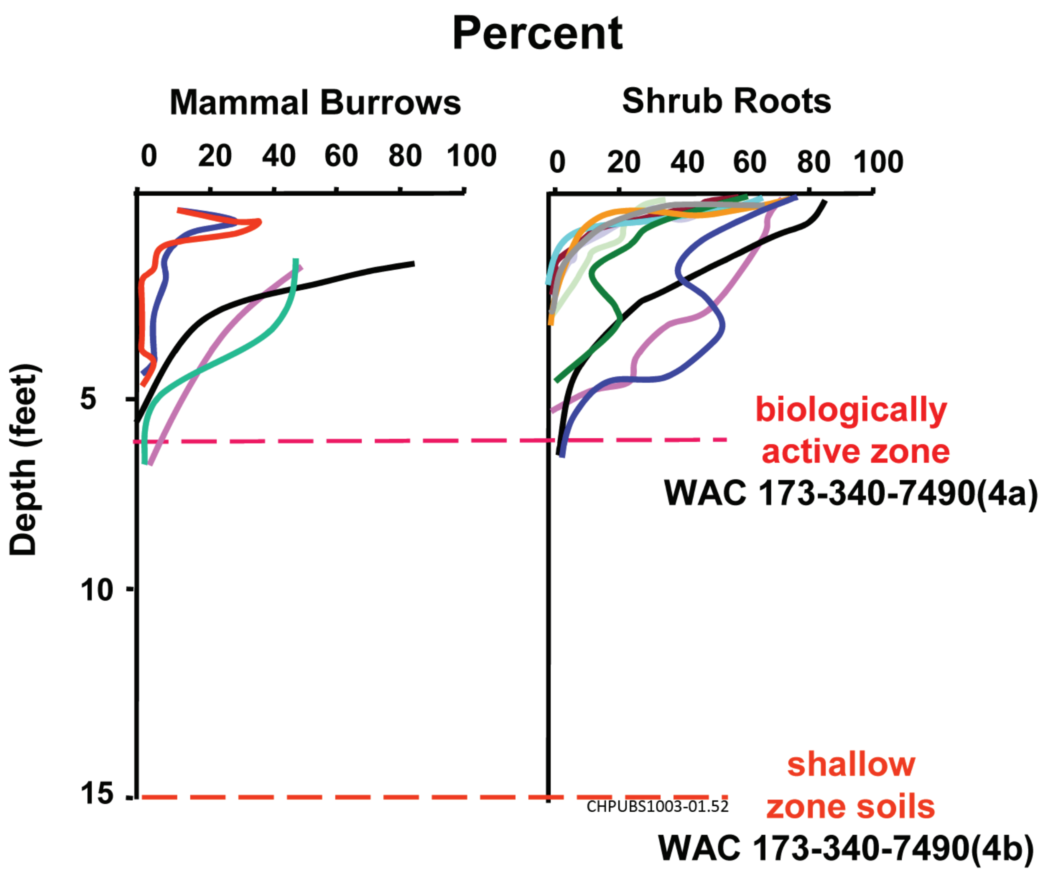
- 216-A-7 Crib
- 216-A-8 Crib
- 216-A-24 Crib
- 216-Z-1&2 Cribs
- 216-Z-1A Tile Field

However, as discussed below in Section B2.0, conditions at 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites might provide ecological exposure pathways under future conditions, which may require further evaluation as part of the alternatives evaluation. Factors that preclude potential ecological exposure pathways and risk under current conditions include: physical barriers preventing exposure, lack of habitat to support receptors capable of waste biointrusion, and an active management program to preclude the establishment of deeply rooted plants and animal burrowing. However, is it uncertain that wastes are buried deeper than plants and animals can access at all of these sites. While many of the site currently do not support habitat, these conditions might not be present in the future. Finally, active management currently precludes biointrusion of plants and animals. Should the program of active management cease, the possibility exists that deeply rooted plants and animal burrowing could be re-established on these sites in the future, creating exposure pathways from buried contaminants in soil. Table B-2 identifies the key characteristics of each of the 16 waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. Section B2.0 of this appendix discusses these factors for each of the sites based on data reported in WIDS. Section B3.0 presents a screening-level ecological risk characterization for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites.



(Source: WMP-20570)

Figure B-1. Conceptual Model of Biotic Activity in Soil



Note: Colored lines represent data on mammal burrow density for pocket gophers, pocket mice, kangaroo rats, and Townsend's ground squirrel. Plant-root density is represented by white bursage, annual bursage, basin big sagebrush, four-winged saltbush, shadescale saltbush, blackbrush, Nevada jointfir, rubber rabbitbrush, range ratany, creosote bush, Anderson's wolfberry, and rabbit thorn.

(Source: WMP-20570)

Figure B-2. Fraction of Burrow and Root Density Versus Depth Below the Ground Surface

B2.0 200-PW-1/3/6 Operable Units Ecological Risk Assessment Site Summaries

This section provides a brief description of each site in the 200-PW-1, 200-PW-3, and 200-PW-6 OU outlined in Table B-2. The site summaries are based on information in WIDS, including information on site regulation/management, current site configuration, original dimensions of the sites, process history, and relevant environmental monitoring, release, and cleanup information.

B2.1 216-Z-1&2 Cribs

The 216-Z-1&2 Cribs consist of two wooden timber boxes connected by a central pipe which appears to have discharged waste at the tops of the boxes (see Figure 2-7 in the FS report). The 216-Z-2 Crib overflowed into the 216-Z-1 Crib, which overflowed into the 216-Z-1A Tile Field. Each unit is set and backfilled in a deep, square excavation. Two risers are visible from the surface of each crib.

The bottom dimensions of each crib are 3.7 m (12 ft) long by 3.7 m (12 ft) wide by 4.3 m (14 ft) deep with 2.1 m (7 ft) overburden depth. These cribs were designed to dispose of aqueous and organic wastes in the soil column. The unit received waste from the 234-5Z, the 236-Z, and the 242-Z Buildings.

Table B-2. Summary of Characteristics for the 200-PW-1/3/6 Operable Unit Waste Sites as Indicators of Exposure Potential for Ecological Receptors

Operable Unit	Site	Physical Barrier Currently Present? (Yes/No)	Overburden, m (ft)	Cover Thickness, m (ft) (see note)	Aboveground Habitat Currently Present? (Yes/No)
200-PW-1	216-Z-1&2 Cribs	No	2.1 (7)	4.3 (14)	Yes
200-PW-1	216-Z-12 Crib	No	4.3 (14)	5.8 (19)	No
200-PW-1	216-Z-18 Crib	No	4.9 (16)	5.5 (18)	No
200-PW-1	216-Z-1A Tile Field	No	3.0 (10)	4.6 (15)	Yes
200-PW-1	216-Z-3 Crib	No	2.4 (8)	5.2 (17)	Yes
200-PW-1	216-Z-9 Trench	No	None	6.4 (21)	No
200-PW-1	241-Z-361 Settling Tank	Yes	None	5.5 (18)	Yes
200-PW-3	216-A-24 Crib	No	3.0 (10)	4.6 (15)	Yes
200-PW-3	216-A-31 Crib	No	None	7.3 (24)	No
200-PW-3	216-A-7 Crib	No	None	4.9 (16)	No
200-PW-3	216-A-8 Crib	No	None	4.3 (14)	Yes
200-PW-3	UPR-200-E-56	No	0.6 (2)	4.6 (15)	Yes
200-PW-6	216-Z-10 Injection/ Reverse Well	No	None	45.7 (150)	No
200-PW-6	216-Z-5 Crib	No	4.3 (14)	5.5 (18)	No
200-PW-6	216-Z-8 French Drain	No	None	4.6 (15)	No
200-PW-6	241-Z-8 Settling Tank	Yes	1.8 (6)	1.8 (6)	No

Notes:

Cover thickness measured to the bottom of the waste site. Contaminants might be present at shallower depths (< 10-15 ft) in waste site soils, potentially representing ecological exposure pathways.

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Liquid wastes discharged to these cribs would percolate into the soil, forming a layer of contamination at the bottom, 6.4 m (21 ft) bgs. However, it is not known if the wooden boxes leaked, potentially contaminating soils around the boxes at shallower depths and creating ecological exposure pathways.

Surface radiological surveys are performed routinely. In 1981, several characterization and monitoring wells were placed around the 216-Z-1&2 Cribs. The maximum depth of the plutonium and americium contamination was found approximately 30 m (99 ft) below the bottom of the waste site. From 1991 to 2005, soil-vapor extraction operations removed 24,528 kg (54,075 lb) of carbon tetrachloride from the 216-Z-1A/Z-18 Well Field. Monitoring results suggest the presence of radionuclides in the near-surface and deeper soils.

B2.1.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, rabbitbrush.

Cover Thickness: The site is covered with 2.1 m (7 ft) of backfill (overburden) for a total of 4.3 m (14 ft) of backfill.

Physical Barrier: None.

B2.2 216-Z-12 Crib

The site is an inactive, belowgrade waste management unit. The site consists of a deep rectangular excavation with a vitrified, perforated, clay pipe running the length of the crib. A second 6-in.-diameter steel pipe (bypass pipeline) was installed in 1968 and runs the length of the crib to the west of the original pipe. The bottom 1.5 m (5 ft) of the excavation was backfilled with gravel and covered with a polyethylene barrier. The remaining excavation was backfilled to grade. It is marked and posted with Underground Radioactive Material signs.

The bottom dimensions of the crib are 91.4 m (300 ft) long by 6.1 m (20 ft) wide by 5.8 m (19 ft) deep with 4.3 m (14-ft) overburden depth. The crib received Plutonium Finishing Plant liquid process waste and laboratory waste from the 234-5Z Building via the 241-Z-361 Settling Tank. According to process history information (see Figure 2-6 in the FS report), waste entered the crib through a perforated vitrified clay pipe at a depth 4.6 m (15 ft) bgs. While there is overburden (reportedly to a depth of 18 feet) which presumably limits ecological exposure pathways, it is not known if ponding of effluent resulted in residual contamination of soils on the walls of the crib at depths shallower than 10 to 15 ft (considered as depths below which ecological exposure pathways are unlikely to be present).

The crib was partially vitrified as part of an in situ vitrification test project that resulted in a 408 metric ton (450-ton) block of vitrified soil, extending to a depth of 7.3 m (24 ft). The test demonstrated that transuranic contaminants and 26,000 ppm of fluorides were retained in the vitrified product. The crib was downposted to underground radioactive material. Fifteen soil sample locations were used to determine that the surface of the crib was free of contamination. The vent risers were sealed as a preventive measure for potential passive radioactive emissions.

A surface radiological survey is performed annually. The highest concentration of plutonium was located in the sediment immediately below the bottom of the crib. No plutonium level greater than 1 pCi/g was detected from 12 to 30 m (40 to 98 ft) below the crib bottom. Low levels of plutonium and americium were detected 36 m (118 ft) below the crib bottom, which was the maximum depth analyzed.

B2.2.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 4.3 m (14 ft) of backfill (overburden) for a total of 5.8 m (19 ft) of backfill to the floor of the crib.

Physical Barrier: None.

B2.3 216-Z-18 Crib

The 216-Z-18 Crib is a belowgrade inactive management unit. The crib consists of five parallel, north-south running trenches bisected by a steel distribution pipe. Near the center of each trench, two perforated, fiberglass-reinforced epoxy pipes exit each side of the distribution line. The distribution and trench piping lie on a 0.3 m (1-ft) thick bed of gravel. The pipes were buried under an additional 0.3 m (1 ft) of gravel, a membrane, and sand cover. The trenches then were backfilled to grade. The site is marked and posted with Underground Radioactive Material signs.

The bottom dimensions of the crib are 63.1 m (207 ft) long by 3.05 m (10 ft) wide by 5.5 m (18 ft) deep with 4.9 m (16 ft) overburden depth. This unit received wastes from the 241-Z-361 Settling Tank. The crib disposed of solvent and acidic aqueous waste from the Plutonium Reclamation Facility in the 236-Z Building.

The most significant release path for this site is to groundwater. In 1981, several characterization and monitoring wells were placed around the 216-Z-18 Crib. The maximum depth of the plutonium and americium contamination was found approximately 30 m (99 ft) below the bottom of the waste site. From 1991 to 2005, soil-vapor extraction operations removed 24,528 kg (54,075 lb) of carbon tetrachloride from the 216-Z-1A/216-Z-18 Well Field.

B2.3.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 4.9 m (16 ft) of backfill (overburden) for a total of 5.5 m (18 ft) of backfill to the bottom of the waste site.

Physical Barrier: None.

B2.4 216-Z-1A Tile Field

The tile field is located inside a chain-link fence that is radiologically posted. It is a belowgrade trunk line oriented north to south with seven pairs of lateral pipes spaced in a herringbone pattern. The vitrified clay pipe lies on a gravel bed. The length of the tile field was expanded twice. The original section is known as 216-Z-1AA. The expanded sections are known as 216-Z-1AB and 216-Z-1AC. The excavation was backfilled to grade.

The total length of the tile field, including all three extensions, is 79.3 m (260 ft) by 4.6 m (15 ft) deep with 3.0 m (10 ft) overburden depth. The bottom dimensions of 216-Z-1AA are 22.9 m (75 ft) long by 30.5 m (100 ft) wide. The bottom dimensions of 216-Z-1AB are 30.5 m (100 ft) long by 30.5 m (100 ft) wide, and the bottom dimensions of 216-Z-1AC are 25.9 m (85 ft) long by 30.5 m (100 ft) wide. The site received waste from the 234-5Z, 236-Z, and 242-Z facility operations at the Z Plant. The tile field was originally constructed to receive liquid waste overflow from the 216-Z-1&2 Cribs. Later the cribs were bypassed and the waste was routed directly into the tile field.

According to the process history (Figure 2-4 in the FS report), discharge piping to the tile field were originally placed on a gravel bed 4.3 m (14 ft) bgs. Process history descriptions also include mention of the tile field receiving overflows from other units. While there is overburden (reportedly to a depth of 15 feet) which presumably limits ecological exposure pathways, it is not known if ponding of effluent resulted in residual contamination of soils on the walls or portions of the floor of the tile field at depths shallower than 10 to15 ft (considered as depths below which ecological exposure pathways are unlikely to be present).

Surface radiological surveys are performed on a routine basis. Characterization efforts identified radionuclide contamination and high concentrations of carbon tetrachloride below the waste site structures. In 1981, several characterization and monitoring wells were placed around the 216-Z-1A Tile Field. The maximum depth of the plutonium and americium contamination was approximately 30 m (99 ft) below the bottom of the waste site. Soil-vapor extraction operations were begun in 1992 to extract carbon tetrachloride from the vadose zone beneath the 216-Z-1A Tile Field.

B2.4.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, rabbitbrush.

Cover Thickness: The site is covered with 3.0 m (10 ft) of backfill (overburden) for a total of 4.6 m (15 ft) of backfill to the bottom of the site.

Physical Barrier: None.

B2.5 216-Z-3 Crib

The 216-Z-3 Crib was constructed of three 1.2-m (4-ft) long, perforated corrugated metal culverts laid horizontally, end to end, on gravel-filled excavation. Wire screens were welded on the ends of the pipes to prevent gravel from intruding into the pipe, with 2.5 cm (1-in.) holes drilled every 15 cm (6 in.) around the circumference of the pipe at 30 cm (1-ft) intervals. The culvert rests on a 5.2-m (17-ft) bed of gravel, 2.4 m (8 ft) below grade. Two layers of asphalt roofing paper were laid over the crib construction and the site was backfilled to grade.

The dimensions of the crib are 20.1 m (66 ft) long by 8.4 m (28 ft) wide by 5.2 m (17 ft) deep with 2.4 m (8-ft) overburden depth. The diameter of the associated culvert style distribution drain pipe is 0.9 m (3 ft).

Environmental monitoring for this crib includes several local monitoring wells and regular radiological surveys. In 1959, groundwater samples indicated alpha contamination in the groundwater below the 216-Z-3 Crib. Soil-vapor extraction operations began in 1992 to extract carbon tetrachloride from the vadose zone beneath the 216-Z-1A Tile Field.

B2.5.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, rabbitbrush.

Cover Thickness: The site is covered with 2.4 m (8 ft) of backfill (overburden) for a total of 5.2 m (17 ft) of backfill to the bottom of the waste site.

Physical Barrier: None.

B2.6 216-Z-9 Trench

The 216-Z-9 Trench is marked and posted with Underground Radioactive Material signs. In 1999, a gravel bio-barrier, measuring 6.1 m (20 ft) by 4.0 m (13 ft), was placed over an area of surface contamination. This area also is posted as underground radioactive material. The 216-Z-9 Trench is an inactive, belowgrade waste management unit. It is a rectangular structure, with a concrete cover supported by six concrete columns. The trench walls and support columns are covered in an acid-resistant brick. Two stainless steel pipes discharge effluent above the trench bottom.

The dimensions of the trench are 36.6 m (120 ft) long by 27.4 m (90 ft) wide by 6.4 m (21 ft) deep. The 216-Z-9 waste site is an enclosed trench that received solvent and aqueous wastes from the Z Plant Recovery of Uranium and Plutonium by Extraction (RECUPLEX) process. The 216-Z-9 Trench was the only waste site used for solvent disposal during the RECUPLEX operation. Solvents used in the process included carbon tetrachloride, dibutyl phosphate, and dibutyl butyl phosphonate.

According to the process history, two stainless steel pipes discharged effluent above the trench bottom (21 ft, see Figure 2-3 in the FS report). The discharged effluent volume reportedly was greater than the soil pore volume (see Section 2.4.1.1 in the FS report), but it is not known if the ponded effluent resulted in residual contamination of soils on the walls of the trench, above the trench bottom. Therefore the possibility exists of contaminants being present at depths in soil shallower than 15 feet (considered as a depth below which ecological exposure pathways are unlikely to be present).

A surface radiological survey is performed routinely at this site. In 1981, several characterization and monitoring wells were placed around the 216-Z-9 Trench. The maximum depth of the plutonium and americium contamination was approximately 30 m (99 ft) below the bottom of the waste site. From 1991 to 2005, soil-vapor extraction operations removed 54,183 kg (119,453 lb) of carbon tetrachloride from the 216-Z-9 Well Field. Groundwater Wells 299-W15-8, 299-W15-9, 299-W15-82, 299-W15-84, 299-W15-85, 299-W15-86, and 299-W15-95 monitor this unit. Scintillation probe profiles indicate that breakthrough to the groundwater of radionuclides has not occurred (1983). Four 1-in.-diameter core samples were collected from the bottom of the crib in 1959 to determine the amount of plutonium in the soil. The samples were collected through two risers and two vent stacks that extended through the concrete crib cover. Additional core samples of the soil were collected to a depth of 2.4 m (8 ft) in 1973 to characterize the crib contaminants.

B2.6.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Physical Barrier: None.

Cover Thickness: The site is covered with a total of 6.4 m (21 ft) of backfill (from surface to the trench bottom).

Active Management: This is site is managed by Fluor Hanford/Plutonium Finishing Plant to include, at a minimum, annual monitoring and herbicide and pesticide application as needed.

B2.7 241-Z-361 Settling Tank

The unit is an underground reinforced-concrete structure with a 0.95-cm (3/8-in.) steel liner. The tank has inside dimensions of 7.9 by 4.0 m (26 by 13 ft) with 0.3 m (1-ft) -thick walls. The bottom slopes, resulting in an internal height variation between 5.2 and 5.5 m (17 and 18 ft). The top is 0.6 m (2 ft) below grade. A 15 cm (6-in.) stainless steel inlet pipe from the 241-Z Tank Pit (WIDS Site Code 241-Z) enters the tank from the north, approximately 4-5 ft from the top of the tank. A single 20 cm (8-in.) stainless steel pipe exits the tank from the south, at the same elevation as the pipe entering the tank (see Figure 2-9 in the FS report). Two manhole covers and frames and several risers are visible above grade.

Process history information, the settling tank is an underground reinforced concrete structure. Evidence shows the tank likely did not leak (see Figure 2-9 in the FS report). Potential ecological exposure pathways likely are not present at this waste site.

The outside dimensions of the settling tank are 8.5 m (28 ft) long by 4.6 m (15 ft) wide by 5.5 m (18 ft) deep. The tank served as a settling tank for liquid waste from the 234-5Z, 242-Z, and 236-Z Buildings. The waste streams were routed through the 241-Z Sump Tanks for neutralization and then to the 241-Z-361 Settling Tank to settle out any solids. After passing through the settling tank, the waste was routed to the 216-Z-1&2, 216-Z-3, 216-Z-12, and 216-Z-18 Cribs and the 216-Z-1A Tile Field.

DOE/RL-88-30, *Hanford Site Waste Management Units Report*, states that prioritization of this facility for decommissioning classifies the relative radiological hazard as high in comparison with other 200 Area surplus facilities. Detailed sample results are documented in HNF-8735, *241-Z-361 Tank Characterization Report*. Routine radiation surveys, airborne radionuclide monitoring, and visual inspections are performed.

B2.7.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, rabbitbrush.

Cover Thickness: The site is covered with a total of 5.5 m (18 ft) of backfill.

Physical Barrier: Yes.

Active Management: The following tasks are part of the active management of the 241-Z-361 Settling Tank: routine surveillance and housekeeping; any necessary testing or replacement of the high-efficiency particulate air filter on the tank breather vent; and structural evaluation of the tank every 5 years in accordance with the safety requirements.

B2.8 216-A-24 Crib

The 216-A-24 Crib is surrounded with concrete AC-540 markers and posted with Underground Radioactive Material signs. The crib was built with four sections, each 107 m (350 ft) long, separated by soil berms. The sections were installed at increasingly lower elevations to allow the effluent to cascade from one section to the next. The crib was constructed with a 38-cm (15-in.)-diameter (perforated bottom half), galvanized, corrugated pipe, placed horizontally 3 m (10 ft) below grade. The crib excavation has 46,750 m^3 ($1.65 \times 10^{+05}$ ft^3) of gravel fill and is backfilled. A polyethylene barrier is located between the gravel and the backfill. The side slope is 1.5:1. Eight 20-cm (8-in.)-diameter wells on concrete pads are located on this crib. The wells extend from the bottom of the crib to 0.9 m (3 ft) above grade. Four 38 cm (15-in.) corrugated risers extend from the distributor pipe to grade with filter box assemblies on top of the risers.

The bottom dimensions of the crib are 426.7 m (1,400 ft) long by 6.1 m (20 ft) wide by 4.6 m (15 ft) deep with 3.0 m (10-ft) overburden depth. The crib was built to receive condensate waste from the 241-A, 241-AX, 241-AY, and 241-AZ Tank Farms. The installation of surface condensers greatly reduced the volume of liquid being discharged to the cribs.

Data from 1977 indicate that a breakthrough to the groundwater could have occurred from the first and second sections of the crib. Characterization information collected in 1979 included analysis of plants and animals and three backhoe excavations. None of the excavations found contamination in the overburden soils. The subsurface gravel layers did have considerable levels of contamination, as well as some rabbitbrush and mice, suggesting that potential ecological exposure pathways related to biointrusion could exist. Cesium-137 was the most prevalent contaminant. A routine surface radiological survey is performed annually.

B2.8.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, bunchgrasses

Cover Thickness: The site is covered with 3.0 m (10 ft) of backfill (overburden) for a total of 4.6 m (15 ft) of backfill to the bottom of the crib.

Physical Barrier: None.

B2.9 216-A-31 Crib

The 216-A-31 Crib is located inside a large Underground Radioactive Material area that has a WIDS Site Code of 200-E-103. The crib is marked with cement posts on four corners.

The bottom dimensions of the crib are 21.3 m (70 ft) long by 3.0 m (10 ft) wide by 7.3 m (24 ft) deep. The crib received effluent from the 202-A "L-Cell" via the 241-A-151 Diversion Box. The L-Cell was the location of the final plutonium concentration step in the plutonium-uranium extraction process. The site was deactivated in 1966 by blanking the L-Cell nozzles to the 241-A-151 Diversion Box, which routed effluents to the unit. The unit consists of a 21.3-m by 3.0-m by 7.3-m (70-ft by 10-ft by 24-ft) deep excavation that includes a 7.6-cm (3-in.) Schedule 10 stainless steel perforated distribution pipe placed horizontally 6.4 m (21 ft) below grade. The excavation has 1.8 m (6 ft) of gravel fill and has been backfilled. The side slope is 1:1.5.

While there is overburden (reportedly to a depth of more than 15 feet) which presumably limits ecological exposure pathways, it is not known if ponding of effluent resulted in residual contamination of soils on the walls of the crib at depths shallower than 10 to15 ft (considered as depths and below which ecological exposure pathways are unlikely to be present).

B2.9.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 7.3 m (24 ft) of backfill to the bottom of the crib.

Physical Barrier: None.

B2.10 216-A-7 Crib

The crib is marked and posted with Underground Radioactive Material signs. Both the 216-A-7 and 216-A-1 Cribs are inside this Underground Radioactive Material area.

The bottom dimensions of the crib are 3.0 m (10 ft) long by 3.0 m (10 ft) wide by 4.9 m (16 ft) deep. The crib began receiving catch tank and sump waste from the 241-A-152 Diversion Box in January 1956. The effluent pipeline between the 241-A-152 Diversion Box sump and the crib was blanked off in July 1959. The sump waste was re-routed to the catch tank. From July 1959 through November 1966, the crib received tributyl phosphate from the Plutonium-Uranium Extraction Plant and pump pit/catch tank drainage from the 241-A-152 Diversion Box. A 15 cm (6-in.) perforated vitrified clay pipe is placed horizontally 3.0 m (10 ft) below grade. A 3.0 m (10 ft) length of 15-cm (6-in.) perforated vitrified clay pipe is perpendicular to the first pipe, forming a cross pattern. It is 4.9 m (16 ft) deep and is filled with approximately 2.1 m (7 ft) of coarse rock with a volume of 99 m^3 (3,500 ft^3). The site has been backfilled. The side slope from the surface to 3.0 m (10 ft) is 1:1 and from 3.0 m (10 ft) to the bottom is 2:1.

A surface radiation survey is performed annually. The site is monitored by Well 299-E25-54. Scintillation probe profiles identified contamination between 3.9 m (13 ft) and 9.1 m (30 ft) below the surface. No contamination was identified from 9.1 m (30 ft) to 41.8 m (137 ft). While there is overburden (reportedly to a depth of more than 15 feet) which presumably limits ecological exposure pathways, it is not known if ponding of effluent resulted in residual contamination of soils on the walls of the crib at depths shallower than 10 to15 ft (considered as depths below which ecological exposure pathways are unlikely to be present).

B2.10.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 4.9 m (16 ft) of backfill to the crib bottom.

Physical Barrier: None.

B2.11 216-A-8 Crib

The 216-A-8 Crib and overflow area are surrounded by chain and concrete AC-540 markers. The crib and overflow area are posted with Underground Radioactive Material signs. Crib overflow was accomplished through a 40.6 cm (16-in.) -diameter pipe exiting to the north at the east end of the crib. The pipe emptied into a narrow ditch that flowed northward. A small overflow pond was excavated at the northeast end of the ditch to receive the excess wastewater from the crib.

A 61 cm (24-in.) -diameter, Schedule 20, perforated distribution pipe is located 2.6 to 3.5 m (8.5 to 11 ft) below grade along the length of the crib. The site contains approximately 5,830 m^3 (206,000 ft^3) of gravel fill. The crib excavation side slope is 1:2. Four test risers extended above grade. Two layers of Sisalkraft[1] paper separate the gravel fill from the backfill. The 216-A-508 Control Structure is located west of the crib.

The bottom dimensions of the crib are 259.1 m (850 ft) long by 6.1 m (20 ft) wide by 4.3 m (14 ft) deep. The crib was originally constructed in 1955 to receive condensate and cooling water discharge from the 241-A and 241-AX Tank Farms. In May 1958, it was determined the crib had reached its radionuclide capacity. The effluent was routed to the 216-A-24 Crib via the 216-A-508 Control Structure, and the

[1] Sisalkraft (paper) is a trademark of Fortifiber Corporation, Los Angeles, California.

cooling water was routed to the 216-A-25 Pond. However, the 216-A-8 Crib was intermittently reactivated over the years (from 1966 until 1983) to receive additional tank farm condensate effluent.

Based on the depth of discharge to this crib and possible contamination of side-walls through ponding of wastes, the possibility exists of contaminants being present at depths in soil shallower than 10 to 15 feet (considered as a depth below which ecological exposure pathways are unlikely to be present).

Radiological surveys are performed annually and have previously identified potential ecological exposure pathways through plant biointrusion. In 1979, a large, growing rabbitbrush plant was found to be contaminated with a radiation level of 6,000 counts per minute. The open risers were contaminated with radiological readings ranging from 600 to 6,000 counts per minute. In 1985, the vent filter on the 216-A-508 Control Structure had a direct reading of 10,000 counts per minute. Several rabbitbrush plants were found to be contaminated with a maximum reading of 35,000 counts per minute. In 1988, vegetation growing on the crib had radiological readings of 500 to 20,000 counts per minute, and soil by the crib had radiological readings of 400 to 70,000 counts per minute.

B2.11.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, bunchgrasses.

Cover Thickness: The site is covered with 4.3 m (14 ft) of backfill.

Physical Barrier: None.

B2.12 UPR-200-E-56

The unplanned release (UPR) site, UPR-200-E-56, is a surface-stabilized area located north of the west end of the 216-A-24 Crib. The site is posted and marked as an Underground Radioactive Material area.

The dimensions of the site are 30.5 m (100 ft) long by 30.5 m (100 ft) wide.

On June 13, 1979, Radiation Monitoring was informed that moisture was observed in the excavation east of the 200 East Area perimeter fence where fill soil was being obtained for the construction of the 241-AN Tank Farm. The construction contractor backfilling around the new tanks in the 241-AN Tank Farm had mistakenly selected a borrow area adjacent to the 216-A-24 Crib instead of the designated area, which was farther north. Radiological surveys revealed beta contamination up to 8,000 counts per minute in the moist excavation, on the earthmoving equipment, and in the newly hauled-in soil around the new 241-AN Tanks. The source of the contamination was determined to be moisture from the 216-A-24 Crib that had migrated laterally over the surface of a 10.2-cm (4-in.) crust of hardpan. The hardpan was approximately 4.6 m (15 ft) below normal ground surface. The excavation was dug sloping from 1.5 to 6.1 m (5 to 20 ft) deep, 131.1 m (430 ft) long, and an average of 33.5 m (110 ft) wide. The size of the excavation was approximately 0.4 hectare (1 acre).

In 1979, several hundred yards of contaminated soil were taken out of the 241-AN Tank Farm and returned to the excavation north of the 216-A-24 Crib. However, the volume of material was insufficient to fill the excavation area. It was decided to take contaminated soil and vegetation from nearby perimeter fences and the northeast fence line of the 241-C Tank Farm and place it into the excavation to help fill the excavation area. An additional 15- to 20-cm (6- to 8-in.) layer of clean soil was placed over the excavation and the site was reposted to Underground Radioactive Material.

The area north of the 216-A-24 Crib, known as the 216-A-24 Excavation Site, was used again in 1985 to dispose of contaminated soil from the 244-A Lift Station area (UPR-200-E-100). After the contaminated soil from the 244-A Lift Station was placed into the "crib excavation," the 216-A-24 Crib Excavation was stabilized with 0.6 m (2 ft) of clean dirt and vegetated with wheatgrass.

As described previously using process history information (see Figure 2-14 from the FS report), portions of the UPR were excavated to a minimum depth of 5 ft bgs. If there is no consideration given to the cover, then contaminants may be soil at portions of this site at depths accessible to deep rooted plants and burrowing animals (see Table 2-16 from the FS report for contaminants detected at these shallower depths in soil).

B2.12.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: Moderate vegetation, bunchgrasses.

Cover Thickness: The site is covered with 4.6 m (15 ft) of backfill with an overburden of 0.6 m (2 ft).

Physical Barrier: None.

B2.13 216-Z-10 Injection/Reverse Well

This site is a reverse well extending approximately 0.3 m (1 ft) above grade. The aboveground portion of the well end is capped with a flange. The well casing is constructed of steel pipe. The site was interim stabilized in 1990.

The dimensions of the 216-Z-10 Injection/Reverse Well are 45.7 m (150 ft) deep with a diameter of 0.15 m (0.50 ft). The well received process and laboratory waste from the 231-Z Building via the 231-Z-151 Sump between February and June 1945.

Potential for a release to groundwater is high because of the large volume of waste disposed of at the site. Three wells were drilled near this site in 1947. None of the soil samples from the wells showed any contamination.

B2.13.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered by 45.7 m (150 ft) of backfill.

Physical Barrier: None.

B2.14 216-Z-5 Crib

The 216-Z-5 Crib is an inactive waste management unit located below grade. The crib is oriented in a north-south configuration with a transfer pipe connecting to two wooden sump boxes. Each box was placed at the bottom of a rectangular excavation. The two excavations were then backfilled to grade.

The dimensions for a single crib are 4.3 m (14 ft) long by 4.3 m (14 ft) wide by 5.5 m (18 ft) deep with an overburden of 4.3 m (14 ft). This crib received 231-Z Building plutonium-contaminated process waste via the 231-W-151 Vault. The liquid process waste was discharged to the soil column via the crib. More than 26 million liters (7 million gal) of waste containing approximately 3,000 g (7 lb) of plutonium were discharged to the cribs.

Liquid wastes discharged to this crib would percolate into the soil, forming a layer of contamination at the bottom, 5.5 m (18 ft) bgs. However, it is not known if the wooden boxes leaked, potentially contaminating soils around the boxes at shallower depths and creating ecological exposure pathways. In addition, leaks from the shallow transfer line to the cribs could have release contaminants to soils accessible to ecological receptors.

The cribs were surface stabilized in 1990. This site receives routine radiological surface surveys and well monitoring.

B2.14.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 4.3 m (14 ft) of backfill (overburden) for a total of 5.5 m (18 ft) of backfill.

Physical Barrier: None.

B2.15 216-Z-8 French Drain

The 216-Z-8 French drain is constructed of two sections of 0.9-m (3-ft) -high standard clay tile culverts, stacked vertically underground. The culverts are filled with gravel and rest on a 1.5 m (5-ft) -diameter by 0.9 m (3-ft) -deep bed of gravel with a slope of 2.5:1. There is a 10 cm (4-in.) -thick concrete top 2.4 m (8 ft) below grade. The bottom of the French drain is 5.5 m (18 ft) below grade.

The dimensions of the French drain are 4.6 m (15 ft) with a diameter of 0.9 m (3 ft). The silica storage tank supernate overflowed into the French drain from 1955 to 1962. Approximately 9,590 L (2,530 gal) of neutral-basic waste overflowed from the tank during that time.

Process history information (see Figure 2-15 from the FS report) indicates that the pipe from the 241-Z-8 Settling Tank entered the 216-Z-8 French Drain at a depth of 2.44 m (8 ft) bgs. This pipe appears to have discharged contaminants into gravel contained within a clay tile culvert. It is not known if there have been leaks from the culvert. Such leaks could result in lateral migration of contaminants in soil at depths accessible by ecological receptors. Intrusion into the French drain by deeply-rooted plants or burrowing animals is unlikely to occur.

B2.15.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 4.6 m (15 ft) of backfill to the bottom of the waste site.

Physical Barrier: None.

B2.16 241-Z-8 Settling Tank

The 241-Z-8 Settling Tank is a horizontal cylindrical vessel located 1.8 m (6 ft) below grade. The area above the tank is surrounded by a lightweight chain barricade marked “Caution Underground Radioactive Material” and inactive miscellaneous underground storage tank signs. Inside the barricade on the north end are two capped 10 cm (4-in.) steel vent pipes.

The dimensions of the settling tank are 12.2 m (40 ft) high with a diameter of 2.4 m (8 ft) and an overburden of 1.8 m (6 ft). The tank was used as a solids settling tank for back flushes of the RECUPLEX feed filters. Silica gel was used as a settling agent. The solids and silica gel were flushed to the 241-Z-8 Settling Tank with nitric acid. Overflow from the tank went to the 216-Z-8 French Drain, located approximately 11 m (36 ft) east of the settling tank.

After tank pumping, a sample of sludge beneath the 10.16 cm (4-in.) riser on October 22, 1974, contained 0.02 g/L of plutonium. This concentration calculates to a residual inventory of 0.084 lb (38 g) of plutonium.

As discussed in the process history (see Figure 2-17 in the FS report), there is a small possibility that the tank has leaked, contaminating surrounding soils. While the available data do not show that the tank has leaked, any leaks would contaminate soils at depths (approximatel 1.83 m or 6 ft bgs) that would be accessible to ecological receptors.

B2.16.1 Ecological Exposure Scenario Assessment

Factors contributing to exposure:

Habitat Type: None.

Cover Thickness: The site is covered with 1.8 m (6 ft) of backfill.

Physical Barrier: Yes.

Active Management: This site is managed by CH2M HILL Hanford, Inc., to include, at a minimum, annual surveillance and maintenance inspections.

B3.0 Screening-Level Ecological Risk Characterization

The approach used for this screening-level ecological risk assessment has been to develop a ecological conceptual model that describes the potential exposure pathways from contaminants in waste site soils to plants, soil invertebrates (ants) and wildlife. This ecological conceptual model then was compared with waste site information to identify the potential for complete exposure pathways.

Under current conditions, placement of soil covers and active management precludes exposure pathways to ecological receptors at all of these sites. However, determining if remedial alternatives are needed to protect ecological receptors requires that potential ecological exposures and risks be considered under baseline conditions; in this case, baseline conditions means assuming that the soil covers would no longer be maintained and that other active management methods would no longer be performed. Active management at the DOE decontamination and decommissioning-managed sites includes: (1) visual inspection performed three times a year to look for evidence of subsidence or animal intrusion, (2) a surface radiological survey performed once a year and any areas where radiation is detected covered with soil or posted for further action, (3) herbicide application performed two or three times a year to control any vegetation, and (4) pesticides applied as needed to control ants, termites, mice, and badgers. The exposure potential to ecological receptors is not of concern because of management practices at all sites.

Under baseline conditions, ecological exposure pathways could be present to contaminants in soil to a depth ranging from 10 to 15 feet below ground surface. A depth of 10 feet below ground surface represents a likely depth of the biologically-active zone, which could be penetrated by substantial root masses from deeply-rooted plants and from which soils could be exhumed by insects or burrowing mammals. The depth of 15 feet reflects the standard point of compliance for protection of ecological receptors as described in WAC 173-340-7490(4)(b).

The results from the comparison of the conceptual ecological exposure model with the waste site information, presented in Section B2.0, allows classification of the waste sites in terms of potential ecological exposure pathways likely to be complete and potential ecological exposure pathways unlikely to be complete. Waste sites where complete ecological exposure pathways are likely to be present are:

- 216-Z-1&2 cribs
- 216-Z-12 crib
- 216-Z-18 crib
- 2126-Z-1A tile field
- 216-Z-3 crib
- 2126-Z-9 trench
- 216-A-24 crib
- 216-A-31 crib
- 216-A-7 crib
- 216-A-8 crib
- UPR-200-E-56
- 2126-Z-5 crib

Waste sites where complete ecological exposure pathways are not likely to be present are:

- 241-Z-361 settling tank
- 216-Z-10 reverse well
- 216-Z-8 french drain
- 241-Z-8 settling tank

Ecological exposures were not characterized as part of this screening-level ecological risk assessment. Characterization of ecological exposures was not required to help determine if remedial action was needed for these waste sites. For all of the waste sites, concentrations in soil were associated with human health risks, or presented a potential threat to groundwater. It is anticipated that at least one of the remedial alternatives evaluated in the FS (an alternative evaluating removal, treatment and disposal of soils to a depth of 15 feet) for protection of human health or groundwater also would address contaminants potentially posing a threat to ecological receptors. Therefore, for the purposes of the detailed evaluation of remedial alternatives, quantitative assessment of ecological exposures and risks was not. However, the demonstration that cleanup of contaminated soils will also protect ecological receptors will be addressed as part of remedial design/remedial action (RD/RA). Ecological screening values or preliminary remediation goals (PRGs), which can be used for confirmation sampling, will be identified in the Remedial Action Work Plan (RAWP) for the 200-PW-1, 200-PW-3 and 200-PW-6 sites.

B4.0 References

Canadell, J., R.B. Jackson, J.R. Ehleringer, H.A. Mooney, O.E. Sala, and E.D. Schulze, 1996, "Maximum Rooting Depth of Vegetation Types at the Global Scale," *Oecologia* 108:583-595.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq. Available at: http://uscode.house.gov/download/pls/42C103.txt.

DOE/RL-88-30, 2005, *Hanford Site Waste Management Units Report*, Rev. 14, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
http://www5.hanford.gov/arpir/?content=findpage&AKey=D7294510.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D7294832.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D7295138.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D7295388.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D7295659.

DOE/RL-2004-42, 2005, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase I*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=90&parent=91.

EPA 540-R-97-006, 1997, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final*, OSWER 9285.7-25, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/swerrims/riskassessment/ecorisk/ecorisk.htm.

HNF-8735, 2001, *241-Z-361 Tank Characterization Report*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

HW-9671, 1948, *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area*, Hanford Works, Richland, Washington. Available at: http://www2.hanford.gov/ddrs/common/findpage.cfm?AKey=D197251749.

Kennedy, W.E., Jr., L.L. Cadwell, and D.H. McKenzie, 1985, "Biotic Transport of Radionuclides from a Low-Level Radioactive Waste Site," *Health Physics*, 49:11-24.

PNL-2774, 1979, *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport*, Pacific Northwest Laboratory, Richland, Washington. Available at: http://www.osti.gov/energycitations/servlets/purl/5699771-hgyflC/5699771.pdf.

PNL-5247, 1985, *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site*, Pacific Northwest Laboratory, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196015385.

PNNL, 2008, *Hanford Site Ecological Monitoring & Compliance*, last update June 2008, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/ecomon/default.asp.

Reynolds, T.D. and J.W. Laundré, 1988, "Vertical Distribution of Soil Removed by Four Species of Burrowing Rodents in Disturbed and Undisturbed Soils," *Health Physics*, 54(4):445-450.

RHO-SA-211, 1981, *Intrusion of Radioactive Waste Burial Sites by the Great Basin Pocket Mouse* (Perognathus parvus), Rockwell Hanford Operations, Richland, Washington.

WAC 173-340-7490, "Model Toxics Control Act–Cleanup," "Terrestrial Ecological Evaluation Procedures." Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-7490.

Waste Information Data System Report, Hanford Site database, Richland, Washington.

WMP-20570, 2006, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase I*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.