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APPENDIX D

200-UW-1 OPERABLE UNIT WASTE SITES VADOSE ZONE CONTAMINANT FATE AND TRANSPORT MODELING

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TERMS

COC	contaminant of concern
K_d	distribution coefficient
MCL	maximum contaminant level
NA	not applicable
OU	operable unit
STOMP	Subsurface Transport Over Multiple Phases
VCP	vitrified clay pipeline

APPENDIX D

200-UW-1 OPERABLE UNIT WASTE SITES VADOSE ZONE CONTAMINANT FATE AND TRANSPORT MODELING

D1.0 INTRODUCTION AND PURPOSE

As part of the 200-UW-1 Operable Unit (OU) characterization, vadose zone modeling was conducted to determine the fate and transport of contaminants of potential concern identified for the soil waste sites. The modeling evaluated contaminants that may pose future risk in groundwater as identified in the risk assessment described in Appendix C. Fate and transport modeling evaluated the migration of contaminants from the waste sites into groundwater, including contaminant attenuation and decay. The results of this modeling were used to evaluate and select a remedial strategy for the 200-UW-1 OU.

This appendix also contains an evaluation confirming the appropriateness of the fate and transport models for use in this focused feasibility study (see Attachment D1).

D2.0 MODELING METHODOLOGY

This modeling effort used the Subsurface Transport Over Multiple Phases (STOMP) Version 2.0 (PNNL-11217, *STOMP Subsurface Transport Over Multiple Phases Theory Guide*, and PNNL-12034, 2000, *STOMP Subsurface Transport Over Multiple Phases User's Guide*) finite difference code developed by Pacific Northwest National Laboratory to conduct the simulations. Quantitative predictions of hydrogeologic flow and contaminant transport are generated from the numerical solution of nonlinear partial differential equations that describe subsurface environment flow and transport phenomena. The STOMP code capabilities include the simulation of saturated and unsaturated flow regimes, transport of radioactive elements and nondecaying contaminants, and transport of aqueous phase and nonaqueous phase organic compounds. A complete description of STOMP capabilities and the actual equations and the partial differential approximations are contained in the referenced guides (PNNL-11217 and PNNL-12034).

The conceptual models used to simulate the 200-UW-1 OU waste sites were two-dimensional vertical cross-section representations of the actual physical systems. The conceptual models and input parameters were developed based on historical information and data collected during earlier remedial investigations. The conceptual models were translated into numerical form, using site-specific soil properties to determine the soil profile in the unsaturated zone and underlying saturated zone. Contaminant transport for each profile was simulated using the following three-part process.

1. An initial steady-state model was used to simulate conditions before site activities.

2. A transient model of hydraulic processes during Site activities (from 1944 to 2002) was used to simulate hydraulic loading conditions at the Site during operations

3. A fate and transport model using field-derived soil chemical concentrations and hydraulic conditions from the transient hydraulic model was used to simulate the movement of chemicals in the unsaturated and saturated zone.

Initially, model domains were established in hydraulic steady state to provide for soil profile conditions before the onset of waste site operations. Hydraulic steady state refers to the condition in which soil moisture content and soil moisture movement remain constant through time.

Using the steady-state model results as an initial starting condition, a model time period representing the operational life of the facility was simulated to provide initial hydraulic conditions for the fate and transport modeling. The volumes of wastewater discharged into the facilities created artificially high moisture contents and elevated water tables beneath the facilities. Also, the disturbed ground associated with the area in and around the facility allows more water from precipitation to infiltrate the vadose zone and recharge the aquifer. Increasing the infiltration boundary conditions and including the operational history of the facilities allow the model to account for the enhanced drainage and recharge expected to occur even after wastewater disposal to the facilities ceased.

Based on the hydraulic conditions derived from the simulation of operational conditions, chemical distributions were developed for input into the model. The chemicals modeled were identified and quantified from the sampling inventory for each site and distributed within each profile based on the results of the operational activities simulation results. This initial model starting point was used to simulate the fate and transport of these chemicals in the unsaturated and saturated zone profile beneath each site. The fate and transport simulations initially were run for calendar years 2002 to 3002 (1,000-year simulation); however, based on these initial runs, the times of highest concentrations calculated (peak) were not identified for some contaminants because of their low mobility in the soil column. Based on these observations, an additional simulation was run for calendar years 2002 to 12002 (10,000 years) to identify contaminant peaks for these relatively immobile chemical constituents.

D3.0 PROFILE SECTION CONCEPTUAL MODEL PROPERTIES

D3.1 GEOLOGY

Characterization efforts conducted at the 200-UW-1 OU waste sites have produced detailed descriptions of the local geology. These field investigations conducted at the 299-UW-1 OU waste sites identified and quantified soil hydraulic properties for the soil types encountered during the investigation. The results of these field observations (DOE/RL-95-13, *Limited Field Investigation for the 200-UP-2 Operable Unit*, and BHI-00034, *Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area*) and measurements were simplified to six geologic

soil types underlying the subject waste sites for use in the model. The geology units identified around the 221-U Facility (in order from ground surface to the water table) were as follows:

- Backfill within the site excavations
- Gravel-dominated portion of the Hanford formation
- Sand-dominated portion of the Hanford formation
- Cold Creek unit
- Upper Ringold fine and silty sand
- Ringold Formation unit E silty sandy gravel.

Figure D-1 shows the geology units and Table D-1 lists their respective physical properties used in the model. The aquifer is identified in the Ringold silty-sandy gravel and was simulated as saturated in the profile model. Section 2.3 of this document further discusses the physical setting.

D3.2 SOIL HYDRAULIC PROPERTIES

Soil hydraulic properties for the different geologic units were developed from the existing database of moisture retention and unsaturated hydraulic conductivity data available at the Hanford Site. In general, soil hydraulic properties describe the amount of water that the soil is capable of containing, the capillary pressure at which the soil retains a certain quantity of water, and the rate at which water is capable of moving through the soil. Capillary pressure refers to the suction exerted by the soil to hold water in place. Measurable properties of interest are the soil bulk density, soil saturated moisture content (or porosity), moisture content as a function of capillary pressure, and hydraulic conductivity as a function of soil moisture.

In addition, on the upper layer of the profile, estimates of infiltration rates (net rate of water entering the boundary from the top) were used to simulate the variations in soil conditions and recharge within the backfill and the disturbed soil adjacent to the waste site. An infiltration value of 1.44 cm/year was used in the backfill to represent the relatively higher amount of hydraulic infiltration within this area of the model (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). An infiltration value of 0.35 cm/year was used to represent the areas outside of the backfill and disturbed areas. These values are consistent with reported recharge estimates for the Hanford formation elsewhere at the Site (RPP-6296, *Modeling Data Package for S-SX Field Investigation Report (FIR)*).

Moisture retention characteristic curves can be derived that describe the data in terms of an analytical equation. The characteristic curves allow the relationship to be expressed for the entire continuum of values, which is a necessity of modeling. Moisture content often is expressed in terms of saturation, which is the amount of water contained by the soil relative to the amount the soil could contain. The equation that expresses the moisture retention characteristic curves is

$$S_w = [\frac{\Theta_w - \Theta_r}{\Theta_s - \Theta_r}]$$

where

S_w = degree of water saturation of the porous media (dimensionless)
Θ_w = moisture content of the soil (dimensionless)
Θ_s = saturated moisture content of the soil (dimensionless)
Θ_r = residual moisture content of the soil (dimensionless).

The residual moisture content refers to the absolute minimum amount of water retained by the soil regardless of the amount of pressure applied. It is not measurable, but is determined through the curve-fitting process.

The van Genuchten equation frequently is applied to express the saturation in terms of the soil capillary pressure and three fitted variables:

$$S_w = \{1 + (\alpha[\frac{P_g - P_w}{\rho_w g}])^n\}^{-m} \quad \textit{for } P_g - P_w > 0 \quad \textit{i.e. unsaturated conditions}$$

$$S_w = 1 \quad \textit{for } P_g - P_w \leq 0 \quad \textit{i.e. saturated conditions}$$

where

P_g = absolute pressure of the gas phase present (Pa, usually atmospheric pressure when the gas phase is air)

P_w = absolute pressure of the water phase present (Pa)

$P_g - P_w$ = capillary pressure of the soil on the water phase present (Pa)

ρ_w = density of water (kg/m^3)

G = acceleration of gravity (m/s^2)

α (1/m), n, and m are curve fit parameters

m = 1 - 1/n

S_w is defined as for the previous equation.

The Mualem equation describes hydraulic conductivity as a function of saturation:

$$k_{rw} = (S_w)^{1/2}\{1 - (1 - [S_w]^{1/m})^m\}^2 \quad \textit{and}$$
$$K = k_{rw} * K_{sat}$$

where

K = soil permeability (cm^2) or hydraulic conductivity (cm/s)
k_{rw} = relative permeability or hydraulic conductivity
K_{sat} = saturated permeability (cm^2) or saturated hydraulic conductivity (cm/s)
S_w and m are defined as for the previous equations.

Soil hydraulic properties used in the models were developed based on the previous evaluations unless an appropriate soil type match was not available. In those cases, properties were

determined from the closest soil type available and extrapolated according to the expected characteristics of the soil type. Table D-1 summarizes the soil types and referenced parameters.

D3.3 CONTAMINANT SOIL INTERACTION CHARACTERISTICS

Five sites with potential chemicals of concern were evaluated by the STOMP fate and transport modeling. The sites and chemicals for each site are shown in Table D-2. The contaminants modeled for each site were selected based on the potential to exceed groundwater protection criteria and screening reported in Appendix C. Each chemical is shown in Table D-2 with the depth of the maximum concentration detected in sampling and analysis. The contaminant characteristics for each chemical are model input parameters related to its mobility in the unsaturated and saturated zones.

Technetium-99, nitrate (separately), and nitrogen as nitrate and nitrite are considered highly mobile and are assumed to move unretarded through the vadose zone. However, uranium total metal, antimony, arsenic, and mercury are considered to have some attenuation during migration through the soil. For uranium, two distribution coefficient (K_d) values were used: the conservative and best estimates from PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (Category F, 0.6 mL/g and 3.0 mL/g, respectively). These estimates are within the range of values presented in PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*. The 0.6 mL/g value is considered representative and a best estimate of current Site conditions; however, the higher (less conservative) value also was simulated to provide for comparison and an estimate of the uranium results sensitivity to this parameter. The 0.6 mL/g value is consistent with other 200 West Area vadose zone contaminant transport modeling (e.g., RPP-6296 and RPP-17393, *Modeling Data Package for WMAs* [Waste Management Areas] *T and TX-TY Field Investigation Report*). The *Vadose Zone Hydrogeology Data Package for the 2004 Composite Analysis* (PNNL-14702) provides a best estimate of 0.8 mL/g for the area around U Plant. Uranium exhibits high to moderate mobility, with greater mobility occurring at high and low pH values (PNNL-13895). Some uranium associated with the 216-U-1 and 216-U-2 Cribs discharges has already entered the groundwater from the 200-UW-1 OU. The transport of this fraction was likely enhanced by the discharge history and waste stream chemistry, which included highly acidic waste solutions during the last 2 years of operation (BHI-00187, *Engineering Evaluation/Conceptual Plan for the 200-UP-1 Groundwater Operable Unit Interim Remedial Measure*). This evaluation addresses the uranium remaining in the vadose zone, which represents a less mobile fraction of the uranium, much of which remains within 50 ft of the ground surface (see Figures D-2, D-3, D-5, and D-6). Only at the 216-U-8 Crib were relatively high values of uranium measured at depths around 190 ft below ground surface. The fraction of uranium remaining in the vadose zone is expected to remain less mobile because the highly acidic and high-volume waste discharges that produced the higher mobility no longer occur.

Antimony, arsenic, and mercury are reportedly even less mobile than uranium under the given soil conditions, as reflected in the model by K_d values of 45, 29, and 52, respectively (based on Ecology 94-145, *Model Toxics Control Act Cleanup Levels & Risk Calculations*, CLARC, Version 3.1).

D4.0 MODELED CONTAMINANTS

Data collected from the investigation provided information on the vertical distribution of the contaminants at borehole locations beneath the waste sites. Based on the selected contaminants (Table D-2), the borehole sampling results were used together with site-specific transient hydraulic modeling results (1944-2002 simulation) to generate an input distribution of the chemical profile for fate and transport modeling.

For each waste site, the highest contaminant concentration measured was distributed laterally at each depth in the model profile. Appendix C lists the *Hanford Environmental Information System* identification numbers of the soil sample results used to develop the input contaminant distribution profiles. The contaminant concentration was distributed, based on the calculated aqueous pressure derived from the transient hydraulic modeling, to reflect the contaminant distribution associated with hydraulic infiltration during Site operations (i.e., the moisture plume generated in the transient model was used to direct chemical loading from borehole data). The extent of the chemical plume was defined by a lower limit on the aqueous pressure change. Aqueous pressure change values above this limit were considered representative of chemical loading caused by hydraulic infiltration and distributed laterally through the model profile. The lateral distribution of chemical concentrations was scaled proportional to the aqueous pressure change above the cutoff pressure change levels. At depths where concentrations of the chemical were not detected, a lateral concentration of zero was input into the model.

Where the aqueous pressure exceeded the lower limit, the concentration input to the model equaled

$$C_{i,j} = C_{m_j} * ((\Delta P_{i,j(operational)} - \Delta P_{crit}) / (\Delta P_{\max,j(operational)} - \Delta P_{crit}))^2$$

where

$C_{i,j}$	=	concentration input into model at column i and row j
$C_{m,j}$	=	concentration measurement data representative of depth at row j in the model
$\Delta P_{i,j\ (operational)}$	=	modeled aqueous pressure change at column i and row j caused by facility discharges
ΔP_{crit}	=	minimum aqueous pressure change criterion used to identify the lateral extent of the contaminant
$\Delta P_{max,j\ (operational)}$	=	modeled maximum aqueous pressure change at row j caused by facility discharges.

Note that when $\Delta P_{i,j}$ equals $\Delta P_{max,j}$ at each depth, the input concentration equals the highest concentration measurement.

For the 216-U-1 and 216-U-2 Cribs and the 216-U-8 Crib, the contaminants were distributed where the change in the aqueous pressure profile exceeded 62,500 pascals. For the 216-U-4 Reverse Well and the 216-U-4A French Drain system, the contaminants were distributed where the change in the aqueous pressure profile exceeded 72,500 pascals. For the 200-W-42 Vitrified Clay Pipeline (VCP)/UPR-200-W-163 site, the contaminants were distributed where the change in the aqueous pressure profile exceeded 82,500 pascals. For the 216-U-12 Crib, the contaminants were distributed where the change in the aqueous pressure profile exceeded 22,000 pascals. The minimum distribution level for the aqueous pressure change was selected based on the site disposal history and a review of transient model results. The distributed profile concentrations were compared to inventories of contaminant mass at each site to verify that the profile mass model input was representative of reported conditions.

The chemical concentrations used for the model input are shown in Figures D-2 through D-6. Each figure shows the profile section for a site and includes the lateral distribution of each chemical in the profile section. The STOMP model used the data shown in the profiles as the starting point and simulated the soil-fluid interactions and chemical migration forward through 10,000 years.

D5.0 RESULTS OF FATE AND TRANSPORT MODELING

The modeling results for each waste site in the groundwater zone at approximately 0 m from the edge of the waste site are shown in the time series plots in Figures D-7 through D-11. The peak concentrations (maximum groundwater concentrations over time) for each chemical were compared to their groundwater maximum contaminant levels (MCL) (Tables D-3 through D-7) to evaluate how protective existing conditions are of groundwater. In general, the decision-making process is based on estimated concentrations for the following 1,000 years (model years 2002 to 3002); however, the simulation and discussion include a period of 10,000 years (model years 2002 to 12002) to discuss the less mobile chemicals, with peak concentrations not occurring until after 1,000 years.

The time series plots show the concentration of each chemical at the edge of the waste site in groundwater over time. Each chemical has at least two curves, one showing the maximum concentration (solid line) at the lateral extent in the groundwater, and another (dashed line) showing a concentration averaged from a vertical section of the groundwater. The difference between these lines roughly represents the amount of mixing with the aquifer, vertical migration of the chemical within the saturated zone, and groundwater concentrations anticipated from a well screened across this interval. For comparison to groundwater MCLs, only the maximum groundwater concentration was used. To complete the longer simulation time period of 12,000 years, a coarser grid was used in the model to compensate for the increased computation time required to complete the simulation. The difference in site-specific model grids resulted in a variable aquifer thickness available in the model results for averaging. The variable thickness ranges from 3.75 m to 5 m.

In addition, uranium has been simulated with two different K_ds: 0.6 and 3. These results have been shown as two separate plots to estimate the contaminant's sensitivity to this chemical

characteristic model input parameter. The results for uranium using a K_d of 0.6 are considered the more conservative (more mobile) of the two, resulting in relatively quicker and higher peak concentrations.

Results for antimony, arsenic, and mercury, indicated that these chemicals are essentially immobile at the given concentrations and soil parameters. The results of the fate and transport models indicate that antimony, arsenic, and mercury do not reach groundwater within the 10,000-year simulation time period.

D5.1 RESULTS FOR 216-U-1 AND 216-U-2 CRIBS

The modeling results for the 216-U-1 and 216-U-2 cribs are shown graphically in Figure D-7 and with respect to groundwater MCLs in Table D-3. The model results indicate that Tc-99 may reach groundwater with a resulting peak groundwater concentration greater than the MCL within 1,000 years. Uranium simulated with the more conservative K_d of 0.6 is expected to reach the groundwater within the first 1,000 years, but with concentrations below the MCL.
The concentration may exceed the MCL after about 1,400 years (note that the simulations begin in calendar year 2000). Model results for the same uranium concentrations using a K_d of 3 were below the groundwater MCL for the entire 10,000 years of simulation. Antimony was not predicted in groundwater during the 10,000-year simulation. The curves in Figure D-7 show the sensitivity of the model simulation to the K_d factor, and effect on uranium, given the same soil loading concentrations. The higher K_d value resulted in lower mobility, with a lower peak concentration and curve expanded out over a longer time interval with the area under both curves representing the same mass of contaminant in the system.

The maximum concentrations used in the evaluation are shown and are significantly higher than the calculated average aquifer concentrations, except for Tc-99 initially. This suggests that with the conditions and concentrations modeled, mixing in the aquifer is limited, with the majority of the chemical mass in the upper section of the groundwater (i.e., the chemical is not completely mixing within the saturated zone).

D5.2 RESULTS FOR THE 216-U-4 REVERSE WELL AND 216-U-4A FRENCH DRAIN

The modeling results for the 216-U-4 Reverse Well and 216-U-4A French Drain are shown graphically in Figure D-8 and with respect to groundwater MCLs in Table D-4. The model results indicate that neither uranium nor mercury would have a groundwater concentration greater than the MCL within 1,000 years. Uranium simulated with the more conservative K_d of 0.6 is expected to reach the groundwater within 1,000 years, but with concentrations below the MCL. The concentration may exceed the MCL after about 5,100 years. Model results for the same uranium concentrations, but with a K_d of 3, were below the groundwater MCL for the entire 10,000 years of simulation. Mercury was not predicted to reach groundwater during the 10,000-year simulation.

The higher K_d value for uranium resulted in lower mobility, with a lower peak concentration and curve spread out over a longer time interval with the area under both curves representing the same mass of contaminant in the system, as anticipated.

The maximum concentrations used in the evaluation are shown and are significantly higher than the calculated average aquifer concentrations indicating relatively shallow penetration of the chemical plume in the groundwater.

D5.3 RESULTS FOR THE 216-U-8 CRIB

The modeling results for the 216-U-8 Crib are shown graphically in Figure D-9 and with respect to groundwater MCLs in Table D-5. The model results did not indicate that Tc-99, antimony, or nitrate would result in groundwater concentrations greater than the MCL within 1,000 years. The concentrations of Tc-99 and nitrate peak after 1,000 years at concentrations below the MCL. Antimony was not predicted to reach groundwater during the 10,000-year simulation. Uranium simulated with the more conservative K_d of 0.6 is predicted to exceed the groundwater MCL within 1,000 years; however, the same uranium concentrations simulated with the higher K_d value resulted in uranium reaching the groundwater within 1,000 years, but at concentrations below the MCL.

Nitrogen as nitrate and nitrite concentrations was predicted to exceed the groundwater MCL within 1,000 years.

The maximum concentrations used in the evaluation are shown and they are significantly higher than the calculated average aquifer concentrations, indicating relatively shallow penetration of the chemical plume in the groundwater. The average aquifer concentration for nitrogen in nitrate and nitrite was below the MCL, suggesting that groundwater sampling would result in concentrations below the MCL.

D5.4 RESULTS FOR THE 216-U-12 CRIB

The modeling results for the 216-U-8 Crib are shown graphically in Figure D-10 and with respect to groundwater MCLs in Table D-6. The model results indicate uranium and arsenic would not result in groundwater concentrations greater than the MCL within 1,000 years. Uranium, simulated with the more conservative K_d of 0.6, is expected to reach the groundwater within 1,000 years, but with concentrations below the MCL. The concentration of uranium may exceed the MCL after about 6,250 years. Arsenic is not expected to reach the water table. Model results for the same uranium concentrations, but with a K_d of 3, were below the groundwater MCL for the 10,000 years of the simulation. Nitrogen as nitrate and nitrite concentrations was predicted to exceed the groundwater MCL within a relatively short time interval of 15 to 53 years, and with concentrations below the MCL thereafter. Estimated concentrations are slightly higher at a distance away from the edge of the waste site (e.g., 10 m, 30 m). In addition, these concentrations at a distance away from the edge of the waste site exceed the MCLs for a longer period of time (i.e., > 1,000 years).

D5.5 RESULTS FOR THE 200-W-42 VCP/UPR-200-W-163

The modeling results for the 200-W-42 VCP/UPR-200-W-163 are shown graphically in Figure D-11 and with respect to groundwater MCLs in Table D-7. The model results indicate that Tc-99, uranium total metal, arsenic, and nitrogen as nitrate and nitrate would not result in groundwater concentrations greater than the MCL within 1,000 years, nor would any contaminants result in groundwater concentrations greater than the MCL within 10,000 years.

D6.0 CAPPING SIMULATION

An additional simulation was run for the 216-U-1 and 216-U-2 Cribs waste site to evaluate the effects of placing a cap over the waste site as a proposed mitigation. To simulate a cap, the infiltration into the backfill and Hanford formation was reduced to 0.01 cm/year for the initial 500 years of the run, then 0.015 cm/year to the end of the model time period. The 0.01 cm/year infiltration is the rate estimated for an intact soil or geosynthetic barrier-type cap with an estimated effective life of 500 years. A 50 percent infiltration rate was added after the initial 500 years (0.015 cm/year) to simulate the conditions of a degraded cap. All other modeling parameters, including profile chemical concentrations, remained the same. Figure D-12 shows the time series plot of the model results, and Table D-8 shows the results compared to the previously described model results and groundwater MCLs.

Placement of a cap at the 216-U-1 and 216-U-2 Cribs waste site resulted in predicted groundwater concentrations of Tc-99 below the MCL, based on the model simulation. The cap simulation resulted in peak concentrations that were lower and farther out in time and in lower overall chemical concentrations, than without a cap. Figures D-13 and D-14 show a comparison of the water flow lines through the vadose zone with and without a cap along with the input concentration distributions for Tc-99 and uranium metal, respectively. The flow lines in the figures are identical; the only difference between the figures is the different contaminants' plume geometries. As expected, emplacement of the cap greatly slows the downward movement of water beneath the 216-U-1 and 216-U-2 Cribs. The flow lines derived from the uncapped simulation expand outward from the cribs as they move downward. This results from the enhanced recharge occurring through the waste site relative to the surrounding area remaining unchanged through time. In addition to gravity, the aqueous capillary pressure gradients effect the movement of the water by pulling it from wetter to drier soil regions. Because more water infiltrates through the disturbed ground associated with the cribs than through the surrounding undisturbed ground, water moves laterally away from the waste site as it moves downward. Conversely, the flow lines derived from the capping simulation contract toward the 216-U-1 and 216-U-2 Cribs. This inward movement results from the greatly reduced recharge occurring through the waste site cap relative to the surrounding area.

The cap in the 216-U-1 and 216-U-2 Cribs model simulation extended about 30 m beyond the surface expression of the waste site. While that overlies most of the high-concentration areas of the plumes in the vadose zone estimated for use in the model, it does not cover the plumes in their entirety. Portions of the plume containing concentrations of Tc-99 greater than 50 pCi/g

and uranium greater than 10,000 mg/kg extend out laterally from beneath the cap. Even with these portions of the plumes extending beyond the cap in the vadose zone, the capping simulations indicated that the contaminants in the vadose zone would not result in groundwater concentrations in excess of the MCLs.

The flow lines represent the path of a water particle moving downward from the ground surface. The velocity field used to calculate the flow lines remains constant through time (i.e., steady state). For the uncapped simulation, the flow field calculated in year 2002 was used to calculate the flow lines. Because discharge to the cribs ended by 1967, it is assumed that the flow field in the vadose zone would have essentially reestablished steady-state conditions by 2002. Emplacing a cap changes the physical system, so the flow field calculated in a later year was used to calculate those flow lines. It is assumed that after emplacement of the cap in 2002, the flow field calculated for year 2050 would satisfactorily represent steady-state conditions. Although the infiltration rate through the cap increases from 0.01 cm/year to 0.015 cm/year after 500 years, the figures show such little movement of the water beneath the cap that the small change in infiltration rate would not greatly change the flow lines.

D7.0 CONCLUSIONS

Based on the modeling results, the following conclusions were made:

- For several waste sites, chemical parameters were identified that may pose a contaminant of concern based on predicted groundwater concentrations exceeding MCLs.
  - **216-U-1 and 216-U-2 Cribs**, Tc-99
  - **216-U-8 Crib**

    Uranium at a K_d of 0.6, but not at a K_d of 3

    Nitrogen as nitrate and nitrite, however, with an average aquifer concentration below the MCL.
  - **216-U-12 Crib**, nitrogen as nitrate and nitrite.
- Two different K_d values used for the uranium total metal concentrations resulted in a relatively large range of concentrations, with the lower K_d value resulting in relatively quicker and higher concentration peaks.
- Antimony, arsenic, and mercury were relatively immobile based on the model results, indicating that these chemicals would not encounter groundwater within 10,000 years for antimony and mercury, and 1,000 years for arsenic.
- Simulated placement of a cap over the 216-U-1 and 216-U-2 Cribs results in lower peak concentrations farther into the future, reducing the Tc-99 concentrations below the threshold for potential contaminants of concern.

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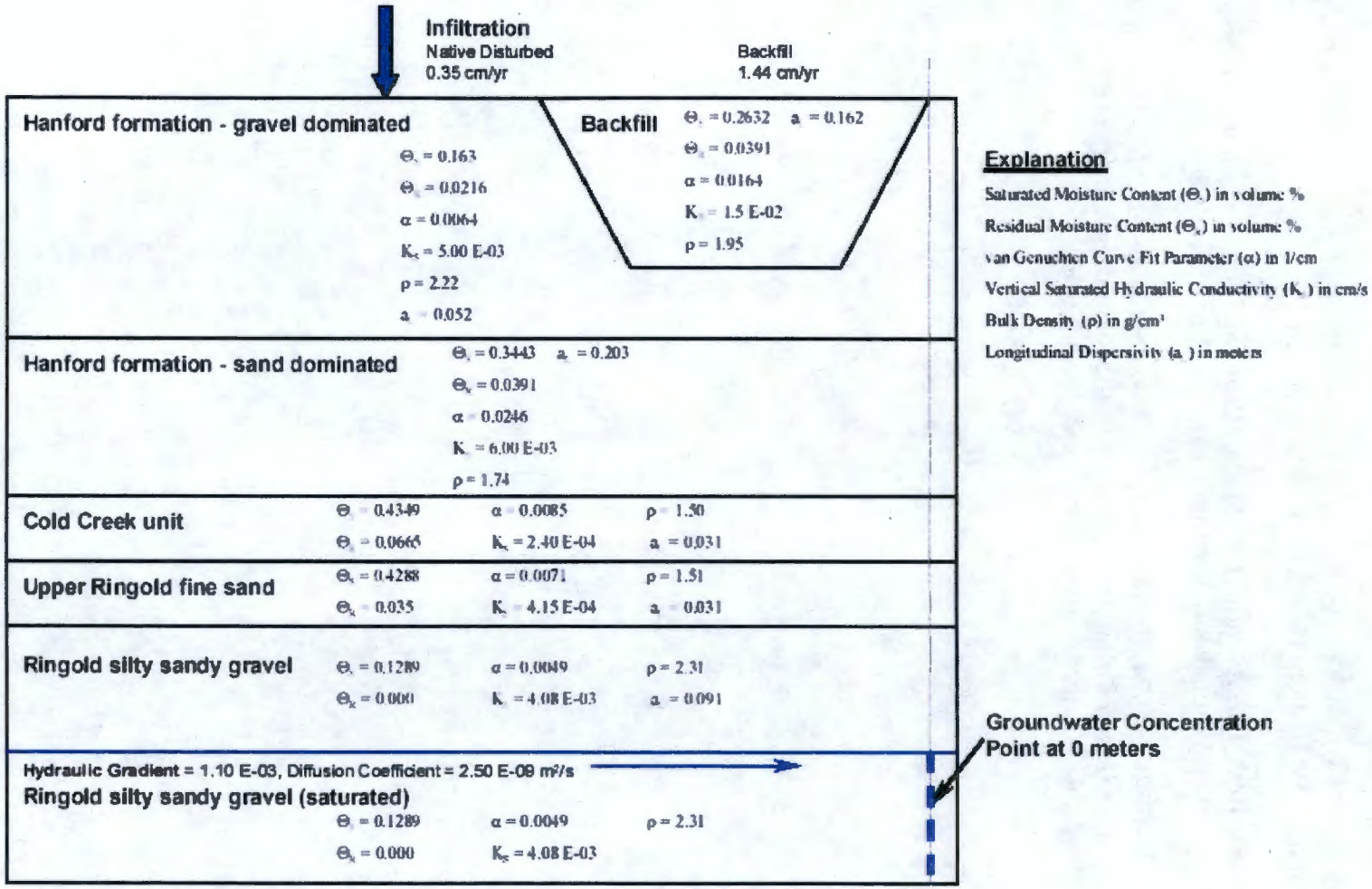


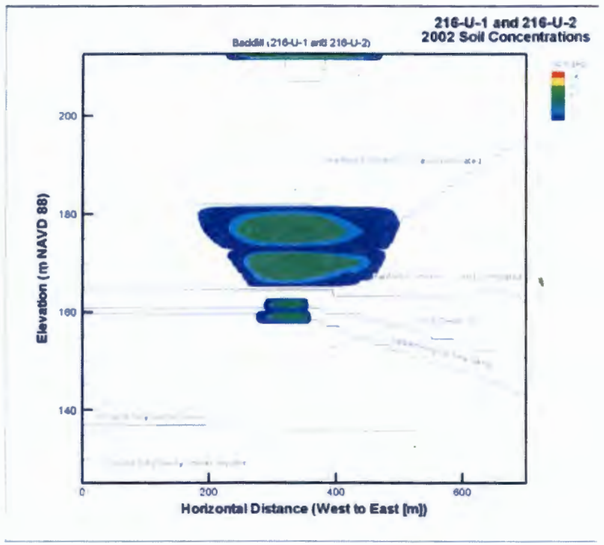
Figure D-1. Conceptual Model Parameter.

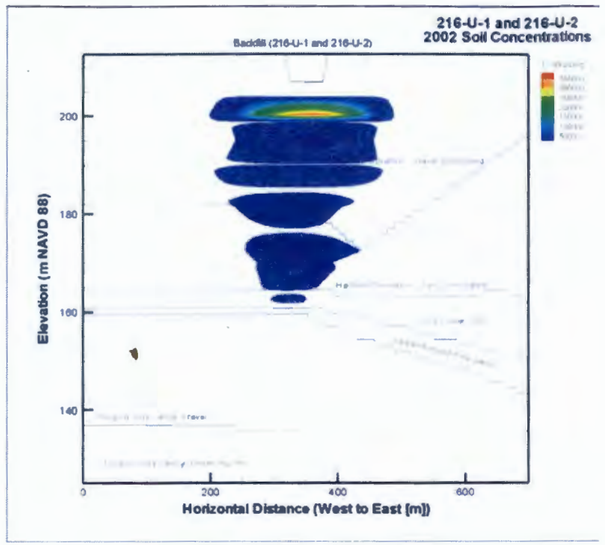
Notes

Conceptual profile shows the generalized geology and relative positions. Layer orientations and thickness are specific to each waste site location.

References and rationale for geologic unit parameters are shown in Table D-1

Figure D-2. Modeling Input Distribution for Technetium-99, Antimony, and Uranium Metal at the 216-U-1 and 216-U-2 Cribs.





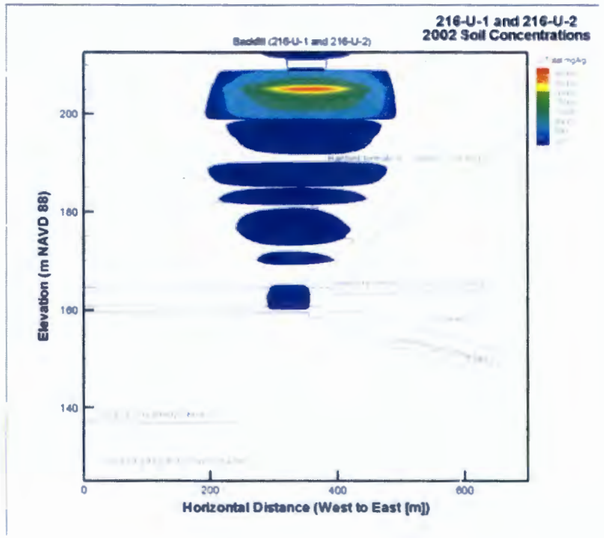
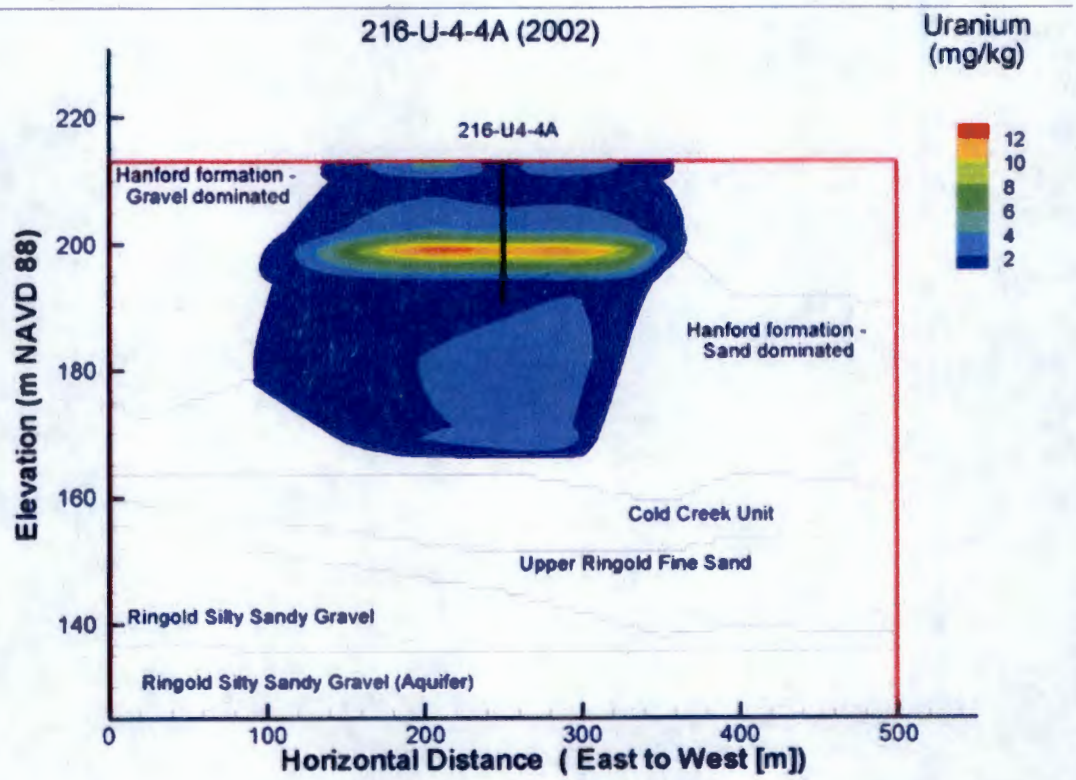


Figure D-3. Modeling Input Distribution for Uranium Metal and Mercury at the 216-U-4 Reverse Well and 216-U-4A French Drain.



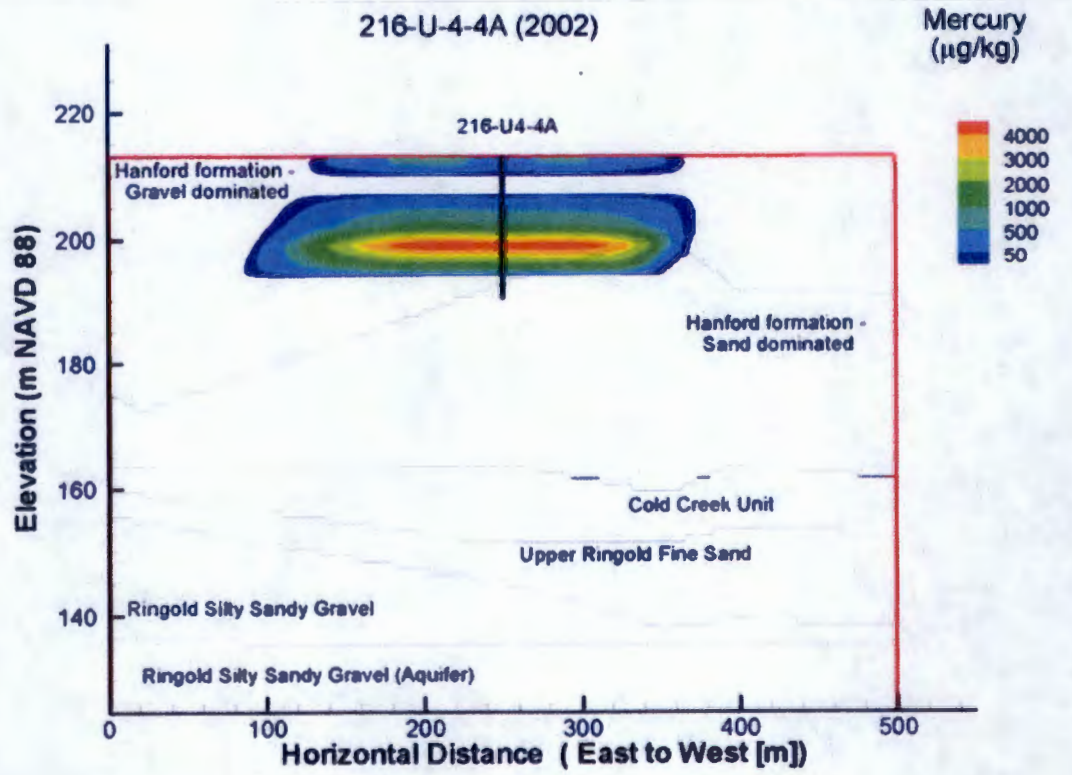


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Figure D-4. Modeling Input Distribution for Nitrogen in Nitrate and Nitrite, Nitrate, Antimony, Technetium-99, and Uranium Metal at the 216-U-8 Crib.

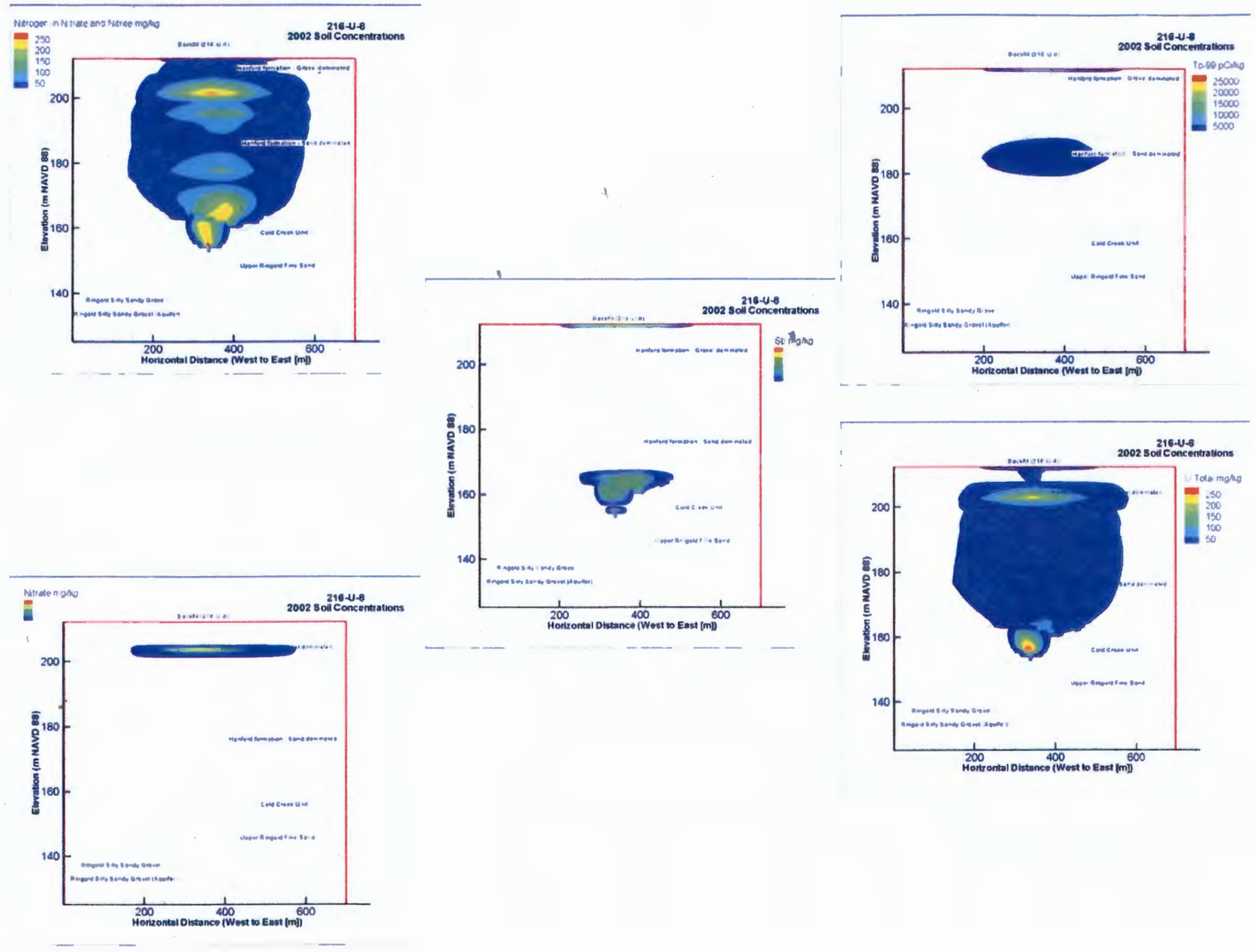
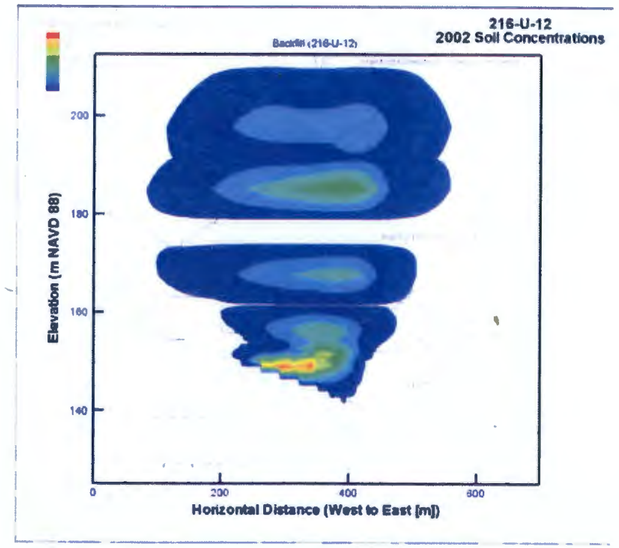
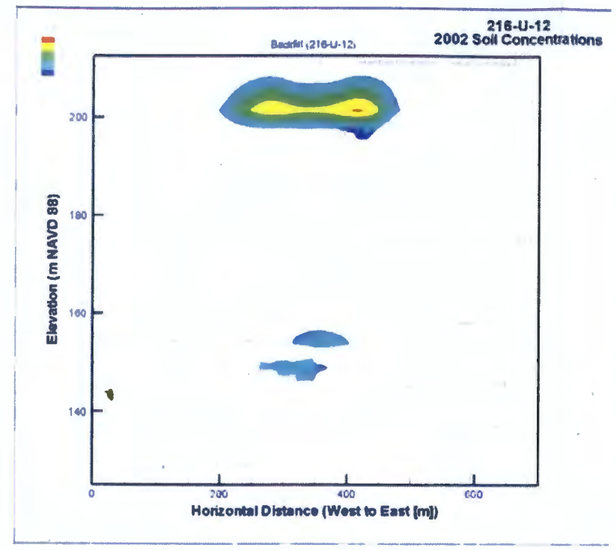


Figure D-5. Modeling Input Distribution for Nitrogen in Nitrate and Nitrite, Arsenic, and Uranium Metal at the 216-U-12 Crib.





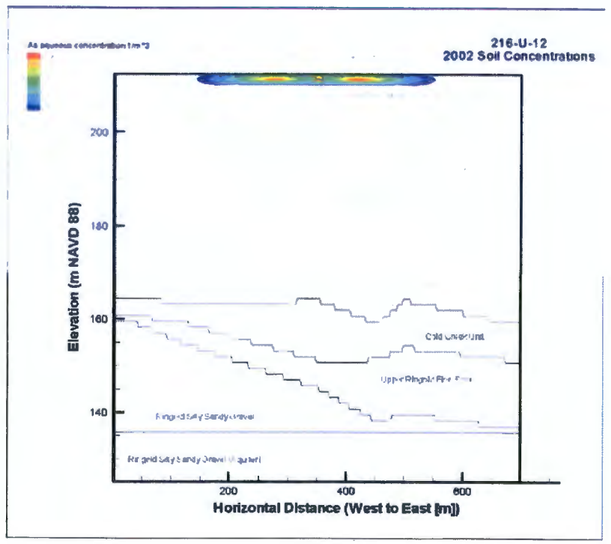
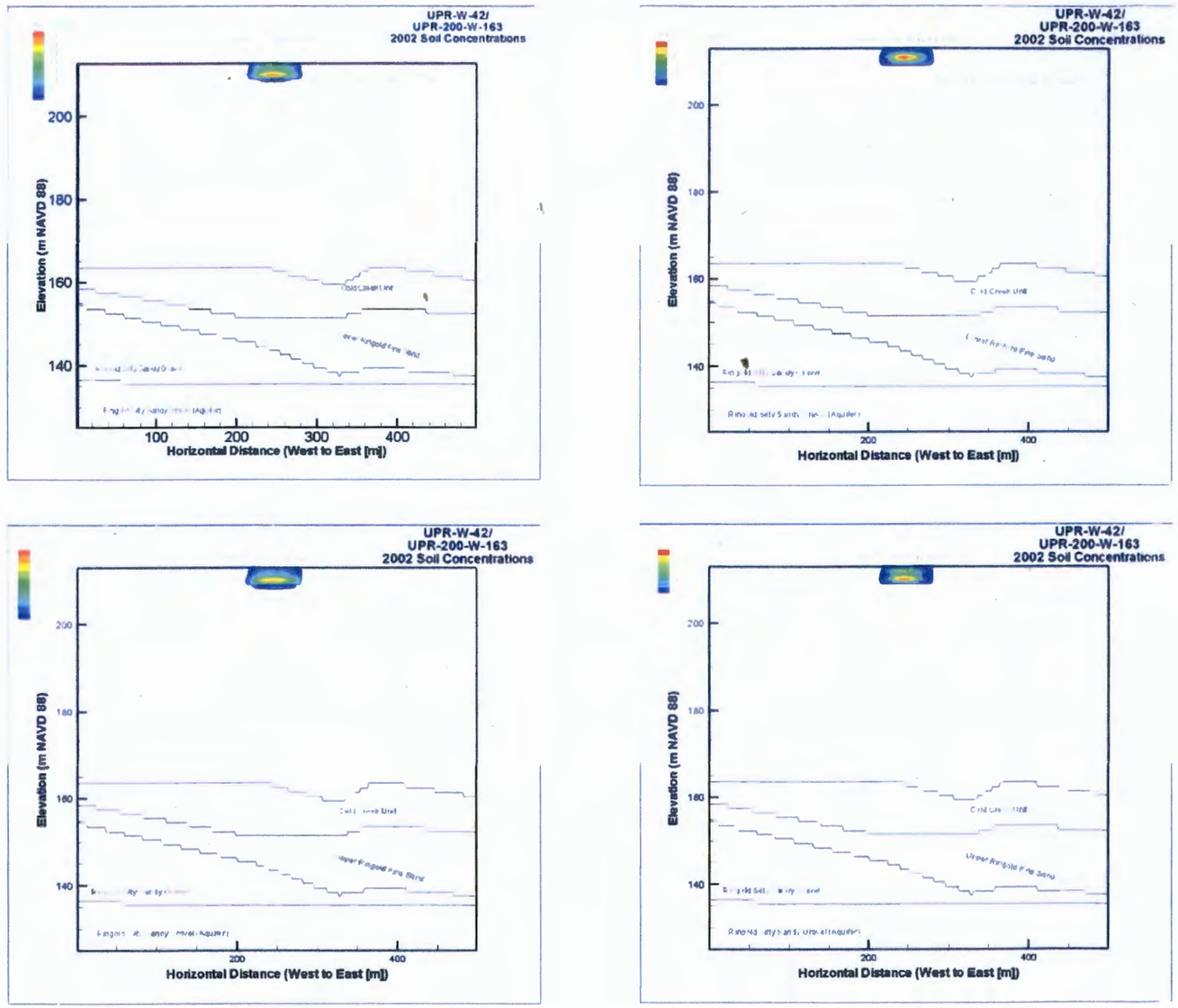


Figure D-6. Modeling Input Distribution for Nitrogen in Nitrate and Nitrite, Arsenic, Technetium, and Uranium Metal at the 200-W-42 Vitrified Clay Pipeline/UPR-200-W-163.



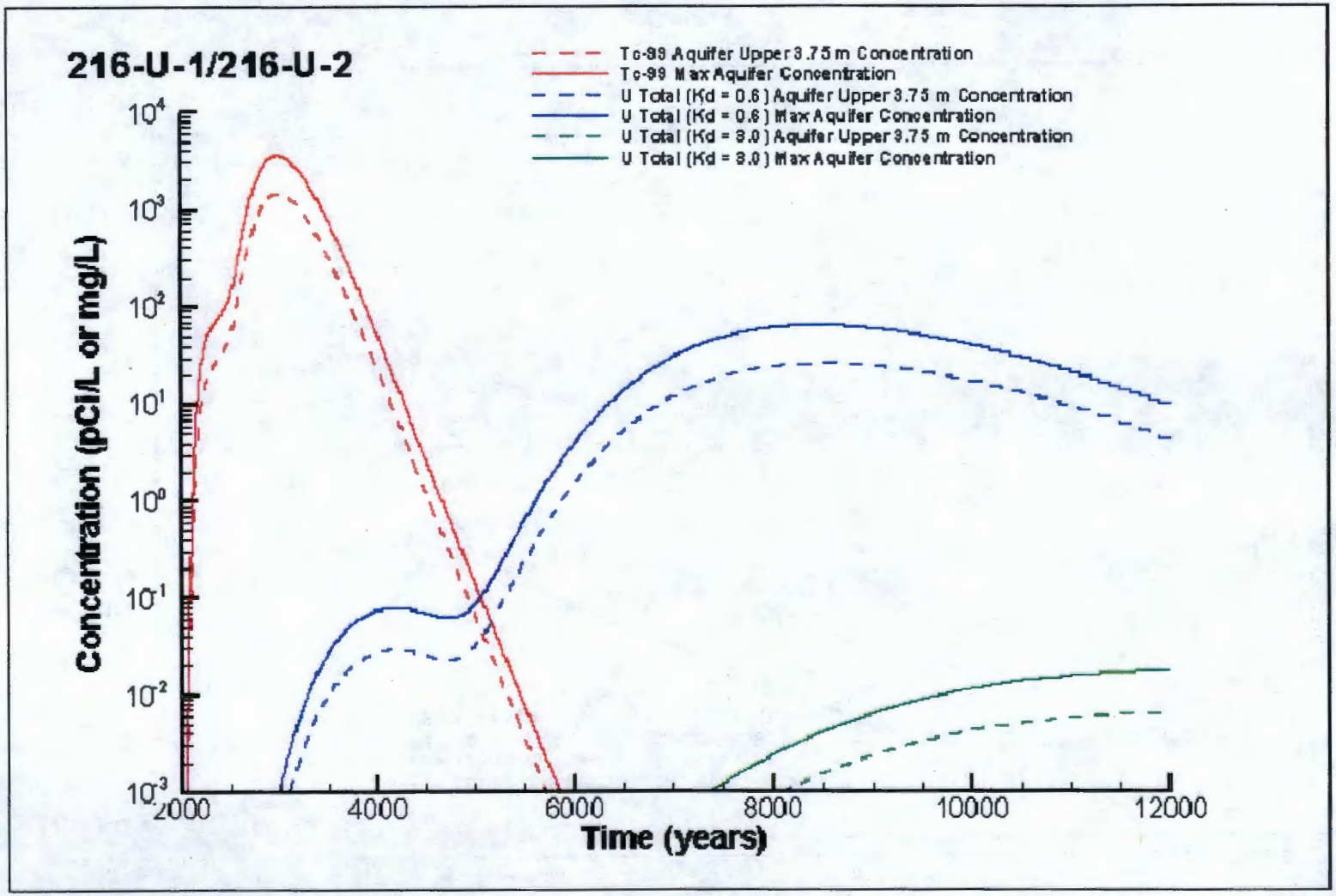


Figure D-7. Groundwater Concentrations for Technetium-99 and Uranium Metal at the 216-U-1 and 216-U-2 Cribs.

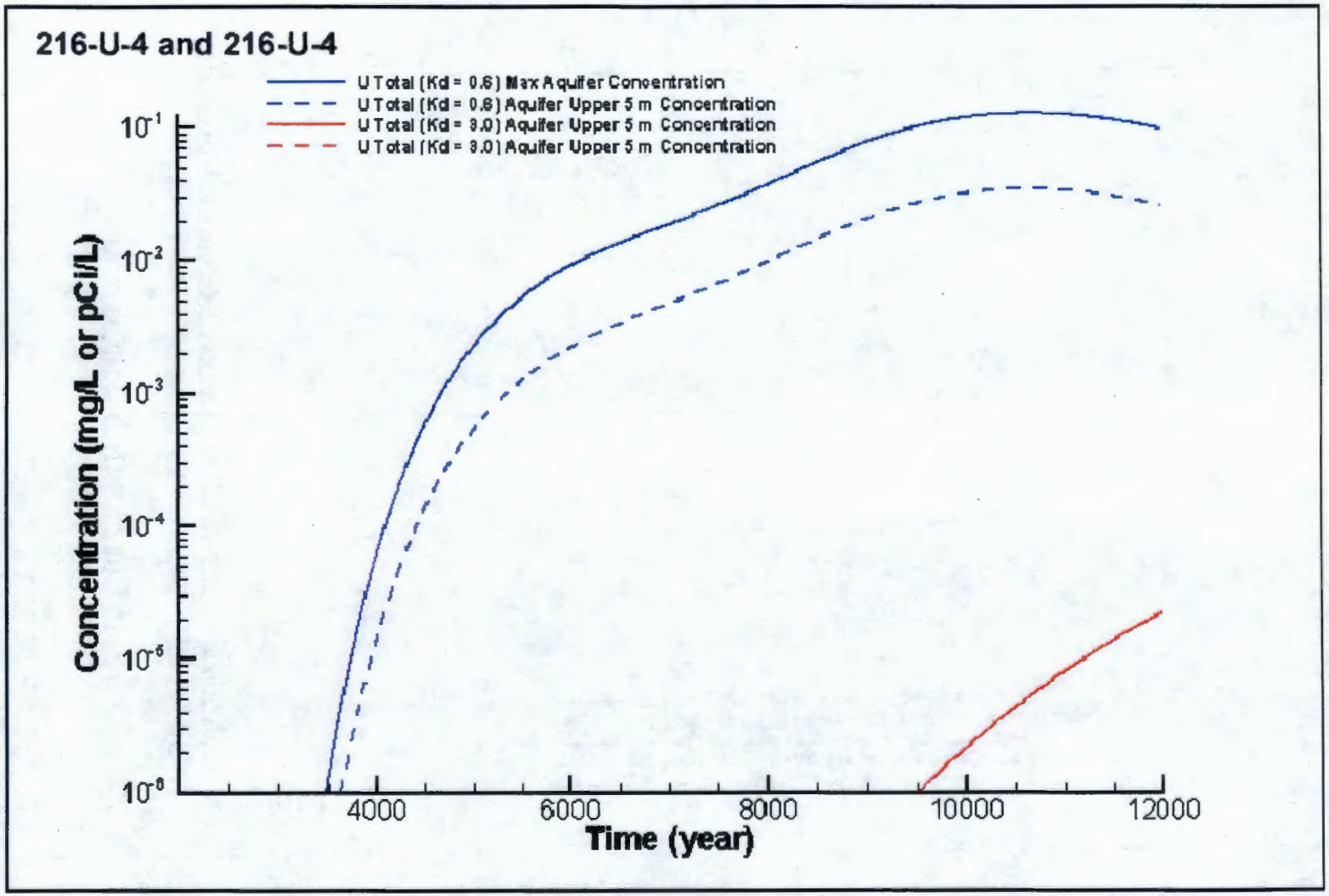


Figure D-8. Concentrations for Uranium Metal at the 216-U-4 Reverse Well and 216-U-4A French Drain.

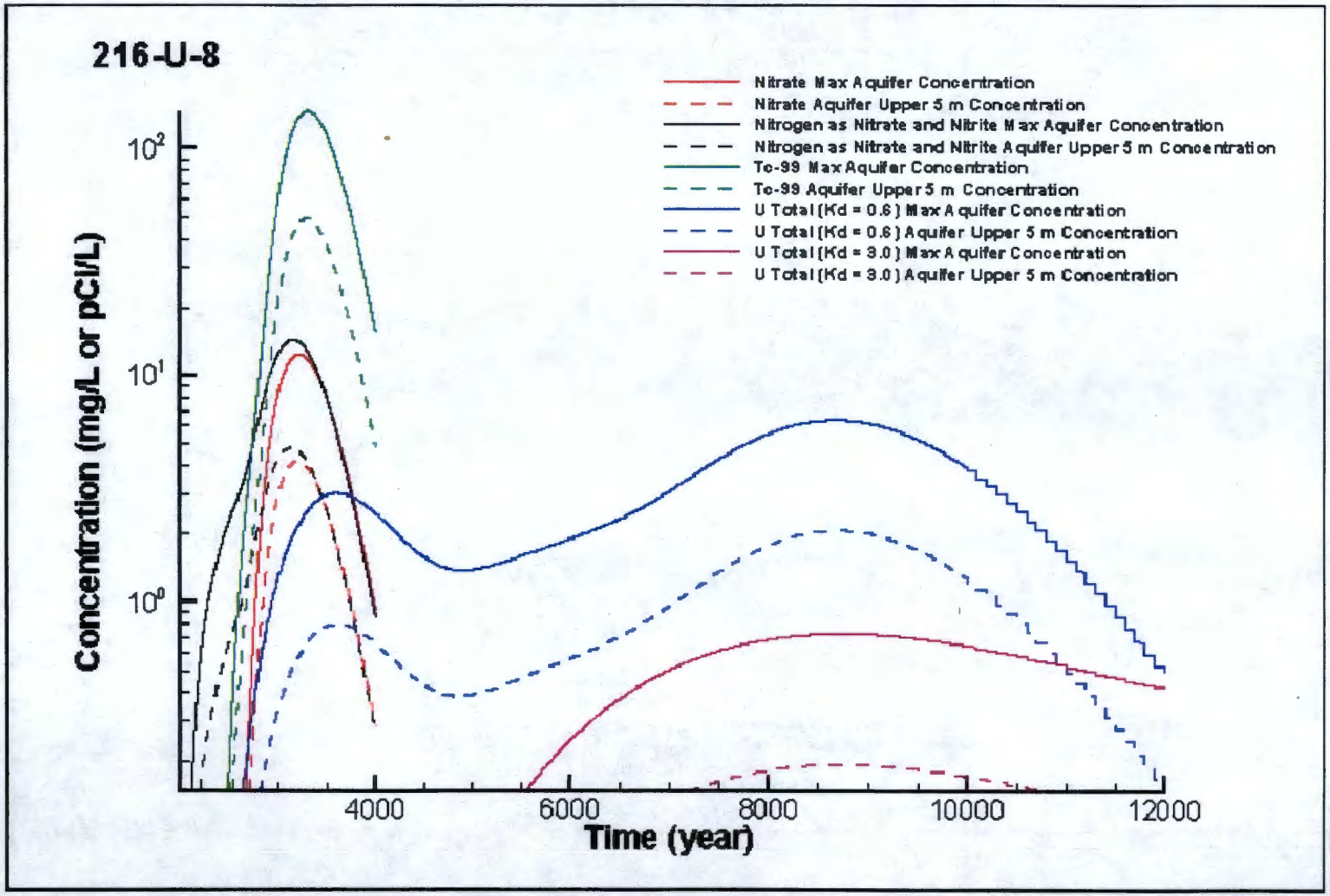


Figure D-9. Groundwater Concentrations for Nitrogen in Nitrate and Nitrite, Nitrate, Technetium-99, and Uranium Metal at the 216-U-8 Crib.

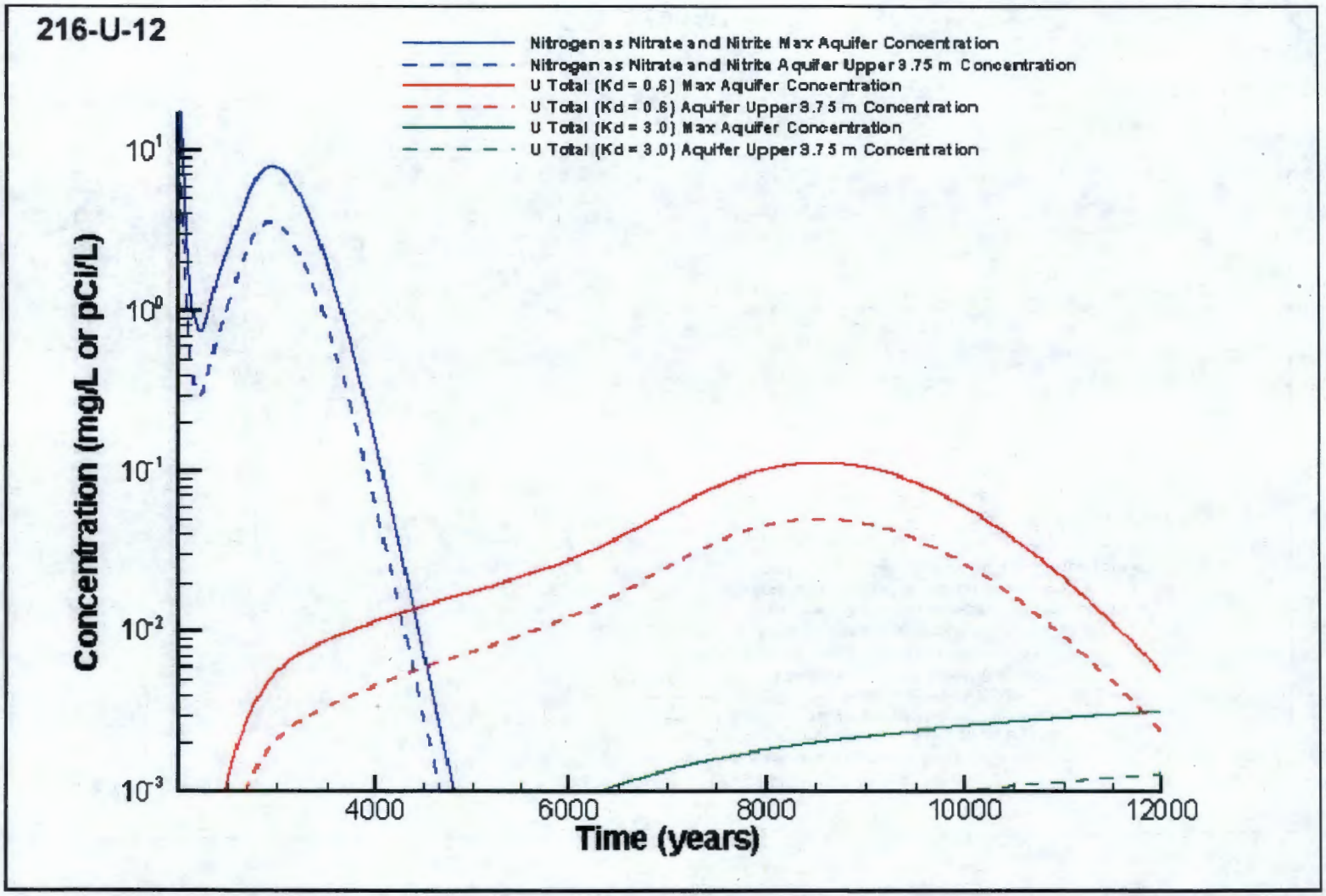


Figure D-10. Groundwater Concentrations for Nitrogen in Nitrate and Nitrite and Uranium Metal at the 216-U-12 Crib.

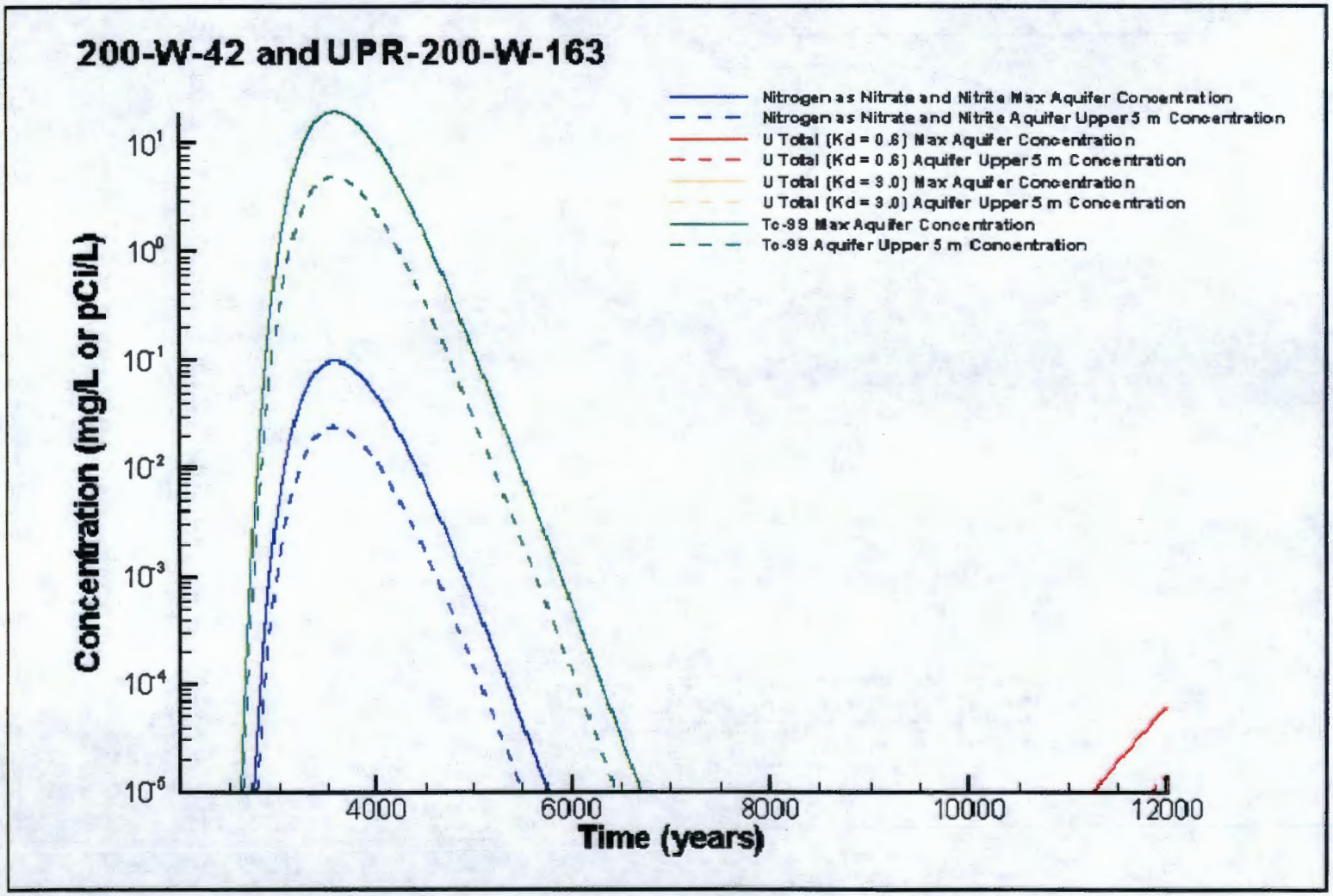


Figure D-11. Groundwater Concentrations for Nitrogen in Nitrate and Nitrite, Technetium, and Uranium Metal at the 200-W-42 Vitrified Clay Pipe/UPR-200-W-163.

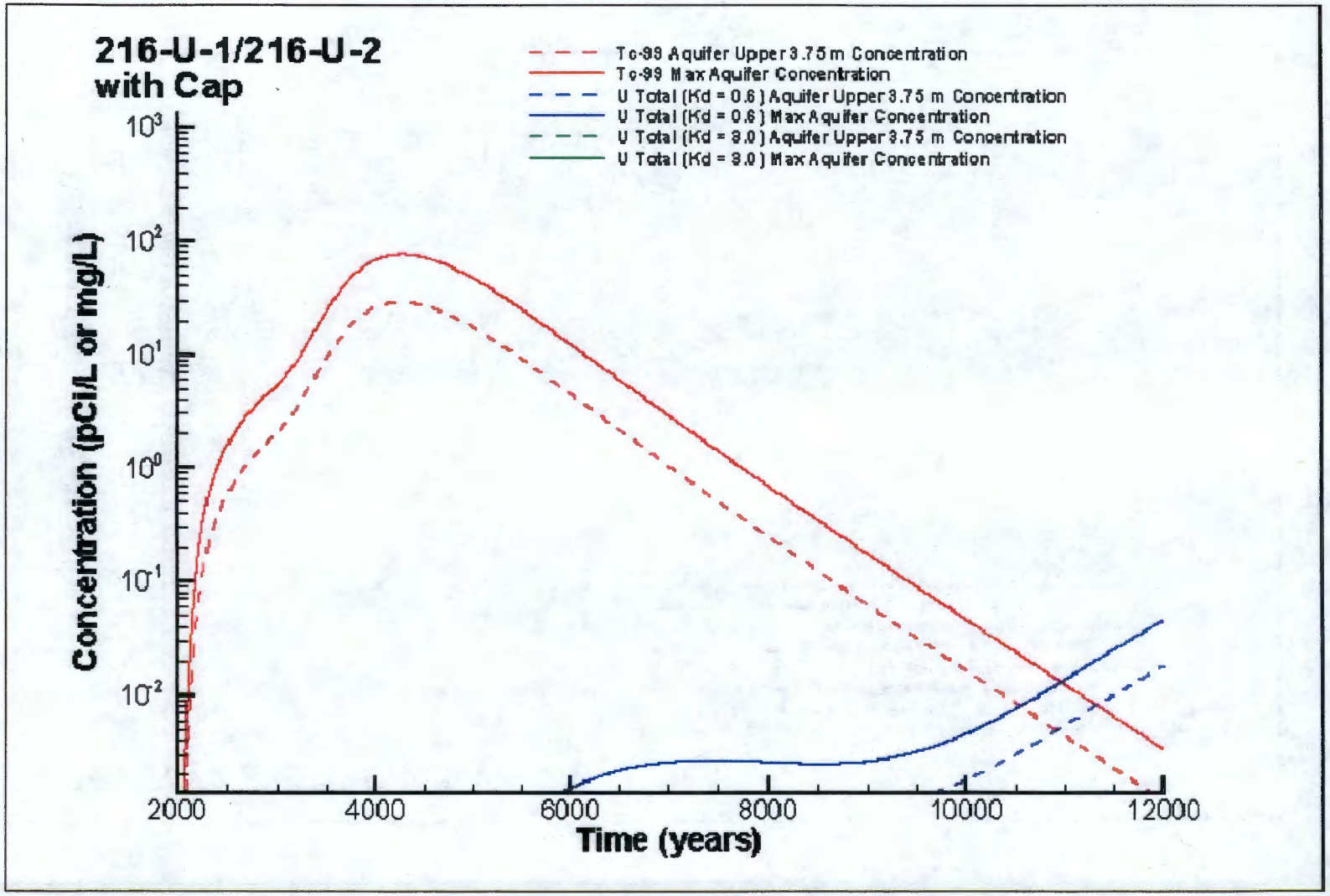


Figure D-12. Groundwater Concentrations for Technetium-99 and Uranium Metal at the 216-U-1 and 216-U-2 Cribs with a Cap.

Figure D-13. Water Flow Lines through the Vadose Zone With and Without a Cap and the Initial Uranium Plume Concentrations.

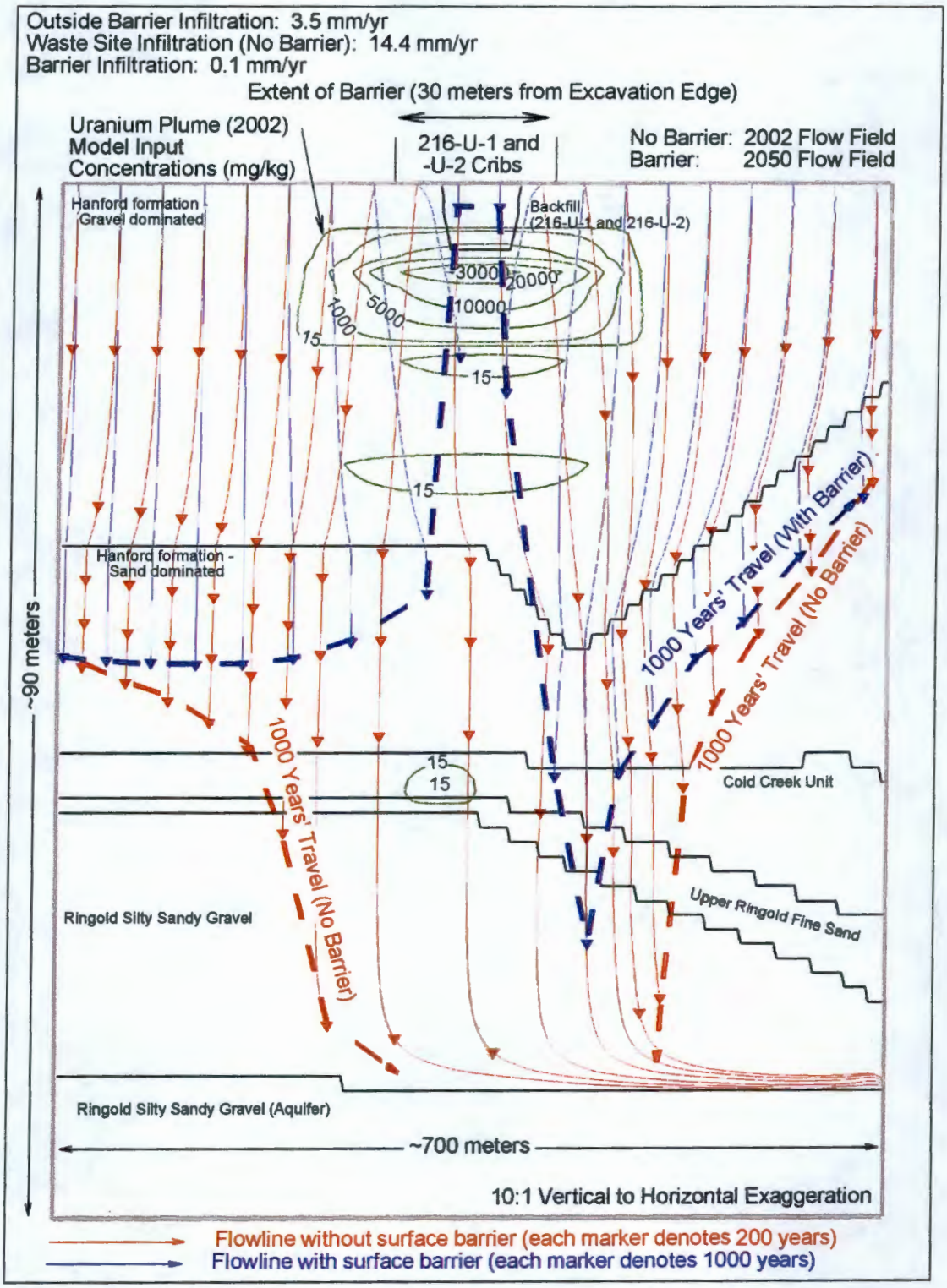


Figure D-14. Water Flow Lines through the Vadose Zone With and Without a Cap and the Initial Technetium-99 Plume Concentrations.

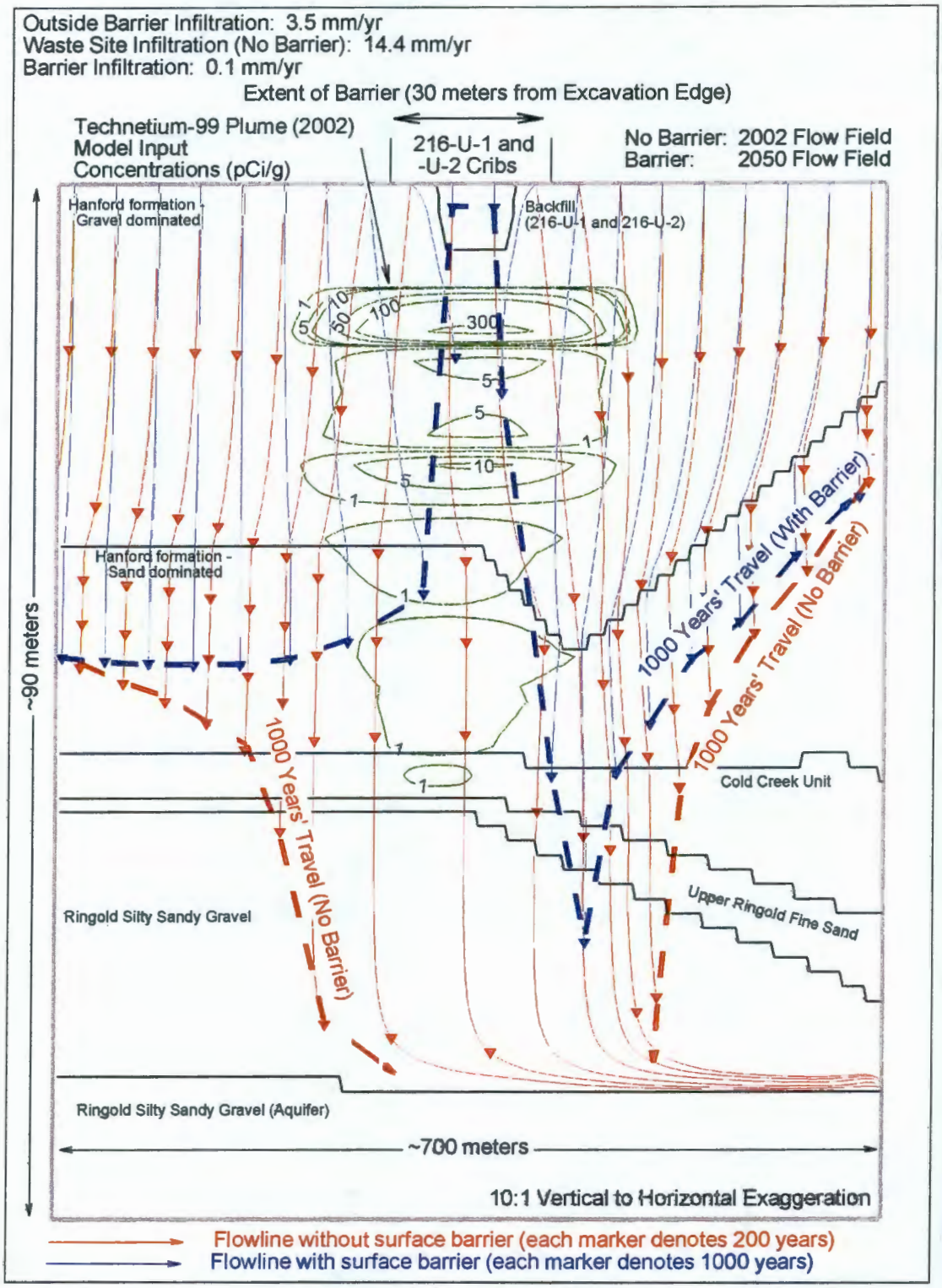


Table D-1. U Plant Area Soil Input Parameters.

U Plant Area Model Soil Type	θS (vol%)	θR (vol%)	Sr (%)	α (1/cm)	n (unitless)	K_S [A] (cm/s)	K_S [A] (m/yr)	Bulk Density (g/cm^3)	Effective Porosity	Longitudinal Dispersivity (m) [C]	Source/Rationale
Backfill	0.2632	0.0391	0.1486	0.0164	1.3917	1.50E-02	4730.4	1.95	0.224	0.162	WHC-EP-0883, Tables 1 and 4, soil category sand and gravel mixed with finer fraction, SSG (corrected best fit and scaled)[B]. Layer 1 of Sandia
Hanford (Gravel Dominated)	0.163	0.0216	0.1325	0.0064	1.5147	5.00E-03	1576.8	2.22	0.141	0.052	WHC-EP-0883, Tables 1 and 4, soil category sandy gravel, SG1 (corrected best fit and scaled). Layer 2 of Sandia
Hanford (Sand Dominated)	0.3443	0.0391	0.1136	0.0246	1.1707	6.00E-03	1892.16	1.74	0.305	0.203	WHC-EP-0883, Tables 1 and 4, soil category sand, S (corrected best fit and scaled). Layer 7 of Sandia
Cold Creek unit	0.4349	0.0665	0.1529	0.0085	1.8512	2.40E-04	75.6864	1.50	0.368	0.031	RPP-6296: Table 2 on pg. 8, Plio-Pleistocene strata. Layer 9 of Sandia
Upper Ringold Sand	0.4288	0.035	0.0816	0.0071	2.7253	4.15E-04	130.8744	1.51	0.394	0.031	BHI-00270, Table B-1 (page B-19), ERDF Well (699-32-72B, 202.5-204 ft), Sample 4-1056; WHC-EP-0883, soil moisture characteristics curve for Sample 4-1056, Page B-21. Layer 9 of Sandia
Ringold Unit E Silty Sandy Gravel	0.1289	0.000	0.0000	0.0049	1.3761	4.08E-03	1286.669	2.31	0.129	0.091	WHC-EP-0698: Ringold gravel Well 299-W-18-33 (170.0 to 170.5 ft) Figure J-8 SMCC. Layer 8 of Sandia
Other Parameters	Diffusion Coefficient		m^2/s	2.50E-09							WHC-SD-WM-EE-004, Rev. 1, Table 3.22
	Hydraulic Gradient		unitless	1.10E-03							WHC-EP-0645, Figure 2-8 map in vicinity of area (well 299-W19-36)

Notes:

[A]Vertical saturated hydraulic conductivity; horizontal saturated hydraulic conductivity = 10 * $K_{sat\ vertical}$

[B]Although backfill is Hanford formation (SG1) at U Plant cribs, the soil is disturbed and is expected to have a lower density and higher hydraulic conductivity than SG1, consistent with soil category SSG (reported in WHC-EP-0883) based on professional judgment.

[C]Longitudinal Dispersivity (m) is based on SAND98-2880.

BHI-00270, *Pre-Operational Baseline and Site Characterization Report for the Environmental Restoration Disposal Facility.*

RPP-6296, *Modeling Data Package for S-SX Field Investigation Report (FIR)*, Rev. 0.

SAND98-2880, *Stochastic Parameter Development for PORFLOW Simulations of the Hanford AX Tank Farm.*

WHC-EP-0645, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds.*

WHC-EP-0698, *Groundwater Impact Assessment Report for the 216-U-14 Ditch.*

WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*

WHC-SD-WM-EE-004, *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford.*

θR = Residual moisture content, by volume = field capacity.

θS = Saturated moisture content, by volume = Total Porosity.

Sr (%) = % moisture saturation calculated as θR / θS .

α (1/cm) = van Genuchten curve fit parameter.

n (unitless) = van Genuchten curve fit parameter .

KS (cm/s) = vertical saturated hydraulic conductivity.

Bulk density calculated as 2.65 (1 - θS) .

Effective porosity calculated as θS – θR.

Table D-2. U Plant Site-Specific Chemical Concentrations and Input Parameters.

Waste Site	Radionuclide Contaminants	Non-radionuclide Contaminants	Max. Conc. (pCi/g or mg/kg)	Depth (m)	Distribution Coefficient (mL/g)	Diffusion Coefficient (m^2/s)	Half-Life (years)
216-U-1 and 216-U-2 Cribs	Tc-99		350	12.6	0	2.5 E-09	214,000
		U Total	32,700	8.61	0.6/3	2.5 E-09	No Value
		Sb	11.4	0.15	45	2.5 E-09	NA
216-U-4 Reverse Well and 216-U-4A French Drain		U Total	12.5	18.6	0.6/3	2.5 E-09	No Value
		Hg	8	53.7	52	2.5 E-09	NA
216-U-8 Crib	Tc-99		25.2	0.61	0	2.5 E-09	214,000
		N as NO_3 and NO_2	304	60.4	0	2.5 E-09	NA
		Nitrate	1200	9.45	0	2.5 E-09	NA
		U Total	280	57.3	0.6/3	2.5 E-09	No Value
		Sb	11.2	0.15	45	2.5 E-09	NA
216-U-12 Crib		N as NO_3 and NO_2	197	64.2	0	2.5 E-09	NA
		Arsenic	8.6	2	29	2.5 E-09	NA
		U Total	5.1	39.3	0.6/3	2.5 E-09	No Value
200-W-42 VCP/ UPR-200-W-163	Tc-99		50.2	3.4	0	2.5 E-09	214,000
		N as NO_3 and NO_2	116	3.7	0	2.5 E-09	NA
		Arsenic	19.1	3.6	29	2.5 E-09	NA
		U Total	160	2.3	0.6/3	2.5 E-09	No Value

Table D-3. 216-U-1 and 216-U-2 Cribs.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Technetium-99	3530	3000	900	2670 – 3850	Yes
Uranium (metal K_d 0.6)	63.6	8500	0.02	3400 - >12002	No
Uranium (metal K_d 3)	NA	>12000	0.02	0.017 at 12002	No
Antimony	NA	>12000	0.006	0 at 12002	No

Notes:

[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.

[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.

COC = contaminant of concern.

MCL = maximum contaminant level.

NA = not applicable.

Table D-4. 216-U-4 Reverse Well and 216-U-4A French Drain.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Uranium (metal K_d 0.6)	0.13	10500	0.02	7100 – 12002	No
Uranium (metal K_d 3)	NA	>12000	0.02	0.0001 at 12002	No
Mercury	NA	>12000	0.002	0 at 12002	No

Notes:
[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.
[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.
COC = contaminant of concern.
MCL = maximum contaminant level.
NA = not applicable.

Table D-5. 216-U-8 Crib.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Technetium-99	146	3250	900	NA	No
Uranium (metal K_d 0.6)	6.3	8600	0.02	2450 - >12002	Yes
Uranium (metal K_d 3)	0.73	8700	0.02	5100 - >12002	No
Antimony	NA	>12002	0.006	0 at 12002	No
Nitrate	12	3160	45	NA	No
Nitrogen in Nitrate and Nitrite	14	3090	10	2920 – 3400	Yes

Notes:
[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.
[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.
COC = contaminant of concern.
MCL = maximum contaminant level.
NA = not applicable.

Table D-6. 216-U-12 Crib.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Uranium (metal K_d 0.6)	0.11	8250	0.02	5300 – 11000	No
Uranium (metal K_d 3)	NA	>12002	0.02	0.003 at 12002	No
Arsenic	NA	>3002	0.05	0 at 3002	No
Nitrogen in Nitrate and Nitrite	17	2027	10	2017 – 2055	Yes

Notes:
[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.
[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.
COC = contaminant of concern.
MCL = maximum contaminant level.
NA = not applicable.

Table D-7. 200-W-42 Vitrified Clay Pipe and UPR-200-W-163.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Tc-99	20	3500	900	NA	No
Uranium (metal K_d 0.6)	NA	8250	0.02	0.00001 at 12002	No
Uranium (metal K_d 3)	NA	>12002	0.02	0 at 12002	No
Arsenic	NA	>3002	0.05	0 at 3002	No
Nitrogen in Nitrate and Nitrite	0.09	3500	10	NA	No

Notes:
[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.
[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.
COC = contaminant of concern.
MCL = maximum contaminant level.
NA = not applicable.

Table D-8. 216-U-1 and 216-U-2 Cribs Comparison to Cap Simulation Results.

Contaminants Modeled	Groundwater Peak Concentration (pCi/L or mg/L)	Time of Peak (calendar years)[1]	MCL (pCi/L or mg/L)	Predicted to Exceed MCLs (calendar years)[2]	Consider as COC?
Technetium-99	3530	3000	900	2670 – 3850	Yes
Technetium-99 (with cap)	**77**	**4200**	**900**	**NA**	**No**
Uranium (metal K_d 0.6)	63.6	8500	0.02	3400 - >12002	No
Uranium (metal K_d 0.6) with cap	**NA**	**>12002**	**0.02**	**11300 - >12002**	**No**
Uranium (metal K_d 3)	NA	>12000	0.02	0.017 at 12002	No
Uranium (metal K_d 3) with cap	**NA**	**>12000**	**0.02**	**0.000003 at 12002**	**No**
Antimony	NA	>12000	0.006	0 at 12002	No
Antimony (with cap)	**NA**	**>12000**	**0.006**	**0 at 12002**	**No**

Notes:
[1] If the groundwater concentration is increasing at 12002 years, time of peak is reported as greater than 12002.
[2] If the groundwater concentration is increasing at 12002 years, the concentration is reported in pCi/L or mg/L.
COC = contaminant of concern.
MCL = maximum contaminant level.
NA = not applicable.

ATTACHMENT D1

TECHNICAL MEMORANDUM
WAC 173-340-747(8)(B) REVIEW FOR STOMP

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ATTACHMENT D1

TECHNICAL MEMORANDUM
WAC 173-340-747(8)(B) REVIEW FOR STOMP

PURPOSE

This attachment presents an evaluation of the use of contaminant fate and transport models (developed using the STOMP [Subsurface Transport Over Multiple Phases] modeling code [PNNL-11217, *Stomp Subsurface Transport Over Multiple Phases Theory Guide*, and PNNL-12034, *STOMP Subsurface Transport Over Multiple Phases Users Guide*) to assist in establishing guidelines for the allowable soil concentration of the contaminants of potential concern identified at the 200-UW-1 Operable Unit (OU). *Washington Administrative Code* (WAC) 173-340-747(3)(e), "Deriving Soil Concentrations for Ground Water Protection," "Overview of Methods," "Alternative Fate and Transport Models," allows the use of fate and transport models (as an alternative to the methods described in WAC 173-340-747(4), "Deriving Soil Concentrations for Ground Water Protection," "Fixed Parameter Three-Phase Partitioning Model;" WAC 173-340-747(5), "Deriving Soil Concentrations for Ground Water Protection," "Overview of Methods," "Variable Parameter Three-Phase Partitioning Model;" and WAC 173-340-747(6), "Deriving Soil Concentrations for Ground Water Protection," "Overview of Methods," "Four-Phase Partitioning Model;" to establish soil concentrations that will not cause contamination of groundwater at levels that exceed the groundwater cleanup levels. WAC 173-340-747(8), "Deriving Soil Concentrations for Ground Water Protection," "Alternative Fate and Transport Models," specifies the procedures and requirements for using fate and transport models other than those specified in WAC 173-340-747, subsections (4) through (6). This evaluation confirms the appropriateness of the fate and transport models for use in the existing 200-UW-1 OU focused feasibility study (FFS).

EVALUATION

The WAC 173-340-747(8) specifies the procedures and requirements for establishing soil concentrations through the use of fate and transport models other than those specified in WAC 173-340-747, subsections (4) through (6). Although the STOMP fate and transport models were not specifically used to develop soil concentrations, they were used to determine whether the concentrations in soil cause contamination of groundwater at levels that exceed the groundwater cleanup levels. The specific assumptions discussed in WAC 173-340-747(8)(b), based on the criteria identified in subsection (8)(c), will be addressed individually in the following discussions.

WAC 173-340-747(8)(b)(i), "Sorption"

WAC Assumption. Sorption values shall be derived in accordance with either subsection (4)(c) of this section or the methods specified in subsection (5)(b) of this section.

Evaluation. Subsection (5)(b) includes methods of deriving K_d values from site data, batch tests, and the scientific literature and represents the best information currently available. K_d values in this case were derived from the scientific literature, which includes many studies performed at the Hanford Site (see PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*). K_d values used in the fate and transport models (developed using STOMP) are presented in PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, and CLARC 3.1 tables (Ecology 94-145, *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation*). The specific values and associated citations are identified in Appendix D, Table D-2, of the FFS.

Result. The WAC criteria have been met. Estimates of K_d values are derived from values available in the Hanford Site literature, much of which includes Site data, results of batch tests, and other methods of measuring contaminant mobility.

WAC 173-340-747(8)(b)(ii), "Vapor Phase Partitioning"

WAC Assumption. If Henry's law constant is used to establish vapor phase partitioning, then the constant shall be derived in accordance with subsection (4)(d) of this section.

Evaluation. Not applicable. No waste sites included contaminants subject to vapor phase partitioning or transport.

Result. Not applicable.

WAC 173-340-747(8)(b)(iii), "Natural Biodegradation"

WAC Assumption. Rates of natural biodegradation shall be derived from site-specific measurements.

Evaluation. Not applicable. No waste sites included contaminants subject to biodegradation.

Results. Not applicable.

WAC 173-340-747(8)(b)(iv), "Dispersion"

WAC Assumption. Estimates of dispersion shall be derived from either site-specific measurements or literature values.

Evaluation. The 200-UW-1 OU models developed with STOMP used the estimates of dispersion contained in SAND98-2880, *Stochastic Parameter Development for PORFLOW Simulations of the Hanford AX Tank Farm*. The dispersion coefficient used for each soil type is listed in Appendix D, Table D-1. SAND98-2880 also served as the basis for the dispersion estimates in PNNL-11800 and the later PNNL-14702, *Vadose Zone Hydrogeology Data Package for the 2004 Composite Analysis*. The use of the estimates of dispersion in SAND98-2880 by the composite analysis indicates that these estimates are applicable to soil types located throughout the Hanford Site.

Result. WAC criteria have been met. Estimates of dispersion are derived from values available in the Hanford Site literature.

WAC 173-340-747(8)(b)(v) "Decaying Source"

WAC Assumption. Fate and transport algorithms may be used that account for decay over time.

Evaluation. The fate and transport algorithms included radioactive decay when appropriate. WHC-EP-0063-3, 1991, *Hanford Site Solid Waste Acceptance Criteria*, includes values of radioactive half-life for the radioisotopes.

Results. The WAC criteria have been met. The fate and transport models include radioactive decay in accordance with the requirements.

WAC 173-340-747(8)(b)(vi), "Dilution"

WAC Assumption. Dilution shall be based on site-specific measurements or estimated using a model incorporating site-specific characteristics. If detectable concentrations of hazardous substances are present in upgradient ground water, then the dilution factor may need to be adjusted downward in proportion to the background (upgradient) concentration.

Evaluation. The fate and transport models incorporated site-specific data to develop hydraulic parameters for the vadose zone and aquifer, where dilution occurs. References for those parameters are provided in Appendix D, Table D-1, of the FFS. Output of the fate and transport STOMP models included groundwater concentrations (which included the effects of dilution) of the contaminants of potential concern at the edge of the waste sites. No adjustments to the dilution occurring within the model are made. The analysis is limited to evaluating the individual contribution from each waste site; no upgradient sources of contamination or existing contamination in the aquifer are included in the analysis. This methodology is consistent with the Proposed Plan remedial action objectives (per agreement with the regulators [Proposed Plan meeting, September 23, 2004, with representatives of both the Environmental Protection Agency and Washington Department of Ecology in attendance). Cumulative effects of multiple waste sites are evaluated as part of the Hanford Sitewide Assessments (System Assessment Capability [SAC]). See Section 2.9 of the FFS for additional information regarding the SAC.

Result. The WAC criteria have been met. Dilution is based on output from the fate and transport model, which included site-specific measurements of hydraulic properties.

WAC 173-340-747(8)(b)(vii), "Infiltration"

WAC Assumption. Infiltration shall be derived in accordance with subsection (5)(f)(ii)(A) or (B) of this section.

Evaluation. Subsection (5)(f)(ii)(B) states that the site-specific measurement or estimate of infiltration shall be based on site conditions without surface caps (e.g., pavement) or other structures that would control or impede infiltration. The estimate used in the fate and transport

assumes no surface barrier or control. The infiltration estimate is based on the Hanford Site average annual precipitation of 16 cm and an evapotranspiration rate of 91 percent (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). The evapotranspiration rate is a regulatory, agreed-on estimate for disturbed but stabilized surfaces (DOE/RL-99-40, *Focused Feasibility Study for the 300-FF-2 Operable Unit*). Infiltration that reaches the water table is referred to as recharge, and recharge is the parameter input to the model STOMP. The resulting recharge rate (1.44 cm/year) represents the long-term annual average recharge to the water table that incorporates both yearly and seasonal variations in precipitation and evapotranspiration.

Results. The WAC criteria have been met. Estimates of infiltration are derived from Hanford Site data and a regulatory, agreed-on evapotranspiration rate.

CONCLUSIONS

The criteria specified in WAC 173-340-747(8) have been met. The criteria specify the procedures and requirements for using fate and transport models (other than those specified in subsections (4) through (6)) to establish soil concentrations that will not cause contamination of groundwater at levels that exceed the groundwater cleanup levels. Based on the evaluation and results of each of the seven assumptions identified in WAC 173-340-747(8)(b), and the considerations of the evaluation criteria identified in WAC 173-340-747(8)(c), the conclusion is that the models developed using STOMP code and their application within the 200-UW-1 OU are appropriate and meet the requirements as set forth in WAC 173-340-747(8).

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APPENDIX E

RISK ASSESSMENT FOR AN INADVERTENT INTRUDER SCENARIO

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TERMS

EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
FFS	focused feasibility study
HAB	Hanford Advisory Board
ILAW	immobilized low-activity waste
RESRAD	RESidual RADioactivity (code)
TD	total depth (to borehole)

APPENDIX E

RISK ASSESSMENT FOR AN INADVERTENT INTRUDER SCENARIO

E1.0 INTRODUCTION

This appendix presents an analysis of three intruder scenarios that are being evaluated for the 200-UW-1 Operable Unit focused feasibility study (FFS) and describes how the scenarios will be assessed in the FFS. These scenarios are provided based on the framework documented in Hanford Advisory Board (HAB) Advice #132, "Exposure Scenarios Task Force on the 200 Area" (HAB 132) and is provided for information only. Inadvertent intruder scenarios are based on the possibility that an individual unwittingly (through human error or loss of knowledge concerning the location of contaminants) engages in an activity that results in contact with waste left in place (10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste"). The reasonably anticipated future land use for the 200 Areas is continued industrial activities based on DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* and the associated record of decision (64 FR 61615, "Hanford Comprehensive Land-Use Plan Environmental Impact Statement, Hanford Site, Richland, Washington; Record of Decision (ROD)"). For locations in the industrial area, such as the U Plant Area, the U.S. Department of Energy dose rate limits for the protection of workers and the affected public will be in effect for as long as facility management operations continue. After a period of 50 years, it is assumed that all operations will have ceased and public entry to the area will be restricted for an additional 100 years by enforcement of institutional controls.

After the cessation of operations, protection of human receptors would be based on U.S. Environmental Protection Agency (EPA) guidance for protection of individuals receiving a reasonable maximum exposure. The goal is to achieve a 10^{-4} to 10^{-6} risk range using a direct exposure dose rate of 15 mrem/year above background as an operational guideline to achieve this goal.

For purposes of evaluating risk, it is presumed that after 150 years an intruder could obtain access to the area, although institutional controls would remain in place. Of the three intruder scenarios proposed for evaluation, the third is considered the worst case scenario because it would have the longest exposure time. If a site had a total dose below the 15 mrem/year direct exposure limit, no further analysis was performed. The proposed intruder scenarios are as follows:

1. Future Construction Trench Worker Intruder Scenario
2. Future Well Driller Intruder Scenario (drill cuttings)
3. Future Rural Residential Intruder Scenario (drill cuttings).

In addition to the intruder scenarios and the baseline evaluations of industrial and groundwater protection scenarios (Appendix C), a hypothetical Native American scenario is evaluated in the FFS. This hypothetical Native American scenario is intended to take into account the

cultural and life-style differences of tribal activities under baseline conditions. This evaluation is presented in Appendix C.

The future rural residential intruder scenario was evaluated for the following four representative waste sites. Of these sites, only the 216-U-12 Crib showed a total dose rate below the direct exposure limit of 15 mrem/year and was not analyzed further.

- 216-U-4 Reverse Well and 216-U-4A French Drain
- 216-U-8 Crib
- 216-U-12 Crib
- UPR-200-W-19 unplanned release (encompasses the area around the 216-U-1 and 216-U-2 Cribs).

These waste sites were evaluated for an exposure time starting at 150 years in the future, when it is postulated that institutional controls will have failed. Areas that have been capped prevent access to materials within 4.6 m (15 ft) below the bottom of the engineered surface barrier. Because construction trenching is expected to be limited to a 4.6 m (15-ft) maximum depth, only exposure scenarios involving well drilling would need to consider encountering residual waste.

E1.1 FUTURE CONSTRUCTION TRENCH WORKER INTRUDER SCENARIO

Contact with contaminants by inadvertently excavating a utilities trench or other construction activity (including the excavation of a basement or building foundation) through a waste site defines a reasonable maximum exposure event that could result in acute exposure to a future worker.

The worker at the trench construction site is assumed to be exposed 8 hours a day for 5 days. The dose to the worker is the sum of the contributions from inhaling resuspended dust, inadvertently ingesting soil, and direct exposure at the center of a 200 m^2 (2,153-ft^2) area of contaminated soil for 40 hours. It is anticipated that this scenario is bounded by the future rural residential intruder scenario because excavation equipment would be used, which would reduce direct exposure, and because of the limited amount of time present at the site during construction of the trench.

E1.2 FUTURE WELL DRILLER INTRUDER SCENARIO

This exposure scenario estimates risk and dose associated with inadvertently drilling a well at a waste site. The drill cuttings (i.e., uncontaminated and contaminated soil) are assumed to have been spread over the work area near the well. Based on the evaluations for DOE/ORP-2000-24, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version,* (immobilized low-activity waste [ILAW] performance assessment) and BHI-00169, *Environmental*

Restoration Disposal Facility Performance Assessment (Environmental Restoration Disposal Facility performance assessment), the diameter of the well for this evaluation is assumed to be 0.3 m (1 ft). Although consistent with the diameters used in Hanford Site performance assessments, this diameter is larger than the range of well diameters commonly found in local communities (10.2 cm to 25.4 cm [4 to 10 in.]). Use of this well diameter may overestimate the dose associated with this exposure scenario. The area on which the driller spreads the cuttings is assumed to be 200 m^2 (2,153 ft^2), a size historically used in Hanford Site performance assessments.

The worker at the well drilling site is assumed to be exposed 8 hours a day for 5 days. The dose to the worker is the sum of the contributions from inhaling resuspended dust, inadvertently ingesting soil, and direct exposure at the center of a 200 m^2 (2,153-ft^2) area of contaminated soil for 40 hours.

E1.3 FUTURE RURAL RESIDENTIAL INTRUDER SCENARIO

This scenario assumes that a receptor is residing within the area and has planted a garden using the drill cuttings taken from a well drilled through the waste site, as discussed earlier in the well driller scenario. The resident receives dose from direct exposure to the radiation field in the garden, inhales resuspended dust, ingests soil at the same rates as the well driller, and consumes garden produce grown in the contaminated soil.[1] The resident is assumed to spread the waste over a garden 200 m^2 (2,153 ft^2) in area and to a depth of 15 cm (6 in.). The garden area was taken from the ILAW performance assessment (DOE/ORP-2000-24) because the size represents an area large enough to supply a significant portion of a person's vegetable and fruit diet, yet small enough to produce a higher (more conservative) estimation of dose.

The resident is assumed to spend 20 percent of the time in the garden, 60 percent of the time indoors exposed to dust from the garden, and 20 percent of the time off site for a period of 30 years. The predicted dose depends on the area of the resident's garden and the amount of time the resident spends in the garden. The radionuclide concentration in the soil and, consequently, the dose rate is inversely proportional to the size of the garden, which implies that a smaller garden will produce a larger dose. However, where direct doses dominate, a smaller garden area (i.e., 200 m^2 [2,153 ft^2]) produces only a moderate increase in total dose.

E2.0 CONCEPTUAL SITE MODELS

Exposure-point concentrations (EPC) for each intruder scenario calculated from the baseline EPCs are presented in Table E-1 for the four representative waste sites. The calculations

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[1] Consumption of groundwater is not included in this evaluation because groundwater in this area currently is under remediation and is not available for use. This scenario is consistent with other inadvertent intruder evaluations conducted for the Central Plateau.

conservatively assume a worst case in which the entire mass of drill cuttings from each well contains the baseline EPCs of radionuclides. The EPCs for each scenario are based on the following dilution factors:

- The EPCs for the rural residential intruder are based on dilution of the drill cuttings by being spread over the garden and mixed with soil as described in Section E1.3.
- The EPCs for the construction trench worker are based on dilution of the contaminated volume of the trench (i.e., from the longest dimension of the waste site) by the volume of material from the entire trench.
- The EPCs for the well driller are based on dilution of the contaminated drill cuttings (i.e., borehole through waste site) by the total volume of drill cuttings that could be reasonably expected in a 40-hour period. This analysis assumes only one borehole is excavated through a given waste site.

Figures E-1 through E-3 represent the conceptual site models for the exposure scenarios. As shown, both the rural residential and well driller intruder scenarios assume that a well is drilled to groundwater through the engineered surface barrier of a given site. The contaminated drill cuttings are brought to the surface and intermixed with soils adjacent to the barrier.

E3.0 RISK ASSESSMENT METHODOLOGY

E3.1 EVALUATION OF POTENTIAL HUMAN HEALTH RISK

Human health risk resulting from radionuclide contaminants of potential concern at the 200-UW-1 Operable Unit was evaluated using the RESidual RADioactivity (RESRAD) computer model. The RESRAD code was developed by Argonne National Laboratory (*RESRAD for Windows* [ANL 2002]) to implement U.S. Department of Energy guidelines for allowable residual radioactive material in soil (DOE Order 5400.5, *Radiation Protection of the Public and the Environment*). The code was evaluated by the EPA for use in performing dose assessments to support the EPA guidance limit for radiation dose from contaminated sites to 15 mrem/year above background (*Establishment of Cleanup Levels for CERCLA with Radioactive Contamination*, OSWER No. 9200.4-18 [EPA 1997]). The RESRAD determinations include calculating the total excess cancer risk for radionuclides using the *Health Effects Assessment Summary Tables* database (EPA 2001) (updated April 16, 2001, "Update of Radionuclide Carcinogenicity Slope Factors," available on the Internet at www.epa.gov/radiation/heast).

E3.2 RESRAD CALCULATION METHODOLOGY

RESRAD is a pathway analysis code that calculates radiation doses to a hypothetical individual living on a contaminated site. ANL/EAD-4, *User's Manual for RESRAD Version 6*, provides information on the design and application of the RESRAD code. It describes the basic models and parameters used in the RESRAD code to calculate dose and risk from residual radioactive materials and the procedures for applying these models to calculate operational guidelines for remediation of soil contamination.

Exposure pathways were evaluated by RESRAD using a rural residential intruder scenario including annual irrigation of 0.76 m (30 in.) per year and 0 m/year for the construction trench worker and well driller scenarios. The exposure pathway evaluations include exposure via inhalation, inadvertent soil ingestion, external gamma radiation, and exposure from water-dependent pathways (e.g., ingestion of plants, meat, milk). The selected exposure pathways are consistent with the recommendations provided by ANL/EAD-4, except for the radon gas exposure pathway. Exposure to radon gas is not a pathway because the scenario lacks enclosed areas that may capture significant amounts of radon. However, the occurrence of radon gas as a daughter product from decay of thorium and uranium isotopes is evaluated by RESRAD.

To use the RESRAD model, appropriate input parameters must be available. Although the RESRAD model provides default values, site-specific input parameters normally are used to obtain representative results. The site-specific and default input parameters used in this evaluation are consistent with those used in preparing the baseline risk assessment presented in Appendix C of this FFS report. Table E-2 summarizes dimension and volume inputs used to calculate intruder EPCs.

E3.3 DOSE AND RISK INTRUDER

Direct Exposure to Radionuclides

The parameters of the exposure pathways described in Appendix C were used with the RESRAD model to evaluate the dose and risk resulting from activities (i.e., concentrations) of individual radionuclides at the 200-UW-1 Operable Unit for each intruder scenario. The intruder RESRAD calculation runs analyze times of 1, 3, 10, 30, 100, 300, and 1,000 years. All exposure point concentrations used in the calculations were adjusted to account for radioactive decay over a period of 150 years.

Excess cancer risks achieve threshold levels 300 years from now (because time 0 of the calculations is 150 years from now) for all the radionuclides evaluated for the representative sites (Table E-1). Table E-3 summarizes the RESRAD input parameters used in each intruder scenario. Table E-4 summarizes the "All Radionuclides, All Pathways" dose and risk estimates for each representative waste site. Dose and risk also are presented graphically for the representative waste sites (Figures E-4 through E-23).

E4.0 CONCLUSIONS

A high uncertainty exists in these risk determinations (i.e., overestimation) because the numerical values are based on the representative sites considered to be at a higher concentration than the other 200-UW-1 Operable Unit waste sites and exposure pathways are incomplete while institutional controls remain in place. The results of the analysis for each intruder scenario are as follows.

- The construction trench worker scenario shows dose and risk values for each waste site to be below regulatory guidelines (15 mrem/year above the background dose and 10^{-4} to 10^{-6} risk) in 150 years (i.e., year 0), when the intruder scenario is assumed to begin. This scenario is most consistent with the anticipated future land use.

- The well driller scenario shows dose and risk values for the 216-U-4 Reverse Well and the 216-U-4A French Drain and 216-U-12 Crib to be below regulatory guidelines (15 mrem/year above the background dose and 10^{-4} to 10^{-6} risk) in 150 years (i.e., year 0), when the intruder scenario is assumed to begin. The dose at the 216-U-8 Crib and the 216-U-1&2 Pump-and-Treat System is 800 and 1,000 mrem/year at a time 150 years from now (time 0 of the calculations). Dose and risk for the 216-U-8 Crib and 216-U-1&2 waste sites do not fall below regulatory guidelines until 235 and 310 years, respectively, from the date of this FFS.

- The rural residential scenario shows dose and risk values for the 216-U-12 Crib to be below regulatory guidelines (15 mrem/year above the background dose and 10^{-4} to 10^{-6} risk) in 150 years (i.e., year 0), when the intruder scenario is assumed to begin. However, dose and risk for the 216-U-4 Reverse Well, 216-U-4A French Drain, 216-U-8 Crib, and 216-U-1&2 Pump-and-Treat System sites do not fall below regulatory guidelines until 160, 400, and 410 years, respectively, from the date of this FFS.

E5.0 REFERENCES

10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, as amended.

64 FR 61615, "Hanford Comprehensive Land-Use Plan Environmental Impact Statement, Hanford Site, Richland, Washington; Record of Decision (ROD)," *Federal Register*, Vol. 64, No. 218, pp. 61615ff, November 12, 1999.

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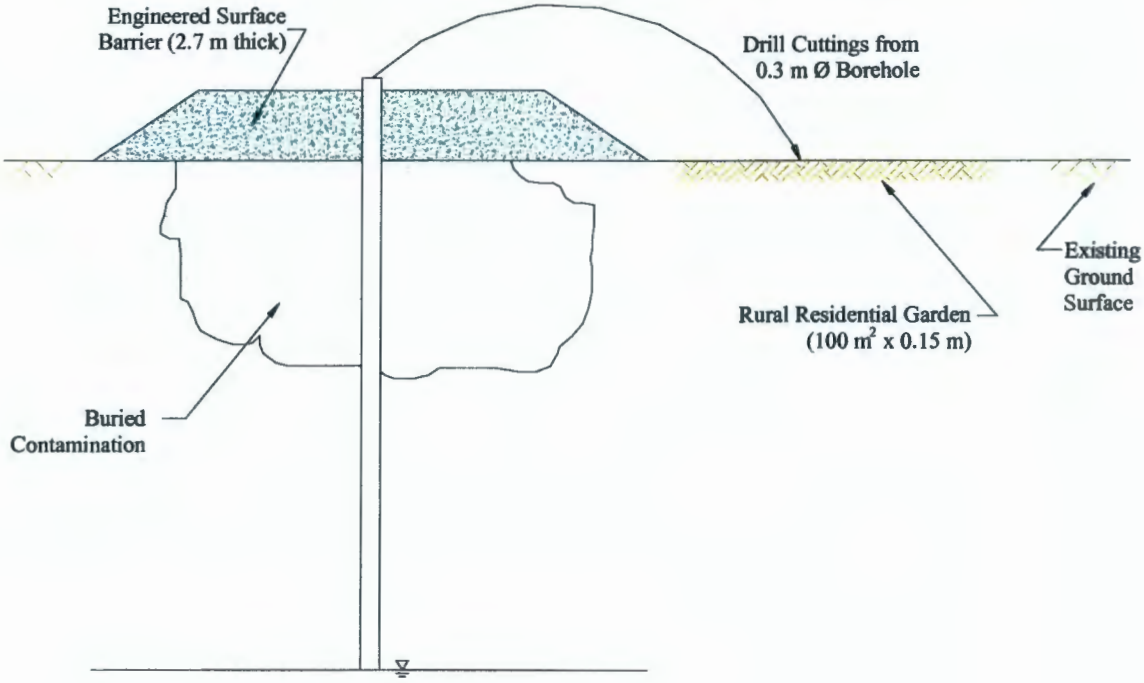
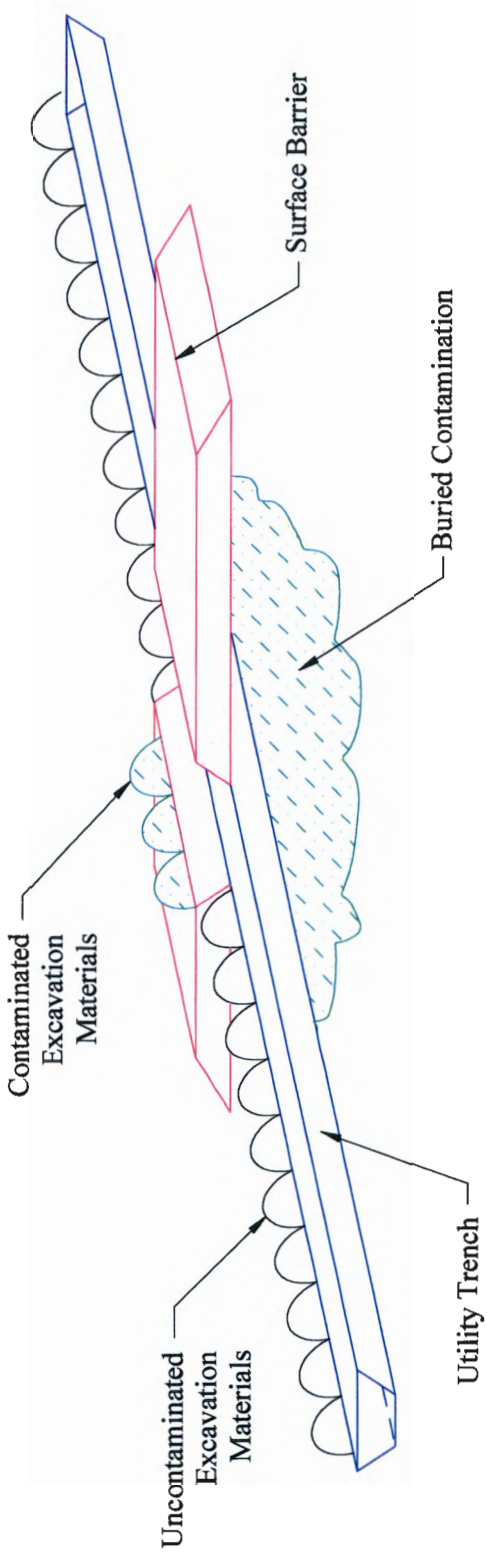
Nichols, Jr., H. L., 1976, *Moving the Earth: The Workbook of Excavation*, McGraw Hill, Third Edition, New York, New York.

Figure E-1. Conceptual Site Model for the Rural Residential Intruder Scenario.



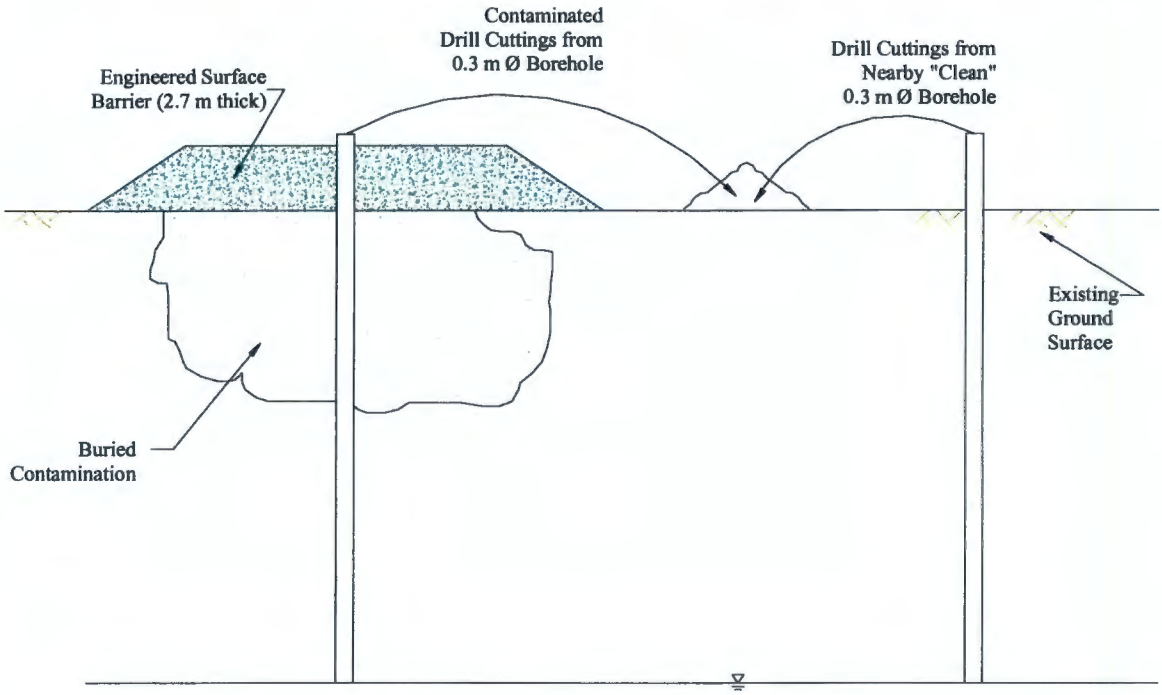
NOT TO SCALE

Figure E-2. Conceptual Site Model for the Construction Trench Worker Intruder Scenario.



NOT TO SCALE

Figure E-3. Conceptual Site Model for the Well Driller Intruder Scenario.



NOT TO SCALE

Figure E-4. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Rural Residential Intruder Scenario).

(Dose in year 0, which represents 150 years in the future, is 1.69 E+01 mrem/year.)
NOTE: Dose will be below 15 mrem/year in approximately year 10 (i.e., 160 years after date of FFS).

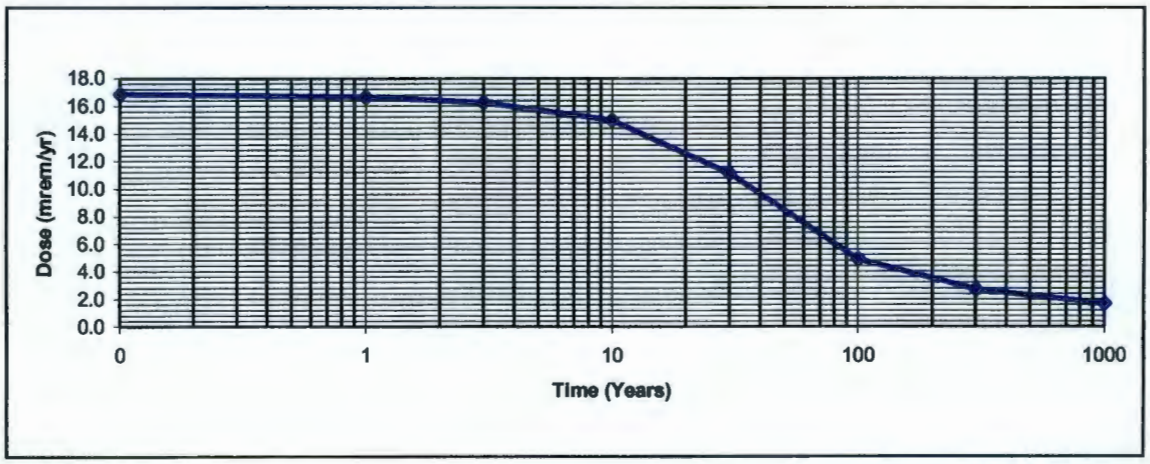


Figure E-5. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Rural Residential Intruder Scenario).

(Risk in year 0, which represents 150 years in the future, is 2.90 E-04.)

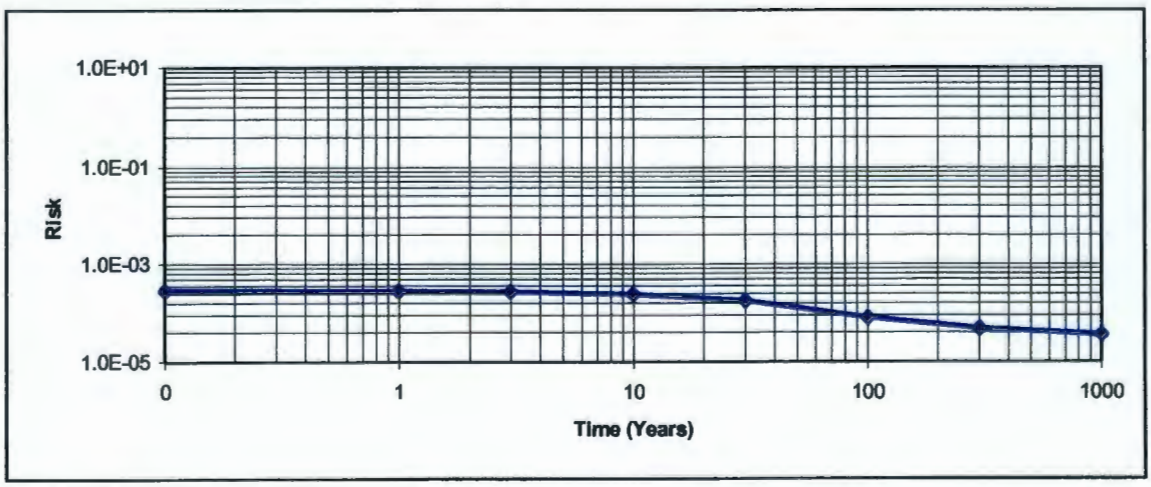


Figure E-6. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Dose Estimate (No Cover, Direct Contact, Rural Residential Intruder Scenario).

(Dose in year 0, which represents 150 years in the future, is 8.28 E+02 mrem/year.)
NOTE: Dose will be below 15 mrem/yr in approximately year 250 (i.e., 400 years after date of FFS).

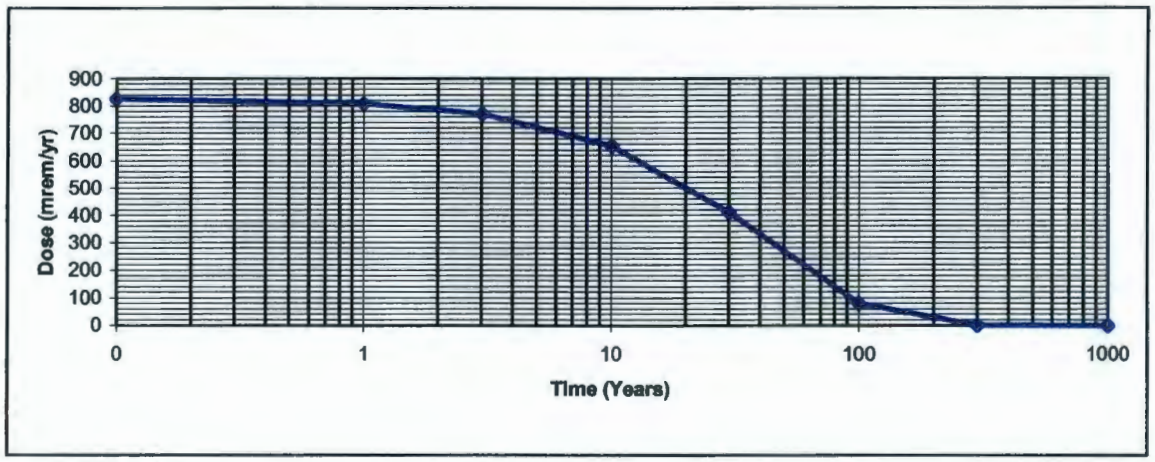


Figure E-7. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Risk Estimate (No Cover, Direct Contact, Rural Residential Intruder Scenario).

(Risk in year 0, which represents 150 years in the future, is 2.65 E-02.)

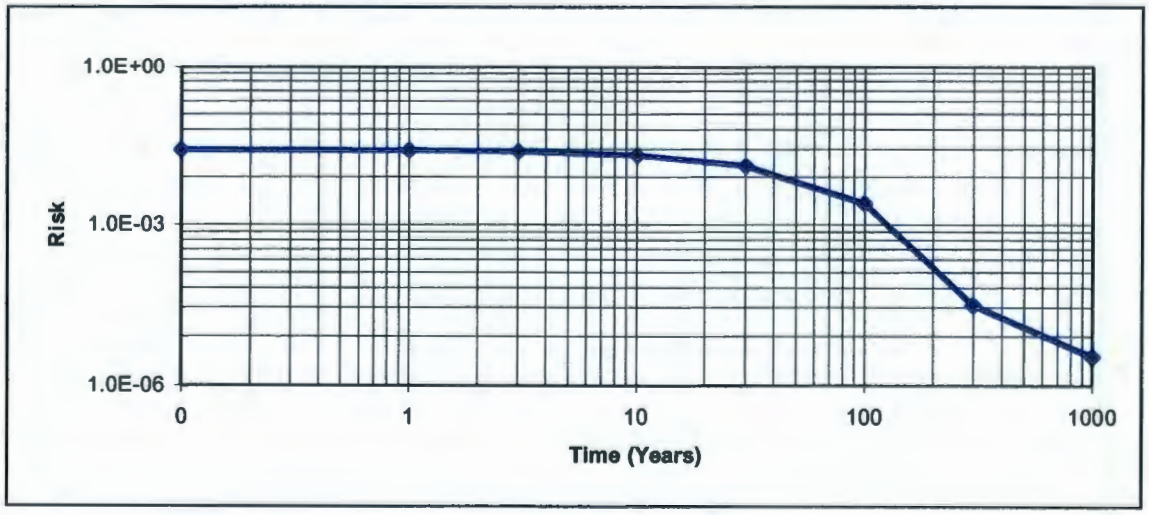


Figure E-8. RESRAD Analysis for the 216-U-12 Crib, All Radionuclides, All Pathways Dose Estimate (No Cover, Direct Contact, Rural Residential Intruder Scenario).

(Dose in year 0, which represents 150 years in the future, is 1.08 E-02 mrem/year.)

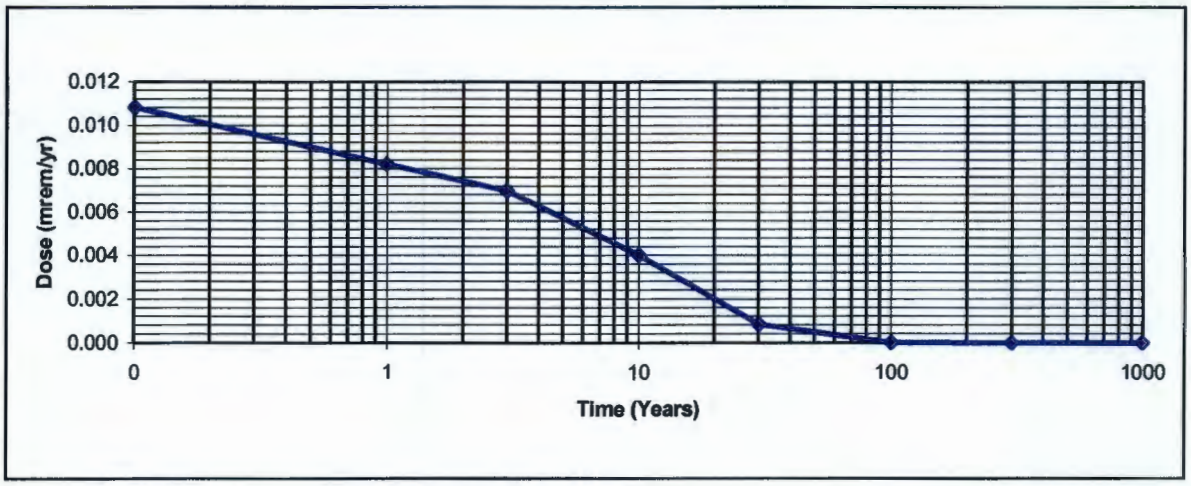


Figure E-9. RESRAD Analysis for the 216-U-12 Crib All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Rural Residential Intruder Scenario).

(Risk in year 0, which represents 150 years in the future, is 8.41 E-08.)

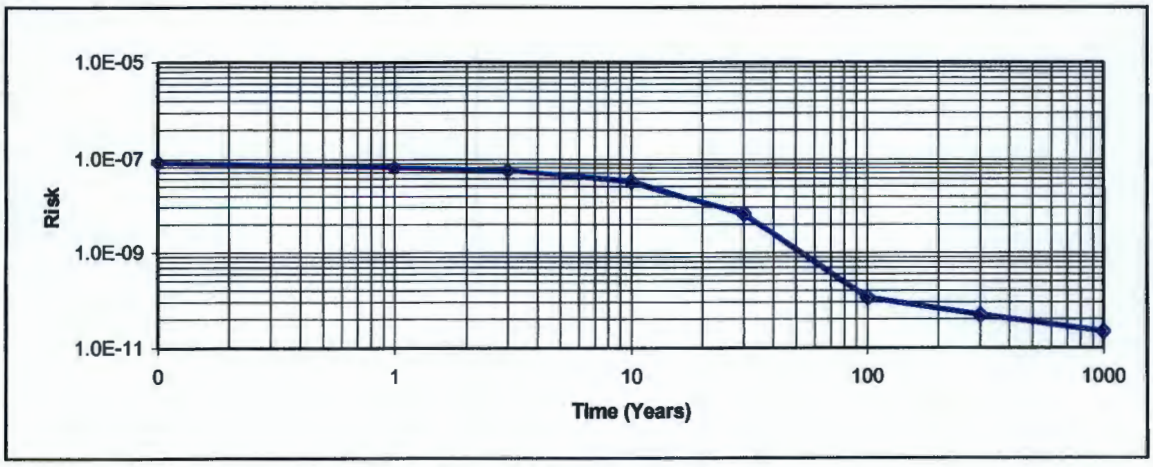


Figure E-10. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Rural Residential Intruder Scenario).

(Dose in year 0, which represents 150 years in the future, is 1.01 E+03 mrem/year.)
NOTE: Dose will be below 15 mrem/yr in approximately year 260
(i.e., 410 years after date of FFS).

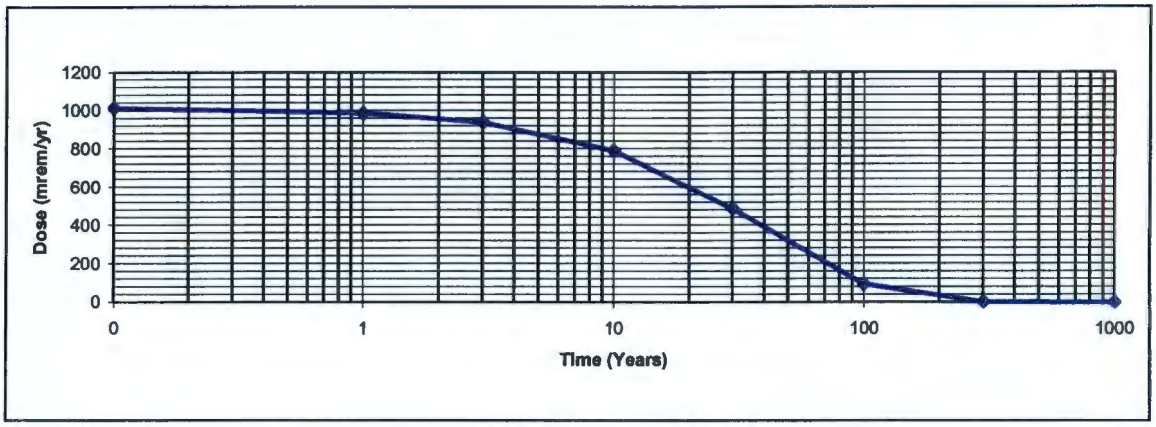


Figure E-11. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Rural Residential Intruder Scenario).

(Risk in year 0, which represents 150 years in the future, is 1.58 E-02.)

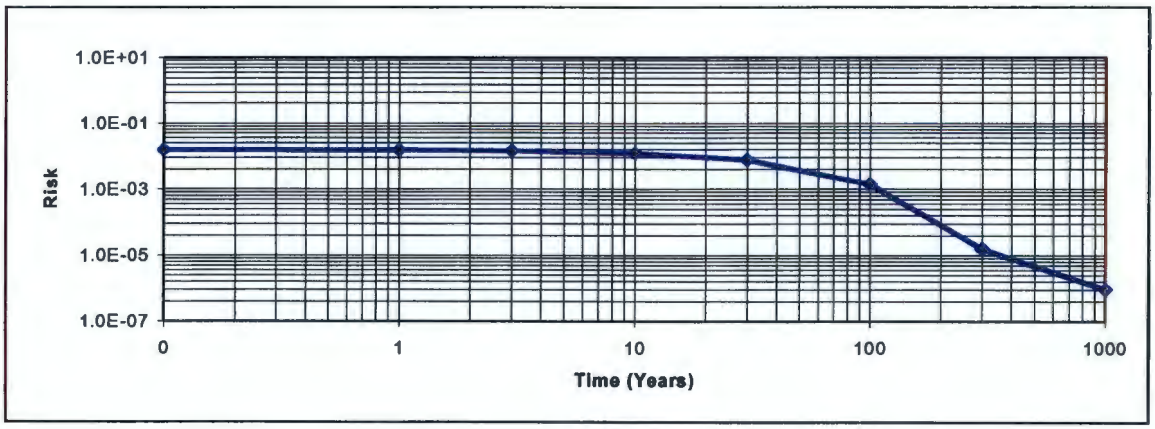


Figure E-12. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Construction Trench Worker).
(Dose in year 0, which represents 150 years in the future, is 5.63 E-02 mrem/year.)

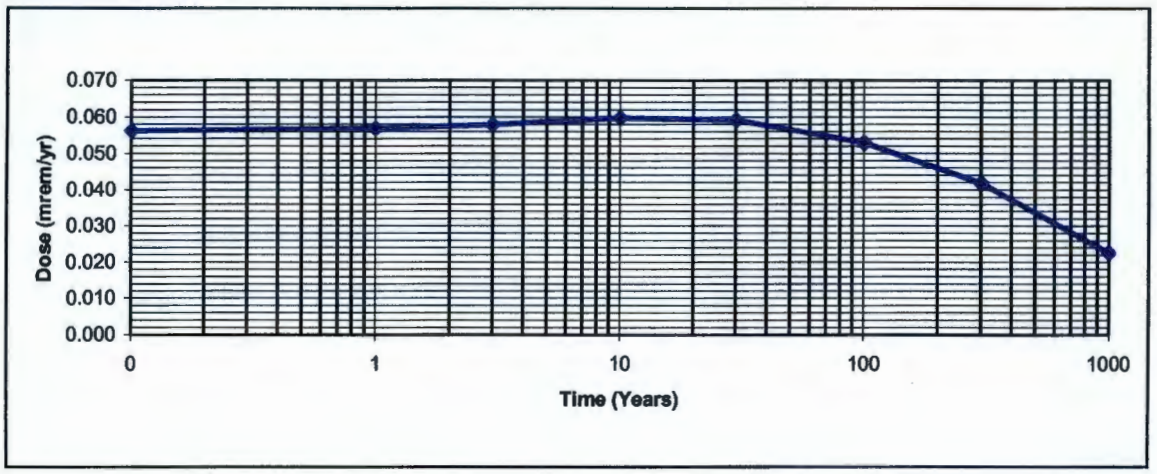


Figure E-13. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Construction Trench Worker).

(Risk in year 0, which represents 150 years in the future, is 4.02 E-07.)

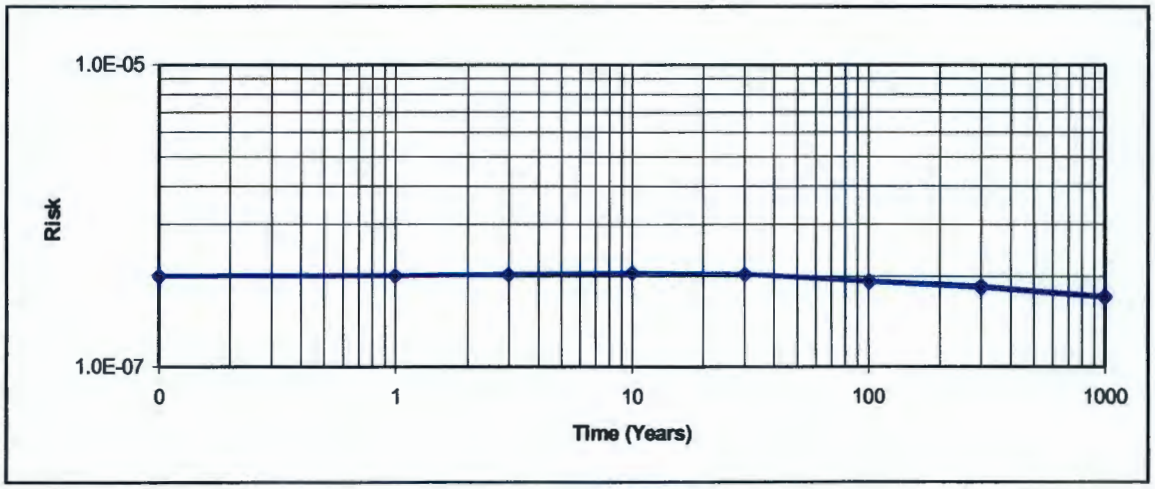


Figure E-14. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Construction Trench Worker).

(Dose in year 0, which represents 150 years in the future, is 5.47 E-01 mrem/year.)

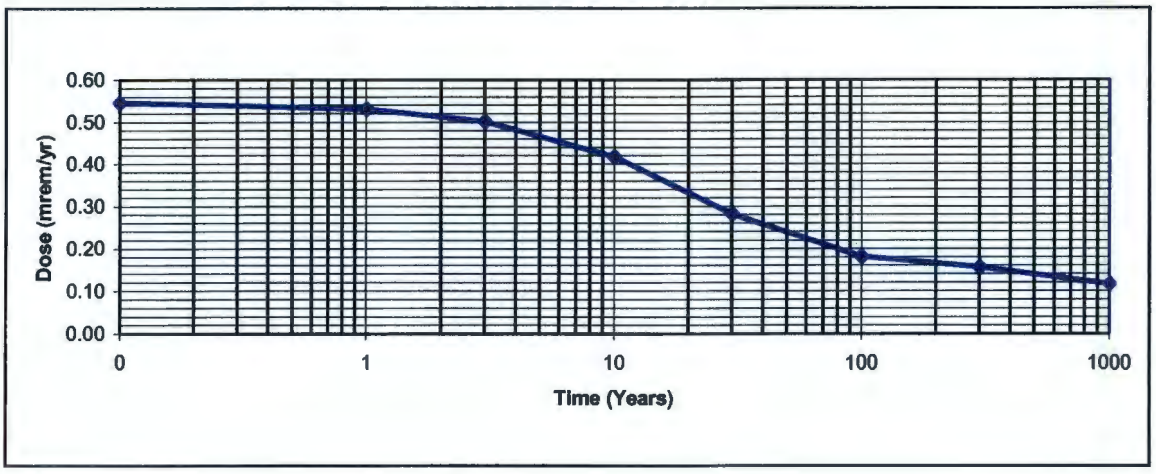


Figure E-15. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Construction Trench Worker).

(Risk in year 0, which represents 150 years in the future, is 3.88 E-03.)

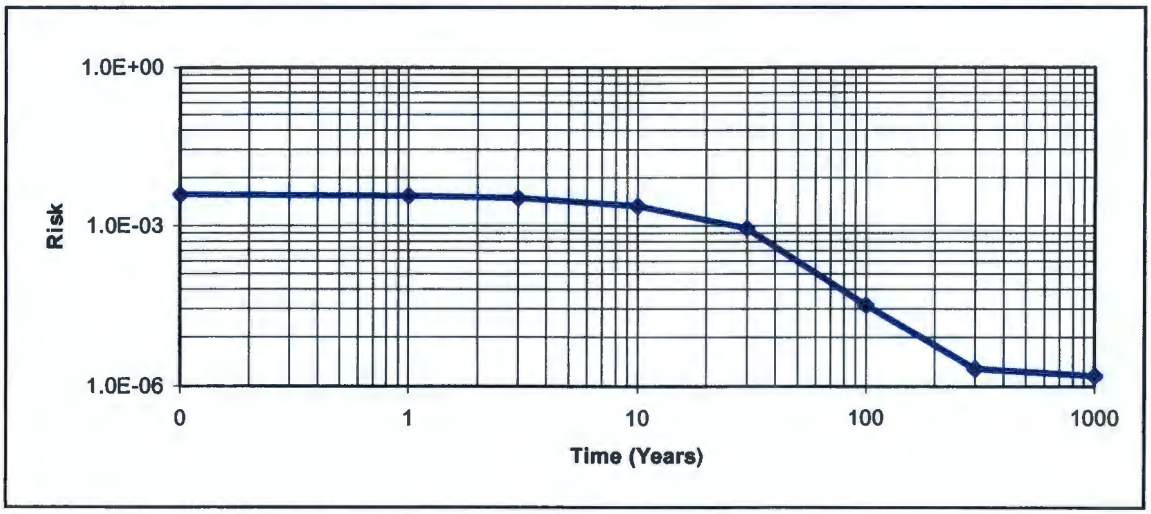


Figure E-16. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Construction Trench Worker).

(Dose in year 0, which represents 150 years in the future, is 2.84 E-02 mrem/year.)

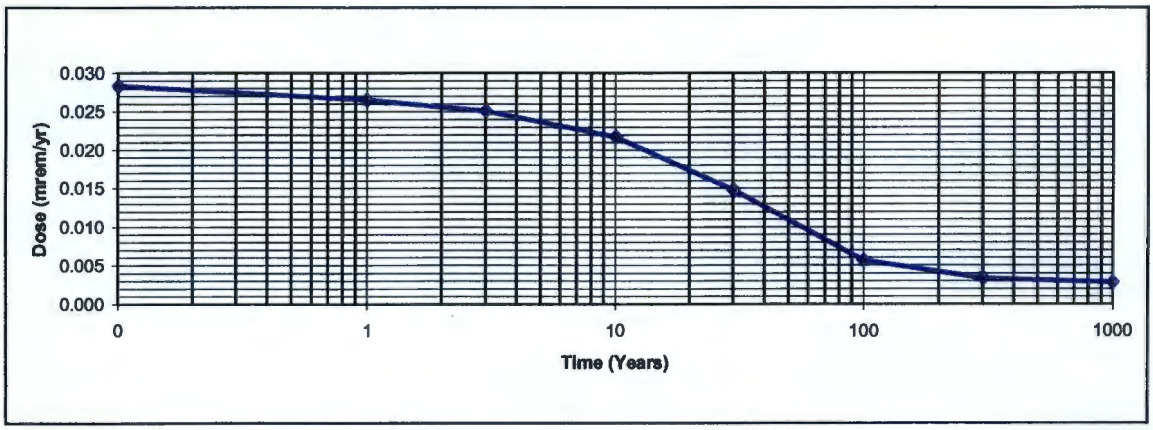


Figure E-17. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Construction Trench Worker).

(Risk in year 0, which represents 150 years in the future, is 3.45 E-07.)

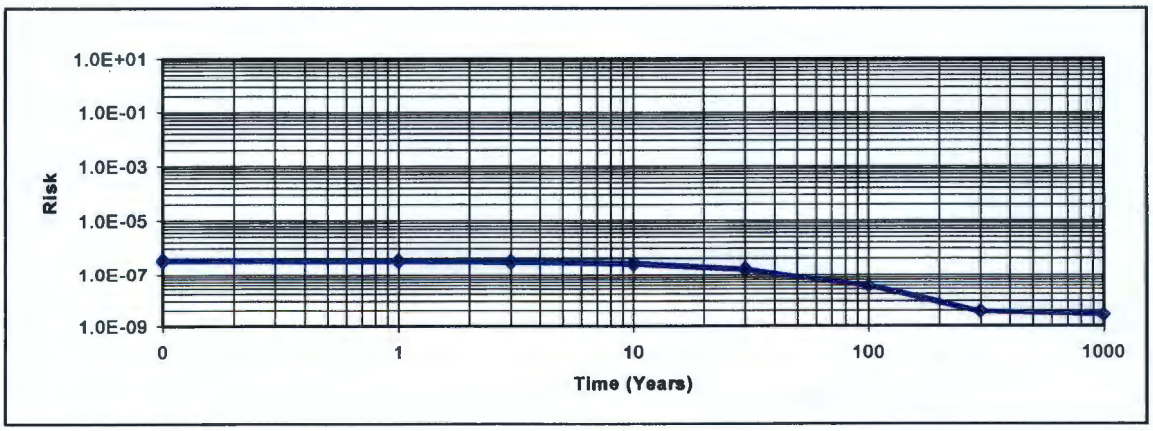


Figure E-18. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Well Driller).
(Dose in year 0, which represents 150 years in the future, is 8.67 E+00 mrem/year.)

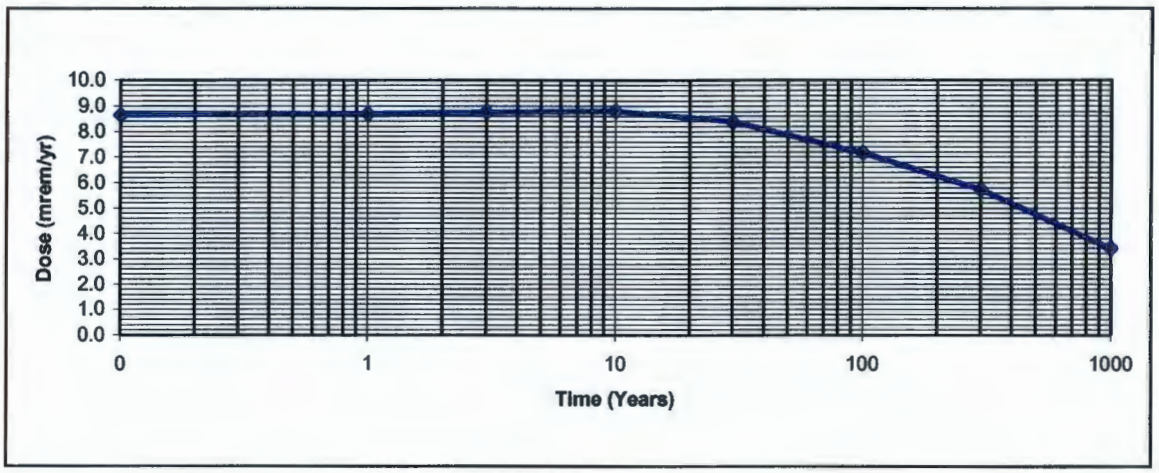


Figure E-19. RESRAD Analysis for the 216-U-4 Reverse Well and 216-U-4A French Drain All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Well Driller).

(Risk in year 0, which represents 150 years in the future, is 7.11 E-05.)

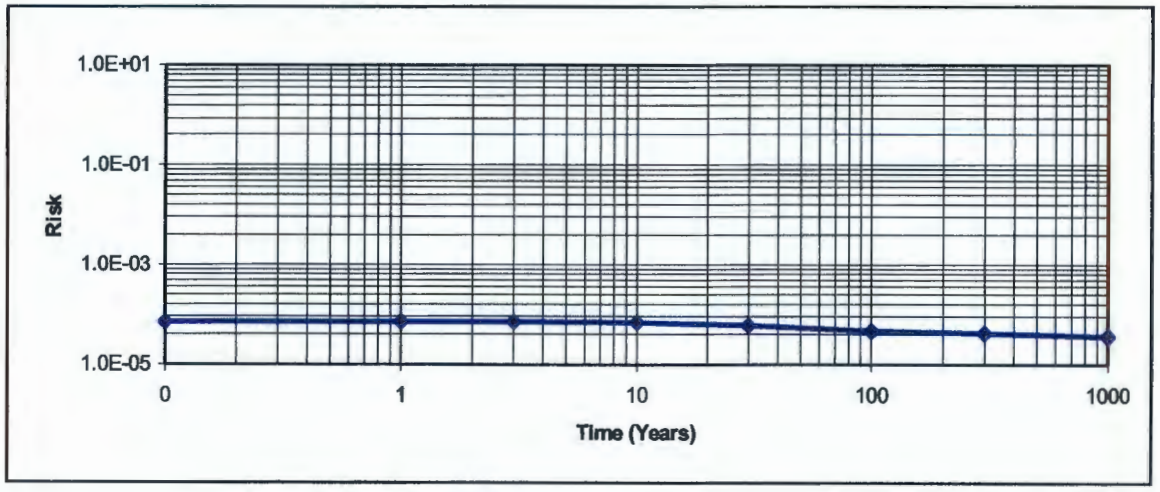


Figure E-20. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Well Driller).

(Dose in year 0, which represents 150 years in the future, is 8.67 E+01 mrem/year.)
NOTE: Dose will be below 15 mrem/year in approximately year 85 (i.e., 235 years after date of FFS).

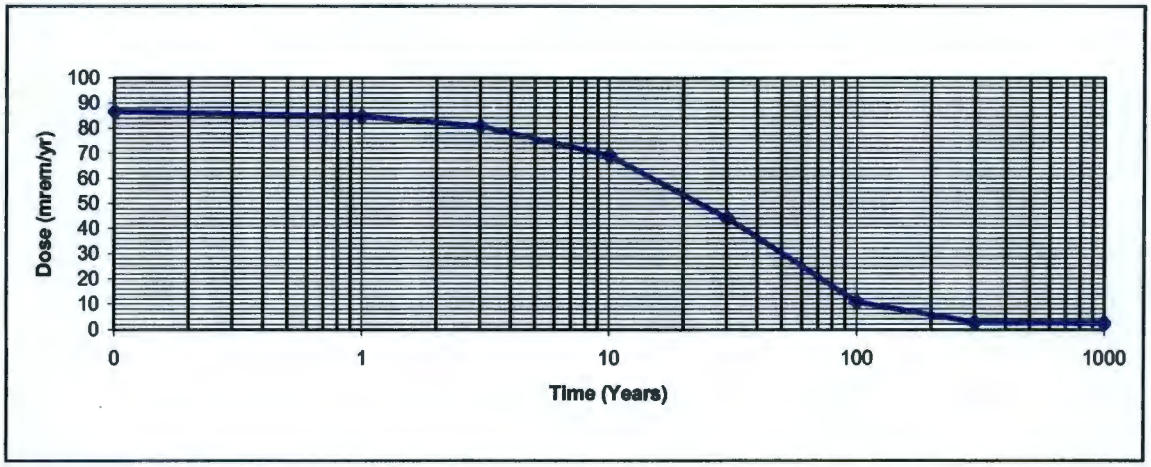


Figure E-21. RESRAD Analysis for the 216-U-8 Crib All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Well Driller).

(Risk in year 0, which represents 150 years in the future, is 1.43 E-03.)

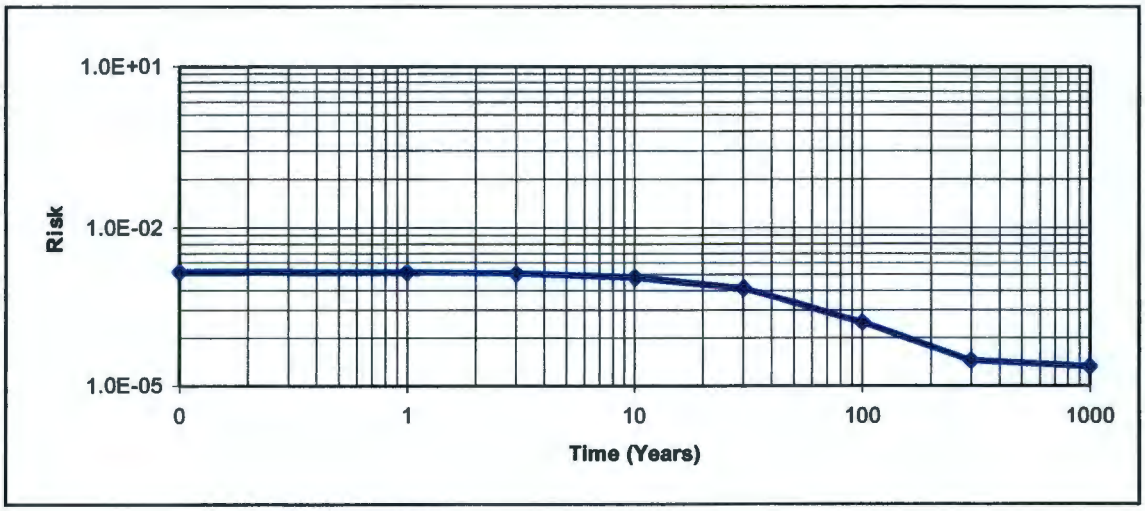


Figure E-22. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Dose Estimate (No Cover, Direct-Contact, Well Driller).

(Dose in year 0, which represents 150 years in the future, is 2.78 E+02 mrem/year.)
NOTE: Dose will be below 15 mrem/year in approximately year 160 (i.e., 310 years after date of FFS).

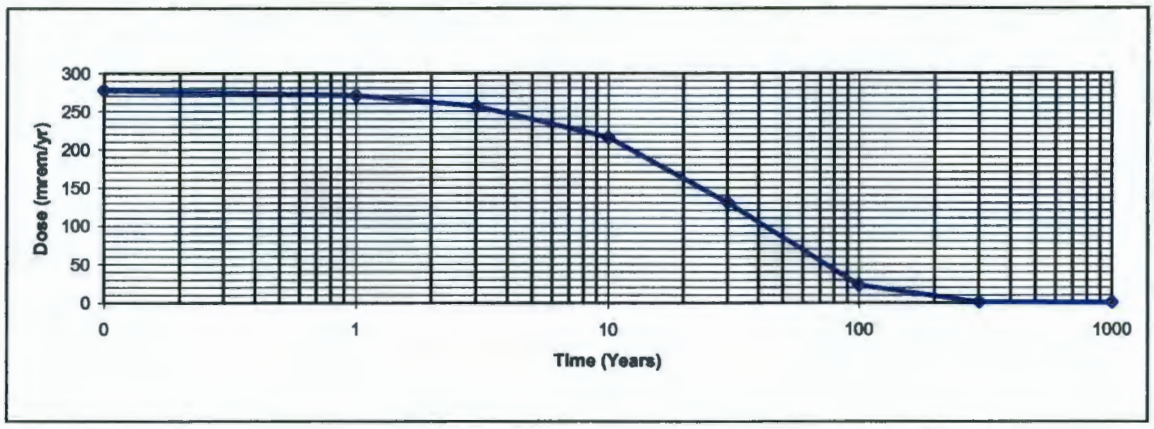


Figure E-23. RESRAD Analysis for the 216-U-1&2 Pump-and-Treat System (UPR-200-W-19) All Radionuclides, All Pathways Risk Estimate (No Cover, Direct-Contact, Well Driller).

(Risk in year 0, which represents 150 years in future, is 3.71 E-03.)

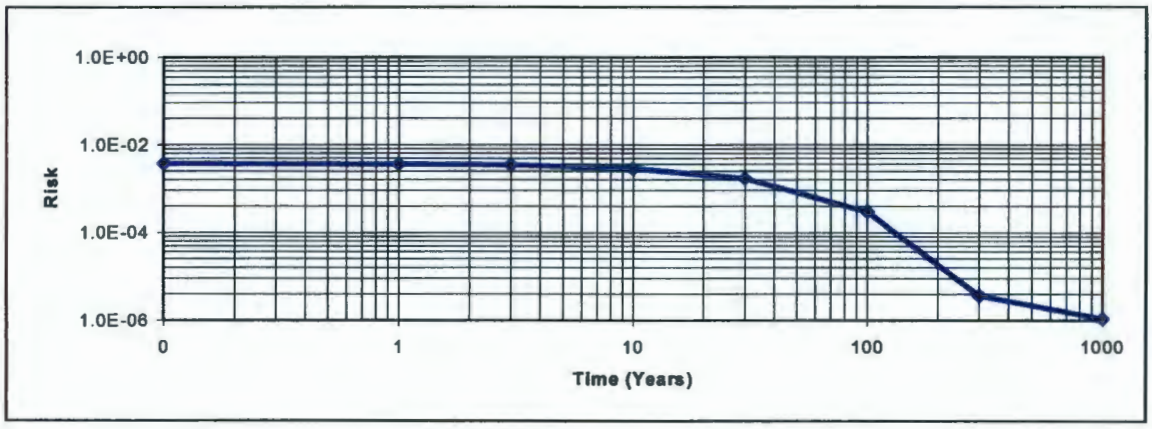


Table E-1. Baseline Exposure-Point Concentrations and Intruder Scenario Exposure-Point Concentrations for the Representative Waste Sites. (2 pages)

Constituent Name	Enter these values into RESRAD for appropriate scenario.									
	RURAL RESIDENTIAL – GARDEN Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)				CONSTRUCTION WORKER Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)			DRILLER Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)		
	$EPC_{Garden} = EPC_{Deep} \times V_{Borehole} / V_{Garden}$ (Occupancy = 60% inside, 20% in garden)				$EPC_{Const} = EPC_{Shallow} \times V_{Contaminated\ Trench} / V_{Total\ Trench}$ (Occupancy = 40 hours/year)			$EPC_{Driller} = EPC_{Deep} \times V_{Contaminated\ Borehole} / V_{Total\ All\ Boreholes}$ (Occupancy = 40 hours/year)		
	216-U-12[1]	216-U-4/4A	216-U-8	216-U-1&2	216-U-4/4A	216-U-8	216-U-1&2	216-U-4	216-U-8	216-U-1&2
Americium-241		2.23E+01	1.07E-01	3.63E-01	5.06E-01	4.70E-02	3.22E-02	6.08E+01	2.92E-01	9.92E-01
Cesium-134				9.07E-23						2.48E-22
Cesium-137		7.41E+00	4.30E+02	4.71E+02	3.56E-02	1.01E+00	4.77E-01	2.02E+01	1.17E+03	1.29E+03
Cobalt-60		2.57E-10	2.11E-10	1.29E-10	2.69E-12			7.02E-10	5.76E-10	3.51E-10
Curium-244		2.09E-05	3.70E-05	2.87E-05	4.71E-07			5.71E-05	1.01E-04	7.83E-05
Europium-152		3.22E-05	5.87E-06	3.31E-06	1.03E-06	2.87E-06	1.43E-06	8.79E-05	1.60E-05	9.04E-06
Europium-154		1.23E-07	1.02E-06	7.18E-07	5.66E-09			3.35E-07	2.78E-06	1.96E-06
Europium-155			3.20E-10			7.81E-13			8.74E-10	
Iodine-129										
Neptunium-237		1.23E-01	1.36E-02	4.06E-02	6.86E-04	1.40E-03	8.66E-03	3.35E-01	3.71E-02	1.11E-01
Plutonium-238		1.79E-02	3.46E-03	2.08E-02	5.10E-04	6.99E-04		4.90E-02	9.45E-03	5.68E-02
Plutonium-239/240		9.78E-01	7.31E-01	2.40E+01	1.99E-03	7.37E-02	1.91E-02	2.67E+00	2.00E+00	6.55E+01
Plutonium-239[2]		7.86E-01	5.88E-01	1.93E+01	1.60E-03	5.93E-02	1.53E-02	2.15E+00	1.61E+00	5.26E+01
Plutonium-240[2]		1.86E-01	1.39E-01	4.56E+00	3.79E-04	1.40E-02	3.62E-03	5.07E-01	3.79E-01	1.24E+01
Radium-226		1.22E-01	1.52E-01		2.79E-03	4.98E-02		3.35E-01	4.14E-01	
Radium-228		3.25E-09			7.40E-11			8.88E-09		
Selenium-79		4.63E-01	1.40E+00	1.33E+00		4.57E-01	1.79E-01	1.27E+00	3.82E+00	3.64E+00
Sodium-22		6.66E-21		1.07E-19				1.82E-20		2.92E-19
Strontium-90		2.86E-01	1.64E+00	5.01E+02	6.50E-03	6.45E-02	6.43E-02	7.81E-01	4.49E+00	1.37E+03
Technetium-99	7.09E-02	2.14E-01	3.72E+00	4.39E+00		1.84E+00	2.48E-02	5.84E-01	1.02E+01	1.20E+01
Thorium-232		2.30E-01			5.23E-03			6.28E-01		
Thorium-234 (not in RESRAD)										

Table E-1. Baseline Exposure-Point Concentrations and Intruder Scenario Exposure-Point Concentrations for the Representative Waste Sites. (2 pages)

Constituent Name	Enter these values into RESRAD for appropriate scenario.									
	RURAL RESIDENTIAL – GARDEN Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)				CONSTRUCTION WORKER Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)			DRILLER Summary of Intruder Scenario Exposure Point Concentrations (pCi/g)		
	$EPC_{Garden} = EPC_{Deep} \times V_{Borehole} / V_{Garden}$ (Occupancy = 60% inside, 20% in garden)				$EPC_{Const} = EPC_{Shallow} \times V_{Contaminated\ Trench} / V_{Total\ Trench}$ (Occupancy = 40 hours/year)			$EPC_{Driller} = EPC_{Deep} \times V_{Contaminated\ Borehole} / V_{Total\ All\ Boreholes}$ (Occupancy = 40 hours/year)		
	216-U-12[1]	216-U-4/4A	216-U-8	216-U-1&2	216-U-4/4A	216-U-8	216-U-1&2	216-U-4	216-U-8	216-U-1&2
Uranium-233/234 (as U-233 in RESRAD)		2.58E-01	1.75E+01	1.46E+00	5.88E-03	4.27E-02	4.15E-02	7.06E-01	4.78E+01	3.98E+00
Uranium-234	3.63E-02	3.54E-01	1.42E+00	1.17E+00		7.08E-01	8.08E-02	9.68E-01	3.88E+00	3.21E+00
Uranium-235	1.88E-02	2.59E-02	1.61E+00	3.27E+00	5.88E-04	2.88E-02	3.81E-03	7.06E-02	4.40E+00	8.93E+00
Uranium-238		3.26E-01	9.83E+00	1.04E+02	5.23E-03	5.24E-01	5.54E-02	8.92E-01	2.68E+01	2.85E+02

[1] Because the 216-U-12 site shows dose below 15 mrem/yr from the worst-case, rural residential intruder scenario, no further evaluations were performed.

[2] The relative activities for Pu-239 and Pu-240 were calculated by multiplying the EPC value for Pu-239/240 by 0.807 and 0.193, respectively.

ANL/EAD-4, 2001, *User's Manual for RESRAD Version 6.*

ANL, 2002, *RESRAD for Windows*, Version 6.21.

EPC = exposure-point concentration.

RESRAD = RESidual RADioactivity (code).

Table E-2. Summary of Site Dimensions and Volumes.

Site Information	216-U-12 (299-W22-78)	216-U-4/4A (299-W19-98)	216-U-8 (299-W19-94)	216-U-1&2 (299-W19-96)
Cap depth (m):	2.7	2.7	2.7	2.7
Borehole diameter (m):	0.3	0.3	0.3	0.3
Surface elevation m):	211.0	215.7	212.3	212.8
TD elevation (m):	152.0	157.4	152.3	158.8
Borehole depth (with cap) (m):	61.7	61.0	62.7	56.7
Depth to groundwater without cap (m):	77.7	77.7	77.7	77.7
Waste site maximum dimension (m):	45.7	3.0	67.7	53.0
Depth of garden for rural-residential scenario (m):	0.15	0.15	0.15	0.15
Surface area of garden (m^2):	200	200	200	200
Rural residential borehole contaminated volume (m^3):	4.4	4.3	4.4	4.0
Rural residential garden total volume (m^3):	30.0	30.0	30.0	30.0
Construction trench contaminated volume (m^3): [1]	45.7	3.0	67.7	53.0
Construction trench total volume (m^3): [1]	918	918	918	918
Driller borehole contaminated volume (m^3): [2]	4.4	4.3	4.4	4.0
Driller borehole total volume (m^3): [2]	11.0	11.0	11.0	11.0

[1] **Construction Trench Worker Scenario**

Construction estimates taken from *Moving the Earth: The Workbook of Excavation* (Nichols 1976) and *Cost Estimating Guides* (Means 2004).

Rate of digging:	1	bucket per	40	seconds
Volume of bucket:	0.33	cubic yard =	0.255	cubic meters
Total time on site:	40	hours	144000	seconds

Total volume in 40 hours = (0.765 m^3 / 40 sec) x 144000 seconds

Total volume in 40 hours = 918 m^3

This is the total construction trench volume for the entire exposure period and includes contaminated soil along the widest dimension of the waste site and clean soil for the remaining trench dug in 40 hours (1 m wide by 1 m deep trench).

[2] **Driller Scenario**

Based on actual drilling operations in U Plant Area soils, the minimum amount of time it would take to drill a well to groundwater is approximately 2.5 days. Assume that this driller optimizes his/her time and has no delays. The driller could drill up to two wells in the 40 hours allotted. For this calculation, assume that one borehole is drilled through the waste site and one borehole is drilled through uncontaminated soil adjacent to the waste site. These two boreholes (12-in. diameter drilled to groundwater) account for the total volume of soil for this scenario.

TD = total depth (of borehole).

Table E-3. Summary of RESRAD Input Parameters.

Description	Parameter	Units	Process Waste Site Group	French Drain Reverse Well Group	Rationale and Citation
			216-U-1/2 Cribs 216-U-8 Crib 216-U-12 Crib 200-W-42 Vitrified Clay Pipe	216-U-4/U-4A	
R011- Contaminated Zone (CZ)	Area of CZ	m2	200	200	See Appendix F, Table F-2
	Thickness of CZ (baseline)	m	Construction Worker and Well Driller = 4.6 Rural Residential = 0.15	Construction Worker and Well Driller = 4.6 Rural Residential = 0.15	Direct-contact exposure cleanup standards. Apply to upper 4.6 m (15 ft).
	Length parallel to aquifer flow	m	53 (216-U-1/2 length) 34 (216-U-8 width) 18 (216-U-12 width) 6.1 (200-W-42 width)	3 (length)	See Appendix F, Table F-7
R017 - Inhalation and External Gamma	Indoor time fraction (industrial scenario)		Construction Worker and Well Driller = 0 Rural Residential = 0.6	Construction Worker and Well Driller = 0 Rural Residential = 0.6	200 Area industrial scenario; on-site 2,000 h/yr (indoors 60%) (rural residential scenario). Construction trench and well driller scenarios are 40 hours total on-site, all outdoors.
	Outdoor time fraction (industrial scenario)		Construction Worker and Well Driller = 0.00456 Rural Residential = 0.2	Construction Worker and Well Driller = 0.00456 Rural Residential = 0.2	200 Area industrial scenario; on-site 2,000 h/yr (outdoors 40%)

NOTE: All RESRAD input parameters are the same as those listed in Table C-26 except as noted above.
ANL/EAD-4, 2001, *User's Manual for RESRAD Version 6.*
ANL, 2002, *RESRAD for Windows*, Version 6.21.
RESRAD = RESidual RADioactivity (dose model).

Table E-4. Summary of All Radionuclides, All Pathways Dose and Risk Estimates for Representative Waste Sites.

Time (yr)[1]	216-U-4/4A		216-U-8		216-U-12[2]		216-U-1&2	
	Dose (mrem/yr)	Risk	Dose (mrem/yr)	Risk	Dose (mrem/yr)	Risk	Dose (mrem/yr)	Risk
Rural Residential Intruder Scenario								
0	1.69E+01	2.90E-04	8.28E+02	2.65E-02	1.08E-02	8.41E-08	1.01E+03	1.58E-02
1	1.67E+01	2.85E-04	8.09E+02	2.58E-02	8.21E-03	6.54E-08	9.88E+02	1.54E-02
3	1.63E+01	2.77E-04	7.72E+02	2.47E-02	7.01E-03	5.58E-08	9.40E+02	1.47E-02
10	1.50E+01	2.49E-04	6.55E+02	2.10E-02	4.02E-03	3.21E-08	7.90E+02	1.24E-02
30	1.12E+01	1.80E-04	4.11E+02	1.32E-02	8.29E-04	6.64E-09	4.85E+02	7.66E-03
100	4.92E+00	8.02E-05	8.09E+01	2.59E-03	1.01E-05	1.14E-10	9.19E+01	1.46E-03
300	2.72E+00	4.81E-05	8.51E-01	3.04E-05	3.42E-06	4.92E-11	1.64E+00	1.58E-05
1000	1.71E+00	3.58E-05	3.52E-02	3.43E-06	1.09E-06	2.21E-11	3.35E-01	9.39E-07
Construction Trench Worker Intruder Scenario								
0	5.63E-02	4.02E-07	5.47E-01	3.88E-03			2.84E-02	3.45E-07
1	5.69E-02	4.07E-07	5.32E-01	3.70E-03			2.66E-02	3.31E-07
3	5.80E-02	4.14E-07	5.02E-01	3.35E-03			2.51E-02	3.14E-07
10	5.99E-02	4.26E-07	4.18E-01	2.38E-03			2.18E-02	2.66E-07
30	5.93E-02	4.15E-07	2.83E-01	8.94E-04			1.49E-02	1.66E-07
100	5.30E-02	3.71E-07	1.82E-01	3.23E-05			5.71E-03	3.46E-08
300	4.19E-02	3.40E-07	1.56E-01	2.13E-06			3.38E-03	3.74E-09
1000	2.27E-02	2.94E-07	1.17E-01	1.59E-06			2.87E-03	2.83E-09
Well Driller Intruder Scenario								
0	8.67E+00	7.11E-05	8.67E+01	1.43E-03			2.78E+02	3.71E-03
1	8.71E+00	7.10E-05	8.47E+01	1.39E-03			2.71E+02	3.61E-03
3	8.78E+00	7.07E-05	8.10E+01	1.33E-03			2.57E+02	3.44E-03
10	8.83E+00	6.85E-05	6.91E+01	1.12E-03			2.16E+02	2.88E-03
30	8.40E+00	6.04E-05	4.43E+01	7.08E-04			1.31E+02	1.74E-03
100	7.18E+00	4.71E-05	1.09E+01	1.62E-04			2.33E+01	3.03E-04
300	5.75E+00	4.17E-05	2.79E+00	3.00E-05			1.07E+00	3.70E-06
1000	3.43E+00	3.61E-05	2.52E+00	2.33E-05			7.58E-01	1.11E-06

Outlined values indicate dose above 15 mrem/year.

[1]Time 0 represents 150 years from date of this focused feasibility study.

[2]Site 216-U-12 is below 15 mrem/year for the worst case rural residential intruder scenario; therefore, analysis of other intruder scenarios was not performed.

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APPENDIX F

COST ESTIMATE BACKUP

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TERMS

BHI	Bechtel Hanford, Inc.
CDI	canyon disposition initiative
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
ERDF	Environmental Restoration Disposal Facility
FFS	focused feasibility study
FH	Fluor Hanford, Inc.
FY	fiscal year
MCACES	Micro-Computer Aided Cost Estimating System
O&M	operations and maintenance
PRG	preliminary remediation goal
RCRA	*Resource Conservation and Recovery Act of 1976*
RTD	removal, treatment, and disposal

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APPENDIX F

COST ESTIMATE BACKUP

F1.0 INTRODUCTION

Cost estimates for this focused feasibility study (FFS) were prepared to the accuracy specified in the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) guidance for remedial investigations and feasibility studies (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*). The specified accuracy for this level of analysis is +50 percent, -30 percent. The costs provide a discriminator for deciding between similarly protective and implementable alternatives for a specific waste site. Therefore, the costs are not absolute costs, but are relational costs used for evaluating the alternatives. Cost estimates were made by waste site without considering logistics and combinations of sites for remedial actions. The economies associated with implementing multiple sites with a common alternative or aggregated remediation are not evaluated in this FFS. They will be considered in the future as part of long-range planning and through the post-Record of Decision activities, such as remedial design. Potential areas of cost sharing to reduce overall remediation costs include the following:

- All waste sites with a common preferred alternative could be remediated at the same time
- Mobilization and demobilization costs could be shared
- Surveillance and maintenance costs could be shared
- Barrier performance monitoring costs could be shared.

F2.0 ALTERNATIVE COST ESTIMATES

This section describes the cost estimates based on the remedial alternatives developed in Chapter 4.0 of this FFS. Table F-1 summarizes the alternatives considered by waste site, total present worth costs, and operations and maintenance costs. Section F2.1 describes cost components that are common to all alternatives. Sections F2.2 through F2.6 provide summary and backup information for costs by waste site.

Present net worth costs were estimated using the real discount rate published in Appendix C of the Office of Management and Budget Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, which is effective through the end of January 2004. Programs with durations longer than 30 years use the 30-year interest rate of 3.2 percent. A discussion of present net worth costs is provided in each of the following sections.

F2.1 ALTERNATIVE 1, NO ACTION

The no-action alternative represents a situation where no legal restrictions, access controls, or active remedial measures are applied to the site. No action implies "walking away from the waste site" and allowing the waste to remain in its current configuration, affected only by natural processes. No maintenance or other activities would be instituted or continued. Section 4.2.1 of this FFS describes the no-action alternative.

Because the no-action alternative assumes no further actions will be taken at a waste site, costs are assumed to be zero. The costs for verification sampling have not been included in this estimate, but may constitute some costs for waste sites without existing data to verify that the preliminary remediation goals (PRG) are met.

F2.2 ALTERNATIVE 2, MAINTAIN EXISTING SOIL COVER, INSTITUTIONAL CONTROLS, AND MONITORED NATURAL ATTENUATION

Section 4.2.2 of this FFS describes the Maintain the Existing Soil Cover, Institutional Controls, and Monitored Natural Attenuation alternative. This alternative includes the cost of maintaining the existing soil cover. The costs for these controls were estimated based on the area of the individual waste sites and a unit cost per area. Details of the cost estimates are provided in Table F-2.

The primary costs associated with this alternative are surveillance and cover maintenance and monitored natural attenuation costs.

The unit cost for surveillance and maintenance was assumed to be the same as the current unit cost for annual surveillance and maintenance activities at the waste sites. These costs account for such activities as site radiation surveys, control of deep-burrowing animals and deep-rooted plants through herbicide or physical removal, maintenance of signs and markers, and repair of the existing soil cover on the sites that have cover. It is assumed that, because the existing soil cover is maintained annually, including costs for replacing all or large portions of the existing cover at specified intervals (i.e., every 20 years) is not necessary.

The costs associated with natural attenuation monitoring are divided into three components: radiological surveys of surface soils, spectral gamma-logging of vadose zone boreholes, and groundwater monitoring. The costs to perform radiological surveys of surface soils at waste sites are assumed to be similar to current survey practices at the site and are included in the surveillance and maintenance costs.

Vadose zone monitoring costs assume spectral-gamma logging of one borehole per waste site to a depth of 15 m (50 ft) once every 5 years until the site meets all PRGs. This monitoring is considered for sites with higher concentrations of contaminants in the shallow zone or near the bottom of crib and trench structures. The cost estimate also assumes that the service life of vadose zone boreholes is 30 years. Costs are included for logging and periodic replacement of these boreholes until all PRGs are met for the site.

It is assumed that groundwater monitoring costs will be required for sites that have higher concentrations of more mobile contaminants deep within the vadose zone and/or where groundwater contamination is known to have occurred. Annual groundwater monitoring costs assume sampling and analysis of mobile deep vadose zone contaminants (e.g., Tc-99 and nitrate) at 1 down-gradient well per waste site at a cost of $2,000[1] per sampling event. Groundwater monitoring costs have been included for sites that are analogous to a representative site with known deep vadose zone or groundwater contamination. The cost estimate also assumes that the service life of groundwater wells is 30 years. Costs include periodic (i.e., every 30 years) replacement of these wells until all PRGs are met for the site.

The cost model used for this alternative consisted of a simple spreadsheet. Durations were used for the representative sites based on the length of time required to reach PRGs. Because the analogous sites do not have data to support the time needed to reach PRGs, costs for institutional controls at analogous waste sites were estimated using the time from the associated representative site.

The present net worth costs for surveillance and maintenance and natural attenuation monitoring are added to the costs for the independent work elements discussed in Section F2.5 to reach the total present worth cost for this alternative. The real discount rate of 3.2 percent is used for discounting real (constant-dollar) flows until all PRGs are reached at each site.

F2.3 ALTERNATIVE 3 – REMOVAL, TREATMENT, AND DISPOSAL

Section 4.2.3 of this FFS describes the removal, treatment, and disposal (RTD) alternative. The base assumption used for the RTD alternative is for excavation to 6.1 m (15 ft) or the bottom of the engineered structure, whichever is deeper. At selected sites with deep vadose zone contamination (the 216-U-1 and 216-U-2, 216-U-8 and 216-U-12 Cribs), the RTD alternative assumes deeper excavation of contaminated soil (approximately 200 ft) to meet groundwater PRGs. Two cost models were used to estimate costs for the RTD alternative. These cost models are the "Trench Template" and the "Retention Basin Template." These cost models are discussed in detail in Section F3.0. Cost estimate inputs for the RTD alternative are included in Tables F-3 and F-4. A breakdown of costs developed in the RTD estimate by waste site is provided in Tables F-5 and F-6.

Institutional control costs were not added to the RTD alternative because the contaminants are assumed to be removed to concentrations at or below the PRGs. If some contaminants remain after excavation, institutional controls may be needed. Because deep vadose zone contaminants will be removed at the sites where impact to groundwater has been shown, it is assumed that groundwater monitoring will not be required.

All costs associated with the RTD alternative are present net worth costs because implementation is estimated to occur in less than 1 year for all sites except those where deep excavation is

[1] The basis for the estimation was developed from costs provided by Fluor Hanford factoring in previous sampling efforts and associated analytical costs.

assumed. Implementation of deep excavation is estimated to require up to 3 years. Implementation costs were broken down by the year in which they occur, with costs incurred in the second and third years discounted to net present worth. The present net worth costs for the alternative are added to the costs for the independent work elements discussed in Section F2.5 to reach the total present worth cost for this alternative.

F2.4 ALTERNATIVE 4, ENGINEERED BARRIER

Section 4.2.4 of this FFS provides a description of the engineered barrier alternative. Cost estimate inputs for this alternative are included in Table F-7. A breakdown of costs developed in the capping estimate is provided in Table F-8. Please note that this table has been separated into Tables F-8a and F-8b for readability. Figure F-1 provides detail of the assumed design.

Operation and maintenance costs for this alternative include barrier performance monitoring and cover repair costs. Barrier performance monitoring assumes $50,000/year for the first 5 years, $20,000/year for the next 10 years, and $20,000 once every 5 years thereafter. The $50,000/year cost is based on actual costs for monitoring the Prototype Hanford Barrier. After 5 years, it is assumed that monitoring costs can be reduced by 60 percent ($50,000 to $20,000) because of increased monitoring efficiencies. After 15 years of annual monitoring, barrier performance will be verified once every 5 years.

For purposes of this FFS, minor repair of the existing soil cover because of wind erosion (i.e., replacement of 6 in. of topsoil layer and revegetation over 2 percent of the barrier area) is assumed about every 20 years. This is considered a conservative estimate because the barrier was designed to require minimal maintenance, particularly once vegetation has been established. The real discount rate of 3.2 percent is used for discounting real (constant-dollar) flows for operations and maintenance costs until all PRGs are reached at each site to obtain the present net worth cost for the alternative.

Institutional controls are an integral component of this alternative and would be required to prevent intrusion to the barrier area and to prevent activities that might alter the integrity and effectiveness of the barrier. Because the barrier may have little effect on deep vadose zone contaminants, groundwater monitoring costs are included for sites (and their analogous sites) that are known to have impacted groundwater. As part of this alternative, costs for dynamic compaction have been included to eliminate any void spaces within the site to ensure that a firm subgrade will be provided to prevent future settling. For the 216-U-1 and 216-U-2 Cribs, an additional cost has been included to inject grout into the void space created by the timber crib structures within the site. This would be done to prevent any future collapse or settling of the site. The 216-U-8 Crib has three timber structures within the site; however, they are filled with gravel and therefore grouting the void space may not be necessary if dynamic compaction was performed.

The present net worth costs for the alternative are added to institutional control costs and the costs for the independent work elements discussed in Section F2.5 to reach the total present worth cost for this alternative.

F2.5 INDEPENDENT WORK ELEMENTS

This section summarizes the cost items associated with activities that will be conducted independently of the remedial alternatives. These costs are in relation to removing sludge and liquid from the 241-U-361 Settling Tank.

Because of the amount of sludge material in Tank 241-U-361, a cost adder common to each alternative is required for removing the sludge and supernatant liquid. The option of removal, stabilization and/or treatment, and disposal of sludge to the Environmental Restoration Disposal Facility (ERDF) is the preferred alternative for handling Tank 241-U-361 sludge materials. Costs for removing sludge in Tank 241-U-361 are provided in the summary tables for each alternative. All costs associated with sludge removal from Tank 241-U-361 are present net worth values. Section 4.3.1 describes this common element.

F3.0 COST MODELS

The Maestro[1] software was used to develop estimates for Alternative 3, RTD; and Alternative 4, Engineered Barrier. Three cost templates were used for this estimate:

- **Trench Cost Model Template**. This template is based on Micro-Computer Aided Cost Estimating System (MCACES) Model, Bechtel Hanford, Inc. (BHI) MCACES (fiscal year) FY 2002 Trench. The Trench Cost Model Template was further modified to develop costs for deep excavation at sites where groundwater protection PRGs are exceeded.

- **Retention Basin Cost Model Template**. This template is based on MCACES Model, BHI MCACES FY 2002 Trench and Retention Basin.

- **Modified RCRA C Barrier Cost Model Template**. This template is based on MCACES Model, BHI MCACES FY 2000 *Resource, Conservation, and Recovery Act of 1976* (RCRA) Subtitle C Barrier.

The trench and retention basin cost model templates were used to develop costs for the RTD alternative. The trench template was used for sites where the engineered structures can be removed using standard excavation equipment. The retention basis template was used for sites where engineered structures contained reinforced concrete where specialized demolition equipment may be required to break up and remove the structure. The deep excavation template was used for sites where excavation to the water table was assumed. The RCRA Subtitle C Barrier template was used to develop costs for all waste sites considered for the capping alternative.

The following sections summarize the assumptions for each Maestro model.

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[1] Maestro is a trademark of Explorer Software Inc., West Vancouver, British Columbia.

F3.1 TRENCH TEMPLATE

This section summarizes the cost inputs, assumptions, and backup used in the Maestro Trench template.

F3.1.1 Remediation Work Scope

The template covers the construction work to remediate a waste site by using conventional construction equipment to excavate contaminated soil for disposal at the ERDF. The template is based on the use of a fixed-price contractor to do the construction work with Fluor Hanford, Inc. (FH), managing the work.

Major assumptions that have been made in the preparation of this estimate are as follows:

- Disposal costs consisting of the ERDF dumping charges, fees, and transportation of waste are included in this estimate.
- All borrow material needed to backfill the excavation or restore the site comes from Pit 30.
- The following work process is used to restore the site:
  - Mobilization consists of setting up a decontamination area, installing a temporary fence around the site, conducting a site survey, and improving and maintaining the site haul road.
  - Environment monitoring and sampling and analysis of low-level-waste soils and materials during the excavation process.
  - Solids (contaminated soil) collection and containment, which includes the following:
    - Excavation of clean overburden soil, hauling, and stockpiling near the waste site, including dust control.
    - Excavation of contaminated soil and loading the soil into containers to be hauled to a queue area. The work also includes site dust control.
  - Disposal of contaminated soil consists of the following activities:
    - Processing at the queue area for transport to ERDF.
    - Other work at the queue area, which includes decontaminating and surveying the containers and adding disposal liners.
  - Site restoration consists of the following activities:
    - Loading and hauling backfill from the overburden stockpile and Pit 30 borrow site.

  - Backfilling and compaction of the waste site. Compaction is limited to equipment compaction. Site dust control is included.

  - Revegetation, consists of planting dry-land grass seed and native bushes and applying fertilizer and initial irrigation, as needed.

  - Demobilization consists of removing the temporary fence, decontamination site, haul road, and miscellaneous cleanup.

  - Project management consists of part-time staff to manage the work and provide technical support.

- Mobilization and demobilization of construction equipment are calculated separately and added to the model-specific mobilization and demobilization costs.

F3.2 DEEP EXCAVATION

This section summarizes cost inputs, assumptions, and backup used in the Maestro Trench Cost Model Template modified for deep excavation at sites where groundwater protection PRGs are exceeded.

F3.2.1 Remediation Work Scope

The template covers the construction work to excavate to approximately 200 ft and to remediate the waste site. Deactivation, assessment, and predecommissioning activities are not included in the estimate. The estimate is based on FH using a fixed-price contractor to do the construction work with FH managing the work.

The following major assumptions have been made in the preparation of this estimate:

- Disposal costs consisting of ERDF dumping charges, fees and transportation of waste from the queue area are included in this estimate.

- All borrow material needed to restore the site comes from Pit 30.

- The following work process is used to restore the site:

  - Mobilization consists of setting up a decontamination area, installing a temporary fence around the site, conducting a site survey, setting up a site trailer and site utilities, and improving and maintaining the site staging area and haul road. Conducting Hanford Site-required training for the fixed-price contractor's crew is included in the mobilization activity.

  - Monitoring, sampling, and analysis of low-level-waste soils and materials, noncontaminated materials, the trench bottom area, and quality control monitoring and sampling. During excavation, air monitoring will be performed.

- Solids collection and containment consists of the following activities:
  - Excavation of overburden soil, hauling, and stockpiling near the ditch waste site, including dust control, using large earthmoving equipment. Two crews will work at the site for 80 percent of the removal process and one crew will complete the work.
  - Excavation of contaminated soil and loading the soil into containers to be hauled to a queue area. The work also includes site dust control. This work will be performed at the same time the overburden is being removed.
- Disposal of contaminated waste consists of the following activities:
  - Processing at the queue area for transport to the ERDF.
  - Other work at the queue area, which includes decontaminating and surveying the containers and adding disposal liners.
  - Transporting to the ERDF, waste disposal, and returning the waste containers.
- Site restoration consists of the following activities:
  - Loading and hauling backfill from the overburden stockpile and the Pit 30 borrow site. The hauling from the stockpile will involve using large earthmoving equipment. One crew will start the work until 20 percent has been backfilled, then two crews will complete the work.
  - Backfilling and compaction of the waste site. Compaction is limited to equipment compaction. Site dust control is included.
- Revegetation consists of planting dry-land grass seed and native bushes and applying fertilizer and irrigation as needed. The waste site, stockpile area, staging area, and haul roads will be replanted.
- Demobilization consists of removing the temporary fence, removing the trailer, disconnecting the utilities, removing the decontamination site and haul road, and performing miscellaneous clean up.
- FH Project management consists of part-time staff to manage the work and provide technical support.
- Fixed-price contractor management consists of full-time staff to manage the work.
- Mobilization and demobilization of construction equipment are calculated separately and added to the costs of the work.

F3.3 RETENTION BASIN

This section summarizes cost inputs, assumptions, and backup used in the Maestro Retention Basin template.

F3.3.1 Remediation Work Scope

The template covers the construction work to remediate a waste site by using conventional construction equipment to excavate contaminated soil for disposal at the ERDF. The template is based on the use of a fixed-price contractor to do the construction work with FH managing the work.

Major assumptions that have been made in the preparation of this estimate are as follows:

- Disposal costs consisting of ERDF dumping charges, fees, and transportation of waste are included in this estimate.
- All borrow material needed to backfill the excavation or restore the site comes from Pit 30.
- The following work process is used to restore the site:
  - Mobilization consists of setting up a decontamination area, installing a temporary fence around the site, conducting a site survey, and improving and maintaining the site haul road.
  - Environment monitoring and sampling and analysis of low-level-waste soils and materials during the excavation process.
  - Solids (contaminated soil) collection and containment consists of the following activities:
    - Excavation of clean overburden soil, hauling, and stockpiling near the waste site, including dust control.
    - Excavation of contaminated soil and loading it into containers to be hauled to a queue area. The work also includes site dust control.
    - Demolishing, excavating, and loading small contaminated concrete structures to be hauled to a queue area.
  - Disposal of contaminated soil consists of the following activities:
    - Processing at the queue area for transport to the ERDF.
    - Other work at the queue area consists of decontaminating and surveying the containers and adding disposal liners.

- Site restoration consists of the following activities:
  - Loading and hauling backfill from the overburden stockpile and Pit 30 borrow site.
  - Backfilling and compaction of the waste site. Compaction is limited to equipment compaction. Site dust control is included.
- Revegetation consists of planting dry-land grass seed and native bushes and applying fertilizer and initial irrigation, as needed.
- Demobilization consists of removing the temporary fence and decontamination site, haul road, and miscellaneous cleanup.
- Project management consist of part-time staff to manage the work and provide technical support.

- Mobilization and demobilization of construction equipment is calculated separately and added to the model-specific mobilization and demobilization costs.

F3.4 RCRA, SUBTITLE C BARRIER TEMPLATE

This section summarizes cost inputs, assumptions, and backup used in the Maestro RCRA Subtitle C Barrier template.

F3.4.1 Remediation Work Scope

The template covers the construction work to build a Modified RCRA Subtitle C Barrier over a waste site. The template is based on the FH use of a fixed-price contractor to do the construction work with FH managing the work.

Assumptions are as follows:

- The borrow site for the fill materials is Pit 30. The borrow material either will be suitable in place at the borrow site or will require processing at the Process Area near Pit 30.
- The standard barrier design called a Modified RCRA Subtitle C Barrier contains eight different layers of fill and a geotextile layer that includes a provisional asphalt layer, and associated drainage and subgrade layers (see Figure F-1). For all waste sites except the 200-W-42 Vitrified Clay Pipeline and UPR-200-W-163 unplanned release, four of the layers associated with the asphalt have been omitted. These layers are a gravel filter layer, a gravel drainage layer, an asphaltic concrete pavement layer, and a base course layer. These four layers are included in the cost template, but cost values have been set equal to zero.

- The cap extends 20 linear ft from the edge of the waste site unless changed by the design engineer.
- The first layer of fill (Layer 8) is pushed ahead of the filling operation. Construction equipment will operate on clean material only.
- No waste, soil, etc., will be removed from the waste site.
- Dust control will be provided during construction.
- Compaction used before construction begins assumes a dynamic compaction method using a 150-ton crane and drop ball.
- A basalt riprap perimeter covers the side slopes of the cap.
- The barrier top surface site is to be seeded with dry-land grasses, fertilized, and mulched. Sagebrush is to be hand planted on the barrier. The site is to be irrigated for 1 month after the barrier is completed to help establish the vegetation.
- Mobilization of the construction site is limited to building a temporary fence, bringing the construction equipment to the site, building a decontamination area, setting field office trailers, providing temporary utilities, and improving the access road.
- Demobilization consists of removing the temporary fence, removing the equipment, miscellaneous cleanup, removing the decontamination area, removing the field office trailers, disconnecting the temporary utilities, and scarifying the road.
- Monitoring of the site involves air sampling by FH radiological control technicians during the dynamic compaction and applying the first layer of backfill.
- The fixed-price contractor will turn over as-built drawings of the site and other required documentationto FH at the completion of the project.
- An allowance for training has been included. It is anticipated that trained crew members are already available because of other work on the Hanford Site; however, a certain amount of retraining is still required.

F4.0 REFERENCES

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

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

OMB Circular No. A-94, 1992, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* Office of Management and Budget, Washington, D C.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

Figure F-1. Modified RCRA Subtitle C Barrier.

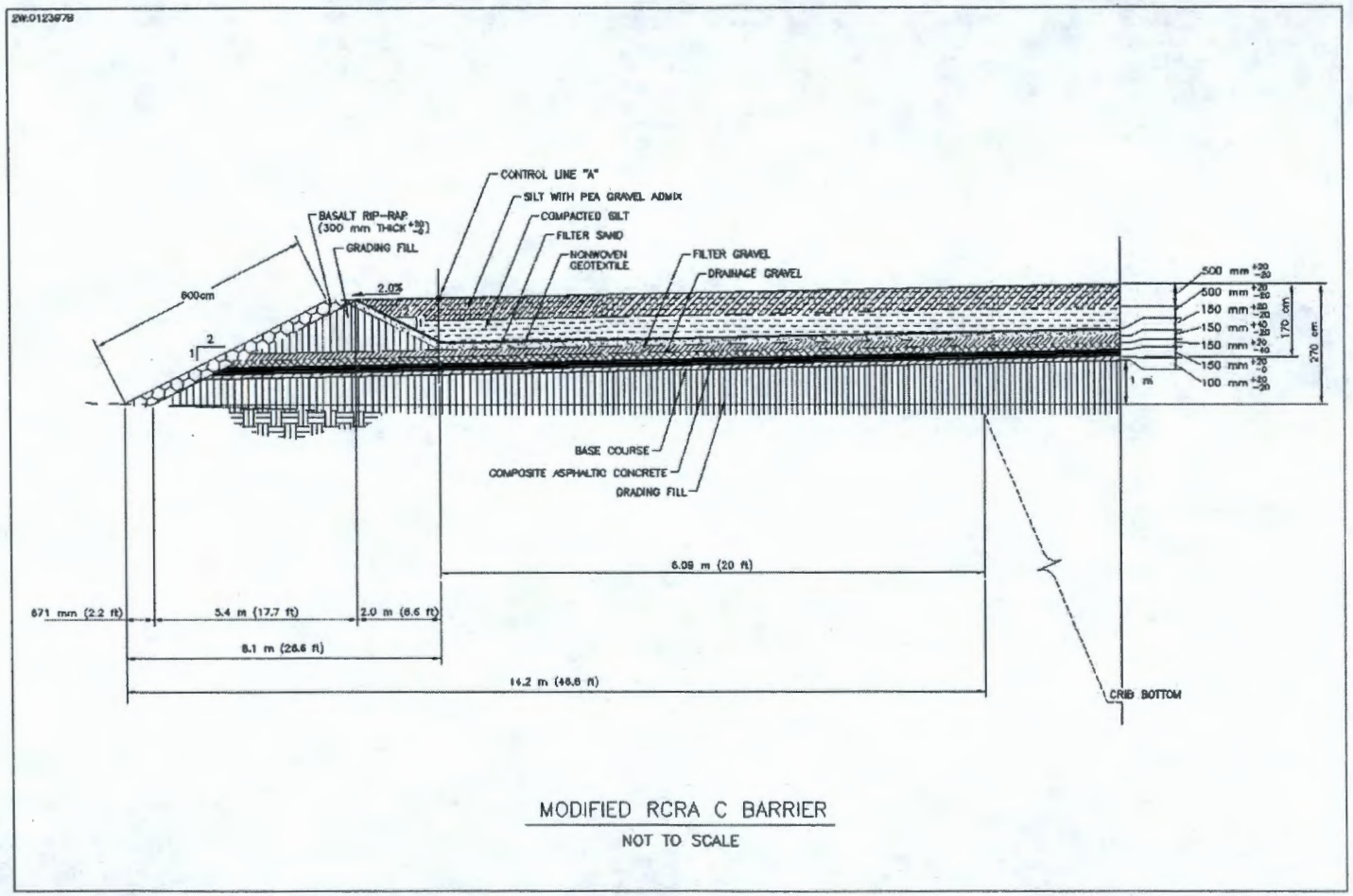

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Table F-1. Cost Summary by Alternative. (2 pages)

Waste Site/Group	Alternative 1: No Action	Alternative 2: Maintain Existing Soil Cover, Institutional Controls, and Monitored Natural Attenuation				Alternative 3: Removal, Treatment, and Disposal				Alternative 4: Engineered Barrier			
		Total Capital Cost	Implementation Time (Years)[1,2]	Total Operations and Maintenance Cost	Present Worth Cost	Total Capital Cost	Implementation Time (Years)[3]	Total Operations and Maintenance Cost	Present Worth Cost	Total Capital Cost	Implementation Time (Years)[1,2]	Total Operations and Maintenance Cost	Present Worth Cost
Process Waste Group													
216-U-1/216-U-2	-	-	1000	$16,325,000	$393,000	$52,973,000	<4	-	$52,973,000	$696,000	1000	$13,805,000	$1,347,000
216-U-5	-	-	141	$2,302,000	$389,000	$552,000	<1	-	$552,000	$366,000	141	$2,223,000	$1,007,000
216-U-6	-	-	141	$2,302,000	$389,000	$494,000	<1	-	$494,000	$353,000	141	$2,222,000	$994,000
216-U-8	-	-	1000	$16,325,000	$393,000	$62,266,000	<4	-	$62,266,000	$944,000	1000	$13,960,000	$1,598,000
216-U-12	-	-	1000	$16,325,000	$393,000	$42,950,000	<4	-	$42,950,000	$460,000	1000	$13,610,000	$1,106,000
216-U-15	-	-	141	$2,302,000	$389,000	$155,000	<1	-	$155,000	$260,000	141	$2,209,000	$899,000
216-U-16	-	-	141	$2,936,000	$528,000	$4,928,000	<1	-	$4,928,000	$1,334,000	141	$2,364,000	$1,998,000
216-U-17	-	-	141	$2,302,000	$389,000	$1,484,000	<1	-	$1,484,000	$550,000	141	$2,249,000	$1,195,000
241-U-361	-	$4,762,000	128	$2,090,000	$5,148,000	$5,078,000	<1	-	$5,078,000	$5,037,000	128	$2,042,000	$5,674,000
200-W-42/UPR-200-W-163	-	-	831	$13,566,000	$393,000	$4,039,000	<1	-	$4,039,000	$2,244,000	831	$11,921,000	$2,906,000
Reverse Well/French Drain Group													
216-U-4/216-U-4A	-	-	125	$916,000	$193,000	$124,000	<1	-	$124,000	$251,000	125	$874,000	$695,000
216-U-4/216-U-4A (with CDI Barrier for Alt 2)	-	-	20	$107,000	$74,000	-	-	-	-	-	-	-	-
216-U-4B	-	-	125	$916,000	$193,000	$115,000	<1	-	$115,000	$248,000	125	$874,000	$692,000
Septic System Group													
2607-W5	-	-	129	$194,000	$46,000	$1,407,000	<1	-	$1,407,000	$1,466,000	129	$990,000	$1,927,000
2607-W7	-	-	129	$194,000	$46,000	$648,000	<1	-	$648,000	$805,000	129	$934,000	$1,257,000
2607-W7 (with CDI Barrier for Alt 2)	-	-	20	$30,000	$22,000	-	-	-	-	-	-	-	-
Solid Waste Group													
200-W-56	-	-	129	$194,000	$46,000	$105,000	<1	-	$105,000	$251,000	129	$891,000	$695,000
200-W-57	-	-	129	$194,000	$46,000	$167,000	<1	-	$167,000	$336,000	129	$900,000	$781,000
200-W-71	-	-	129	$194,000	$46,000	$845,000	<1	-	$845,000	$553,000	129	$928,000	$1,003,000
UPR-200-W-8	-	-	129	$194,000	$46,000	$2,501,000	<1	-	$2,501,000	$1,192,000	129	$1,011,000	$1,657,000
Unplanned Release Group													
UPR-200-W-19	-	-	129	$774,000	$184,000	$5,184,000	<1	-	$5,184,000	$2,056,000	129	$1,130,000	$2,541,000
UPR-200-W-118	-	-	129	$774,000	$184,000	$4,040,000	<1	-	$4,040,000	$1,131,000	129	$1,015,000	$1,596,000
UPR-200-W-118 (with CDI Barrier for Alt 2)	-	-	20	$120,000	$88,000	-	-	-	-	-	-	-	-
Shallow/Surface Waste Site Group													
200-W-77	-	-	129	$194,000	$46,000	$106,000	<1	-	$106,000	$252,000	129	$891,000	$696,000
200-W-85	-	-	129	$194,000	$46,000	$111,000	<1	-	$111,000	$261,000	129	$891,000	$705,000
200-W-87	-	-	129	$194,000	$46,000	$167,000	<1	-	$167,000	$340,000	129	$900,000	$785,000
200-W-89	-	-	129	$194,000	$46,000	$274,000	<1	-	$274,000	$479,000	129	$919,000	$928,000
UPR-200-W-33	-	-	129	$194,000	$46,000	$106,000	<1	-	$106,000	$258,000	129	$891,000	$702,000
UPR-200-W-48	-	-	129	$194,000	$46,000	$121,000	<1	-	$121,000	$277,000	129	$894,000	$721,000
UPR-200-W-55	-	-	129	$194,000	$46,000	$105,000	<1	-	$105,000	$251,000	129	$891,000	$695,000

Table F-1. Cost Summary by Alternative. (2 pages)

Waste Site/Group	Alternative 1: No Action	Alternative 2: Maintain Existing Soil Cover, Institutional Controls, and Monitored Natural Attenuation				Alternative 3: Removal, Treatment, and Disposal				Alternative 4: Engineered Barrier			
		Total Capital Cost	Implementation Time (Years)[1,2]	Total Operations and Maintenance Cost	Present Worth Cost	Total Capital Cost	Implementation Time (Years)[3]	Total Operations and Maintenance Cost	Present Worth Cost	Total Capital Cost	Implementation Time (Years)[1,2]	Total Operations and Maintenance Cost	Present Worth Cost
UPR-200-W-78	-	-	129	$194,000	$46,000	$104,000	<1	-	$104,000	$252,000	129	$891,000	$696,000
UPR-200-W-78 (with CDI Barrier for Alt 2)	-	-	20	$30,000	$22,000	-	-	-	-	-	-	-	-
UPR-200-W-117/UPR-200-W-60	-	-	129	$194,000	$46,000	$208,000	<1	-	$208,000	$399,000	129	$909,000	$846,000

Notes:

[1]Implementation time corresponds to the duration of the alternative required to meet PRGs at representative waste site or analogous site with sufficient data for risk assessment (200-W-42 Vitrified Clay Pipeline and UPR-200-W-163 unplanned release and 216-U-1&2 Pump-and-Treat System).

[2]Implementation time for the 216-U-1 and 216-U-2, 216-U-8, and 216-U-12 Cribs corresponds to the duration of time required for Alternatives 2 and 4 to meet groundwater protection PRGs.

[3]Implementation time for the removal, treatment, and disposal alternative corresponds to the construction period, because PRGs will be met at the completion of remedial construction.

[4]Costs are rounded to nearest $1,000.

CDI = canyon disposition initiative.

PRG = preliminary remediation goal.

Table F-2. Alternative 2, Maintain Existing Soil Cover, Institution Controls and Monitored Natural Attenuation Cost. (2 pages)

Waste Site/Group	Assigned Representative Site	Site Areas (ft^2)	Duration[1]	Institutional Controls		Monitored Natural Attenuation								Miscellaneous Cost[9]	Total Present Net Worth	Total O&M Cost
						Vadose Zone Monitoring				Groundwater Monitoring						
				Annual Surveillance & Maintenance Costs[2,3]	Present Net Worth of Surveillance & Maintenance[4]	Vadose Zone Borehole Spectral-Gamma Logging Cost/ 5 Years[5]	Present Worth of Vadose Zone Borehole Spectral-Gamma Logging[4]	Vadose Zone Borehole Replacement Cost/30 years[6]	Present Worth of Vadose Zone Borehole Replacement[4]	Annual Groundwater Monitoring Cost[7]	Present Worth of Groundwater Monitoring[4]	Groundwater Well Replacement Cost/30 years[8]	Present Worth of Groundwater Well Replacement[4]			
Process Waste Group																
216-U-1/216-U-2	216-U-8	17,748	1000	$1,500	$47,000	$19,000	$112,000	$60,000	$38,000	$2,000	$63,000	$210,000	$134,000	-	$393,000	$16,325,000
216-U-5	216-U-12	4,900	141	$1,500	$46,000	$19,000	$111,000	$60,000	$38,000	$2,000	$62,000	$210,000	$132,000	-	$389,000	$2,302,000
216-U-6	216-U-12	4,200	141	$1,500	$46,000	$19,000	$111,000	$60,000	$38,000	$2,000	$62,000	$210,000	$132,000	-	$389,000	$2,302,000
216-U-8	Representative Site	24,864	1000	$1,500	$47,000	$19,000	$112,000	$60,000	$38,000	$2,000	$63,000	$210,000	$134,000	-	$393,000	$16,325,000
216-U-12	Representative Site[10]	9,000	1000	$1,500	$47,000	$19,000	$112,000	$60,000	$38,000	$2,000	$63,000	$210,000	$134,000	-	$393,000	$16,325,000
216-U-15	216-U-12	400	141	$1,500	$46,000	$19,000	$111,000	$60,000	$38,000	$2,000	$62,000	$210,000	$132,000	-	$389,000	$2,302,000
216-U-16	216-U-12	50,042	141	$6,000	$185,000	$19,000	$111,000	$60,000	$38,000	$2,000	$62,000	$210,000	$132,000	-	$528,000	$2,936,000
216-U-17	216-U-12	13,056	141	$1,500	$46,000	$19,000	$111,000	$60,000	$38,000	$2,000	$62,000	$210,000	$132,000	-	$389,000	$2,302,000
241-U-361	216-U-1 /216-U-2	900	128	$1,500	$46,000	$19,000	$110,000	$60,000	$38,000	$2,000	$61,000	$210,000	$131,000	$4,762,000	$5,148,000	$2,090,000
200-W-42/UPR-200-W-163	216-U-8	39,300	831	$1,500	$47,000	$19,000	$112,000	$60,000	$38,000	$2,000	$63,000	$210,000	$134,000	-	$393,000	$13,566,000
Reverse Well/French Drain Group																
216-U-4/216-U-4A	Representative Site	100	125	$1,500	$46,000	$19,000	$110,000	$60,000	$37,000	-	-	-	-	-	$193,000	$916,000
216-U-4/216-U-4A (with CDI Barrier)	Representative Site	100	20	$1,500	$22,000	$19,000	$52,000	-	-	-	-	-	-	-	$74,000	$107,000
216-U-4B	216-U-4/216-U-4A	25	125	$1,500	$46,000	$19,000	$110,000	$60,000	$37,000	-	-	-	-	-	$193,000	$916,000
Septic System Group																
2607-W5 Tank	UPR-200-W-19	675	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
2607-W5 Field Activities	UPR-200-W-19	13,600								-	-	-	-	-		
2607-W5 Field Abandoned	UPR-200-W-19	18,086								-	-	-	-	-		
2607-W7 Tank	UPR-200-W-19	8	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
2607-W7 Field	UPR-200-W-19	13,600								-	-	-	-	-		
2607-W7 Tank (with CDI Barrier)	UPR-200-W-19	8	20	$1,500	$21,000	-	-	-	-	-	-	-	-	-	$22,000	$30,000
2607-W7 Field (with CDI Barrier)	UPR-200-W-19	13,600								-	-	-	-	-		
Solid Waste Group																
200-W-56	UPR-200-W-19	100	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
200-W-57	UPR-200-W-19	3,600	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
200-W-71	UPR-200-W-19	12,915	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-8	UPR-200-W-19	42,500	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
Unplanned Release Group																
UPR-200-W-19	Representative Site	83,725	129	$6,000	$184,000	-	-	-	-	-	-	-	-	-	$184,000	$774,000
UPR-200-W-118	UPR-200-W-19	43,681	129	$6,000	$184,000	-	-	-	-	-	-	-	-	-	$184,000	$774,000
UPR-200-W-118 (with CDI Barrier)	UPR-200-W-19	43,681	20	$6,000	$88,000	-	-	-	-	-	-	-	-	-	$88,000	$120,000

Table F-2. Alternative 2, Maintain Existing Soil Cover, Institution Controls and Monitored Natural Attenuation Cost. (2 pages)

Waste Site/Group	Assigned Representative Site	Site Areas (ft^2)	Duration[1]	Institutional Controls		Monitored Natural Attenuation								Miscellaneous Cost[9]	Total Present Net Worth	Total O&M Cost
						Vadose Zone Monitoring				Groundwater Monitoring						
				Annual Surveillance & Maintenance Costs[2,3]	Present Net Worth of Surveillance & Maintenance[4]	Vadose Zone Borehole Spectral-Gamma Logging Cost/ 5 Years[5]	Present Worth of Vadose Zone Borehole Spectral-Gamma Logging[4]	Vadose Zone Borehole Replacement Cost/30 years[6]	Present Worth of Vadose Zone Borehole Replacement[4]	Annual Groundwater Monitoring Cost[7]	Present Worth of Groundwater Monitoring[4]	Groundwater Well Replacement Cost/30 years[8]	Present Worth of Groundwater Well Replacement[4]			
Shallow/Surface Waste Site Group																
200-W-77	UPR-200-W-19	120	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
200-W-85	UPR-200-W-19	400	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
200-W-87	UPR-200-W-19	3,600	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
200-W-89	UPR-200-W-19	10,000	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-33	UPR-200-W-19	150	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-48	UPR-200-W-19	1,000	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-55	UPR-200-W-19	100	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-78	UPR-200-W-19	40	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000
UPR-200-W-78 (with CDI Barrier)	UPR-200-W-19	40	20	$1,500	$22,000	-	-	-	-	-	-	-	-	-	$22,000	$30,000
UPR-200-W-117/ UPR-200-W-60	UPR-200-W-19	6,000	129	$1,500	$46,000	-	-	-	-	-	-	-	-	-	$46,000	$194,000

Notes:

[1]Duration corresponds to time required to meet PRGs at representative waste site or analogous site with sufficient data for risk assessment (200-W-42 Vitrified Clay Pipeline and UPR-200-W-163 unplanned release and 216-U-1&2 Pump-and-Treat System).

[2]Surveillance and Maintenance costs are $1,500/site for sites less than 1 acre, $6,000/site for sites 1 to 4 acres, and $1,500 x acreage for sites larger than 4 acres. Estimates are based upon costs provided by Fluor Hanford for previous surveillance and maintenance costs from similarly sized sites.

[3]Surveillance and maintenance costs include maintenance of existing stabilization cover, vegetation control, and radiological surveys.

[4]Real discount rate used for present net worth calculation of 3.2% was from Appendix C of OMB Circular No. A-94, which is effective through the end of January 2004.

[5]Vadose zone monitoring costs assume spectral-gamma logging of one borehole per waste site to a 50-ft depth once every 5 years at a cost of $75/ft for duration until the site meets all PRGs.

[6]The service life of a vadose zone borehole is assumed to be 30 years. Borehole replacement costs assume a 50 foot borehole. Costs are based on knowledge of borehole costs at the Hanford Site.

[7]Annual groundwater monitoring costs assume sampling and analysis of mobile-deep vadose zone contaminants of concern (e.g., Tc-99 and nitrate) at one down-gradient well per waste site at a cost of $2,000 per sampling event.

[8]The service life of a groundwater well is assumed to be 30 years. Well replacement costs assume the well will extend to groundwater (255 ft) plus a 10-ft well screen.

[9]Miscellaneous costs include removal of sludge from the 241-U-361 Settling Tank.

[10]Site 216-U-12 is considered analogous to 216-U-8 for the direct-contact exposure scenario, because a borehole could not be installed directly through the crib during site characterization activities. Because the borehole data for 216-U-12 are adjacent to the crib structure, it is assumed that the data for 216-U-8 are more representative of subsurface conditions for the direct-contact exposure pathway for 216-U-12. The 216-U-12 duration used for cost estimate purposes assumes the same duration as for 216-U-8 where the time to meet PRGs for direct-contact exposure pathway controls the implementation time.

[11]Construction QA/QC costs are included in the estimates.

[12]Costs rounded to nearest $1,000.

OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.

CDI = canyon disposition initiative.
O&M = operations and maintenance.
PRG = preliminary remediation goal.

Table F-3. Alternative 3, Trench Template Cost Input Parameters.

Waste Site/Group	Site-Specific Required Inputs					
	Non-Contaminated Soil Volume (bank ft^3)	Contaminated Soil Volume (bank ft^3)	Top Excavation Length (linear ft)	Top Excavation Width (linear ft)	Bottom Area (ft^2)	Depth of Excavation (linear ft)
Process Waste Group						
216-U-1/216-U-2	183230234	3549600	934	862	55348	200
216-U-5	67175	73500	115	115	4900	15
216-U-6	65689	63000	85	150	4200	15
216-U-8	186775814	4972800	982	872	68264	200
216-U-12	178524253	1962090	910	820	22000	200
216-U-15	23625	6000	65	65	400	15
216-U-16	210964	850714	313	242	50042	17
216-U-17	145613	235008	258	118	13056	18
200-W-42/ UPR-200-W-163	659900	589600	2010	65	39300	15
Reverse Well/French Drain Group						
216-U-4 /216-U-4A	16875	1500	55	55	100	15
216-U-4B	13740	135	50	50	25	15
Septic System Group						
2607-W5 Field - Active	9221	68000	151	115	13600	5
2607-W5 Field - Abandoned	10785	90428	189	119	18086	5
2607-W7 Field	9221	68000	151	115	13600	5
Solid Waste Group						
200-W-56	351	300	19	19	100	3
200-W-57	1701	10800	69	69	3600	3
200-W-71	48777	129150	293	79	12915	10
UPR-200-W-8	80962	425000	455	130	42500	10
Unplanned Release Group						
UPR-200-W-19	96090	837250	455	227	83725	10
UPR-200-W-118	173041	655215	254	254	43681	15
Shallow/Surface Waste Site Group						
200-W-77	389	360	17	24	120	3
200-W-85	621	1200	29	29	400	3
200-W-87	2087	10800	129	39	3600	3
200-W-89	2781	30000	109	109	10000	3
UPR-200-W-33	418	450	19	24	150	3
UPR-200-W-48	935	2999	41	41	1000	3
UPR-200-W-55	351	300	19	19	100	3
UPR-200-W-78	256	120	14	17	40	3
UPR-200-W-117	3144	18000	209	39	6000	3

Table F-4. Alternative 3, Retention Basin Template Cost Input Parameters.

Waste Site/Group	Site-Specific Required Inputs						
	Noncontaminated Soil Volume (bank ft^3)	Contaminated Soil Volume (bank ft^3)	Demolition Waste (Bank ft^3)	Top Excavation Length (linear ft)	Top Excavation Width (linear ft)	Bottom Area (square ft)	Depth of Excavation (linear ft)
Process Waste Group							
241-U-361	103125	22500	785	105	105	900	25
Septic System Group							
2607-W5 Tank	14607	7425	742.5	78	48	675	11
2607-W5 Diversion Box #2	3639	315	31.5	34	32	35	9
2607-W7 Tank	5063	88	8.8	37	35	8	11

Table F-5. Alternative 3, Trench Template Cost.

Waste Site/Group	Mobilization	Monitoring and Sampling	Uncontaminated Soil	Solids Collection	Disposal Cost[3]	Site Restoration	Revegetation	Demobilization	Project Management	Subtotal[1]	Misc. Costs[2]	Total Present Net Worth Cost	Total Capital Cost	Total O&M Cost
Process Waste Group														
216-U-1/216-U-2	$569,000	$2,090,000	$11,623,000	$2,615,000	$17,636,000	$13,704,000	$534,000	$67,000	$4,134,000	$52,973,000	-	$52,973,000	$52,973,000	-
216-U-5	$27,000	$50,000	-	$47,000	$325,000	$27,000	$7,000	$19,000	$50,000	$552,000	-	$552,000	$552,000	-
216-U-6	$26,000	$49,000	-	$43,000	$278,000	$24,000	$7,000	$19,000	$48,000	$494,000	-	$494,000	$494,000	-
216-U-8	$572,000	$2,550,000	$11,841,000	$3,529,000	$24,705,000	$14,208,000	$582,000	$67,000	$4,213,000	$62,266,000	-	$62,266,000	$62,266,000	-
216-U-12	$564,000	$17,980,000	$11,356,000	$1,602,000	$9,797,000	$13,392,000	$564,000	$67,000	$3,810,000	$42,950,000	-	$42,950,000	$42,950,000	-
216-U-15	$24,000	$42,000	-	$9,000	$27,000	$4,000	$3,000	$19,000	$27,000	$155,000	-	$155,000	$155,000	-
216-U-16	$54,000	$190,000	-	$396,000	$3,747,000	$248,000	$22,000	$19,000	$252,000	$4,928,000	-	$4,928,000	$4,928,000	-
216-U-17	$33,000	$78,000	-	$133,000	$1,034,000	$78,000	$7,000	$19,000	$102,000	$1,484,000	-	$1,484,000	$1,484,000	-
200-W-42/UPR-200-W-163	$63,000	$243,000	-	$381,000	$2,791,000	$222,000	$43,000	$21,000	$275,000	$4,039,000	-	$4,039,000	$4,039,000	-
Reverse Well/French Drain Group														
216-U-4/216-U-4A	$23,000	$41,000	-	$5,000	$7,000	$2,000	$2,000	$19,000	$25,000	$124,000	-	$124,000	$124,000	-
216-U-4B	$23,000	$41,000	-	$4,000	$1,000	$1,000	$2,000	$19,000	$24,000	$115,000	-	$115,000	$115,000	-
Septic System Group														
2607-W5 Field Active	$27,000	$45,000	-	$30,000	$300,000	$20,000	$7,000	$19,000	$39,000	$487,000	-	$487,000	$487,000	-
2607-W5 Field Abandoned	$28,000	$47,000	-	$39,000	$429,000	$26,000	$7,000	$19,000	$45,000	$640,000	-	$640,000	$640,000	-
2607-W7 Field	$38,000	$45,000	-	$30,000	$300,000	$20,000	$7,000	$30,000	$39,000	$509,000	-	$509,000	$509,000	-
Solid Waste Group														
200-W-56	$22,000	$40,000	-	$200	$1,000	$100	$1,000	$18,000	$22,000	$105,000	-	$105,000	$105,000	-
200-W-57	$24,000	$41,000	-	$5,000	$48,000	$3,000	$3,000	$19,000	$24,000	$167,000	-	$167,000	$167,000	-
200-W-71	$30,000	$54,000	-	$65,000	$570,000	$39,000	$8,000	$19,000	$60,000	$845,000	-	$845,000	$845,000	-
UPR-200-W-8	$41,000	$108,000	-	$191,000	$1,872,000	$122,000	$16,000	$19,000	$132,000	$2,501,000	-	$2,501,000	$2,501,000	-
Unplanned Release Group														
UPR-200-W-19	$55,000	$210,000	-	$404,000	$3,963,000	$250,000	$25,000	$20,000	$257,000	$5,184,000	-	$5,184,000	$5,184,000	-
UPR-200-W-118	$48,000	$154,000	-	$308,000	$3,101,000	$193,000	$17,000	$19,000	$200,000	$4,040,000	-	$4,040,000	$4,040,000	-
Shallow/Surface Waste Site Group														
200-W-77	$22,000	$40,000	-	$200	$2,000	$100	$1,000	$18,000	$22,000	$106,000	-	$106,000	$106,000	-
200-W-85	$23,000	$40,000	-	$1,000	$6,000	$400	$1,000	$18,000	$22,000	$111,000	-	$111,000	$111,000	-
200-W-87	$24,000	$41,000	-	$5,000	$48,000	$3,000	$3,000	$19,000	$24,000	$167,000	-	$167,000	$167,000	-
200-W-89	$25,000	$42,000	-	$13,000	$133,000	$8,000	$5,000	$19,000	$29,000	$274,000	-	$274,000	$274,000	-
UPR-200-W-33	$22,000	$40,000	-	$300	$3,000	$200	$1,000	$18,000	$22,000	$106,000	-	$106,000	$106,000	-
UPR-200-W-48	$23,000	$40,000	-	$1,000	$13,000	$1,000	$2,000	$19,000	$22,000	$121,000	-	$121,000	$121,000	-
UPR-200-W-55	$22,000	$40,000	-	$200	$1,000	$100	$1,000	$18,000	$22,000	$105,000	-	$105,000	$105,000	-
UPR-200-W-78	$22,000	$40,000	-	$100	$1,000	$100	$1,000	$18,000	$22,000	$104,000	-	$104,000	$104,000	-
UPR-200-W-117	$25,000	$41,000	-	$8,000	$80,000	$5,000	$4,000	$19,000	$26,000	$208,000	-	$208,000	$208,000	-

Notes:

[1]All costs in subtotal are present net worth costs.

[2]Miscellaneous cost includes cost of removal of sludge from the 241-U-361 Settling Tank.

[3]Disposal cost includes Environmental Restoration Disposal Facility disposal.

[4]Costs rounded to nearest $1,000.

[5]Construction quality assurance-quality control costs are included in the estimates.

Misc. = miscellaneous.

O&M = operations and maintenance.

Table F-6. Alternative 3, Retention Basins Cost.

Waste Site/Group	Mobilization	Monitoring and Sampling	Solids Collection	Waste Packaging/ Preparation for Disposal	ERDF Disposal Cost	Site Restoration	Revegetation	Demobilization	Project Management	Subtotal[1]	Miscellaneous Costs[2]	Total Present Worth Cost	Total Capital Cost	Total O&M Cost
Process Waste Group														
241-U-361	$25,000	$49,000	$48,000	$16,000	$90,000	$16,000	$5,000	$19,000	$48,000	$316,000	$4,762,000	$5,078,000	$5,078,000	-
Septic System Group														
2607-W5 Tank	$24,000	$42,000	$12,000	$6,000	$33,000	$4,000	$2,000	$19,000	$28,000	$170,000	-	170000	170000	-
2607-W5 Diversion Box	$23,000	$40,000	$2,000	$200	$3,000	$400	$1,000	$18,000	$22,000	$110,000	-	110000	110000	-
2607-W7 Tank	$24,000	$42,000	$12,000	$6,000	$2,000	$4,000	$2,000	$19,000	$28,000	$139,000	-	139000	139000	-

Notes:
[1]All costs in subtotal and miscellaneous costs are present worth costs.
[2]Miscellaneous cost includes cost of removal of sludge from the 241-U-361 Settling Tank.
[3]Costs rounded to nearest $1,000.
[4]Construction quality assurance-quality control costs are included in the estimates.
ERDF = Environmental Restoration Disposal Facility. O&M = operations and maintenance.

Table F-7. Alternative 4, Modified RCRA Subtitle C Barrier Template Cost Inputs. (2 pages)

Waste Site/Group	Site-Specific Required Inputs		Common Inputs/Assumptions				Volumes (cubic yards)		
	Waste Site Length (linear feet)	Waste Site Width (linear feet)	Haul Distance to Pit 30 (miles)	Haul Distance to Silt Borrow (Area C) (miles)	Haul Distance to Soil Process Area (miles)	Cap Overlap (linear feet)	Silt Loam (Layer 1 & 2)	Common Fill (Layer 8 & Berm)	Pit Material Pea Gravel & Sand
Process Waste Group									
216-U-1/216-U-2	174	102	3.2	3.8	3.2	20	2820	4561	1737
216-U-5	70	70	3.2	3.8	3.2	20	992	2042	633
216-U-6	40	105	3.2	3.8	3.2	20	925	1994	596
216-U-8	222	112	3.2	3.8	3.2	20	3786	5832	2316
216-U-12	150	60	3.2	3.8	3.2	20	1646	3036	1034
216-U-15	20	20	3.2	3.8	3.2	20	213	785	151
216-U-16	262	191	3.2	3.8	3.2	20	6952	9683	4194
216-U-17	204	64	3.2	3.8	3.2	20	2263	3939	1410
241-U-361	30	30	3.2	3.8	3.2	20	323	989	221
200-W-42/UPR-200-W-163	1965	20	3.2	3.8	3.2	20	9808	19373	6306
Reverse Well/French Drain Group									
216-U-4/216-U-4A	10	10	3.2	3.8	3.2	20	126	606	94
216-U-4B	5	5	3.2	3.8	3.2	20	91	526	71
Septic System Group									
2607-W5 Tank	45	15	3.2	3.8	3.2	20	298	962	206
2607-W5 Field Active	136	100	3.2	3.8	3.2	20	2240	3776	1388
2607-W5 Field Abandoned	174	100	3.2	3.8	3.2	20	2775	4505	1710

Table F-7. Alternative 4, Modified RCRA Subtitle C Barrier Template Cost Inputs. (2 pages)

Waste Site/Group	Site-Specific Required Inputs		Common Inputs/Assumptions				Volumes (cubic yards)		
	Waste Site Length (linear feet)	Waste Site Width (linear feet)	Haul Distance to Pit 30 (miles)	Haul Distance to Silt Borrow (Area C) (miles)	Haul Distance to Soil Process Area (miles)	Cap Overlap (linear feet)	Silt Loam (Layer 1 & 2)	Common Fill (Layer 8 & Berm)	Pit Material Pea Gravel & Sand
2607-W7 Tank	4	2	3.2	3.8	3.2	20	298	962	206
2607-W7 Field	136	100	3.2	3.8	3.2	20	2240	3776	1388
Solid Waste Group									
200-W-56	10	10	3.2	3.8	3.2	20	126	606	94
200-W-57	60	60	3.2	3.8	3.2	20	791	1743	510
200-W-71	262.5	49.2	3.2	3.8	3.2	20	2360	4233	1480
UPR-200-W-8	425	100	3.2	3.8	3.2	20	6306	9320	3839
Unplanned Release Group									
UPR-200-W-19	425	197	3.2	3.8	3.2	20	11271	14976	6758
UPR-200-W-118	209	209	3.2	3.8	3.2	20	6157	8698	3722
Shallow/Surface Waste Site Group									
200-W-77	8	15	3.2	3.8	3.2	20	136	630	101
200-W-85	20	20	3.2	3.8	3.2	20	213	785	151
200-W-87	120	30	3.2	3.8	3.2	20	870	1957	565
200-W-89	100	100	3.2	3.8	3.2	20	1733	3085	1082
UPR-200-W-33	10	15	3.2	3.8	3.2	20	184	729	132
UPR-200-W-48	32	32	3.2	3.8	3.2	20	348	1032	236
UPR-200-W-55	10	10	3.2	3.8	3.2	20	126	606	94
UPR-200-W-78	5	8	3.2	3.8	3.2	20	136	630	101
UPR-200-W-117/UPR-200-W-60	200	30	3.2	3.8	3.2	20	1356	2818	872

Table F-8a. Alternative 4, Engineered Barrier Cost Summary. (2 pages)

Waste Site/Group	Barrier Construction															
	Mobilization	Dynamic Compaction	Layer 1 -20" Topsoil W/Peagravel	Layer 2 -20" Topsoil	Layer 3 -6" Sand Filter	Layer 4 -6" Gravel Filter	Layer 5 -6" Gravel Drainage	Layer 6 -6" Asphaltic Concrete	Layer 7 -4" Base Course	Layer 8 -40" Fill	Berm	Other Minor Work Items	Revegetation	Demobilization	Project Management	Subtotal[1]
Process Waste Group																
216-U-1/216-U-2	$117,000	$29,000	$72,000	$50,000	$45,000	$0	$0	$0	$0	$105,000	$45,000	$26,000	$13,000	$77,000	$70,000	$649,000
216-U-5	$112,000	$10,000	$21,000	$15,000	$14,000	$0	$0	$0	$0	$31,000	$31,000	$9,000	$5,000	$77,000	$41,000	$366,000
216-U-6	$112,000	$9,000	$19,000	$14,000	$12,000	$0	$0	$0	$0	$27,000	$31,000	$8,000	$5,000	$77,000	$39,000	$353,000
216-U-8	$119,000	$40,000	$100,000	$69,000	$62,000	$0	$0	$0	$0	$147,000	$51,000	$36,000	$17,000	$77,000	$84,000	$803,000
216-U-12	$114,000	$16,000	$37,000	$27,000	$24,000	$0	$0	$0	$0	$55,000	$38,000	$15,000	$8,000	$77,000	$50,000	$460,000
216-U-15	$110,000	$4,000	$4,000	$3,000	$3,000	$0	$0	$0	$0	$5,000	$20,000	$3,000	$2,000	$76,000	$30,000	$260,000
216-U-16	$126,000	$79,000	$198,000	$137,000	$122,000	$0	$0	$0	$0	$292,000	$63,000	$71,000	$32,000	$78,000	$138,000	$1,334,000
216-U-17	$115,000	$22,000	$53,000	$38,000	$34,000	$0	$0	$0	$0	$78,000	$44,000	$20,000	$10,000	$77,000	$59,000	$550,000
241-U-361	$110,000	$5,000	$6,000	$5,000	$4,000	$0	$0	$0	$0	$7,000	$23,000	$4,000	$3,000	$76,000	$32,000	$275,000
200-W-42/UPR-200-W-163	$146,000	$62,000	$156,000	$108,000	$97,000	$27,000	$44,000	$695,000	$114,000	$231,000	$224,000	$56,000	$25,000	$85,000	$172,000	$2,244,000
Reverse Well/French Drain Group																
216-U-4/216-U-4A	$109,000	$4,000	$3,000	$2,000	$2,000	$0	$0	$0	$0	$3,000	$18,000	$2,000	$2,000	$76,000	$29,000	$251,000
216-U-4B	$109,000	$4,000	$2,000	$2,000	$2,000	$0	$0	$0	$0	$2,000	$17,000	$2,000	$2,000	$76,000	$29,000	$248,000
Septic System Group																
2607-W5 TANK	$110,000	$4,000	$5,000	$4,000	$4,000	$0	$0	$0	$0	$6,000	$23,000	$3,000	$3,000	$76,000	$30,000	$268,000
2607-W5 FIELD ACTIVE	$115,000	$23,000	$56,000	$39,000	$35,000	$0	$0	$0	$0	$81,000	$41,000	$21,000	$10,000	$77,000	$59,000	$557,000
2607-W5 FIELD ABANDONED	$116,000	$29,000	$70,000	$49,000	$44,000	$0	$0	$0	$0	$103,000	$45,000	$26,000	$12,000	$77,000	$68,000	$641,000
2607-W7 TANK	$109,000	$4,000	$2,000	$2,000	$2,000	$0	$0	$0	$0	$2,000	$17,000	$2,000	$2,000	$76,000	$29,000	$248,000
2607-W7 FIELD	$115,000	$23,000	$56,000	$39,000	$35,000	$0	$0	$0	$0	$81,000	$41,000	$21,000	$10,000	$77,000	$59,000	$557,000
Solid Waste Group																
200-W-56	$109,000	$4,000	$3,000	$2,000	$2,000	$0	$0	$0	$0	$3,000	$18,000	$2,000	$2,000	$76,000	$29,000	$251,000
200-W-57	$111,000	$8,000	$16,000	$12,000	$11,000	$0	$0	$0	$0	$23,000	$29,000	$7,000	$4,000	$76,000	$38,000	$336,000
200-W-71	$116,000	$22,000	$53,000	$37,000	$33,000	$0	$0	$0	$0	$77,000	$49,000	$20,000	$10,000	$77,000	$59,000	$553,000
UPR-200-W-8	$125,000	$67,000	$169,000	$117,000	$104,000	$0	$0	$0	$0	$249,000	$71,000	$60,000	$27,000	$78,000	$123,000	$1,192,000
Unplanned Release Group																
UPR-200-W-19	$136,000	$130,000	$330,000	$229,000	$203,000	$0	$0	$0	$0	$489,000	$81,000	$117,000	$52,000	$79,000	$211,000	$2,056,000
UPR-200-W-118	$117,000	$69,000	$173,000	$120,000	$107,000	$0	$0	$0	$0	$256,000	$60,000	$62,000	$28,000	$78,000	$61,000	$1,131,000
Shallow/Surface Waste Site Group																
200-W-77	$109,000	$4,000	$3,000	$3,000	$3,000	$0	$0	$0	$0	$3,000	$19,000	$2,000	$2,000	$76,000	$29,000	$252,000
200-W-85	$110,000	$4,000	$4,000	$3,000	$3,000	$0	$0	$0	$0	$5,000	$20,000	$3,000	$2,000	$76,000	$30,000	$261,000
200-W-87	$112,000	$8,000	$16,000	$12,000	$11,000	$0	$0	$0	$0	$23,000	$32,000	$7,000	$4,000	$77,000	$38,000	$340,000
200-W-89	$114,000	$18,000	$41,000	$29,000	$26,000	$0	$0	$0	$0	$60,000	$37,000	$16,000	$8,000	$77,000	$52,000	$479,000

Table F-8a. Alternative 4, Engineered Barrier Cost Summary. (2 pages)

Waste Site/Group	Barrier Construction															
	Mobilization	Dynamic Compaction	Layer 1 -20" Topsoil W/Peagravel	Layer 2 -20" Topsoil	Layer 3 -6" Sand Filter	Layer 4 -6" Gravel Filter	Layer 5 -6" Gravel Drainage	Layer 6 -6" Asphaltic Concrete	Layer 7 -4" Base Course	Layer 8 -40" Fill	Berm	Other Minor Work Items	Revegetation	Demobilization	Project Management	Subtotal[1]
UPR-200-W-33	$110,000	$4,000	$3,000	$3,000	$3,000	$0	$0	$0	$0	$4,000	$20,000	$3,000	$2,000	$76,000	$30,000	$258,000
UPR-200-W-48	$110,000	$5,000	$6,000	$5,000	$5,000	$0	$0	$0	$0	$8,000	$23,000	$4,000	$3,000	$76,000	$32,000	$277,000
UPR-200-W-55	$109,000	$4,000	$3,000	$2,000	$2,000	$0	$0	$0	$0	$3,000	$18,000	$2,000	$2,000	$76,000	$29,000	$251,000
UPR-200-W-78	$109,000	$4,000	$3,000	$3,000	$3,000	$0	$0	$0	$0	$3,000	$19,000	$2,000	$2,000	$76,000	$29,000	$252,000
UPR-200-W-117/ UPR-200-W-60	$113,000	$12,000	$26,000	$18,000	$17,000	$0	$0	$0	$0	$37,000	$40,000	$10,000	$6,000	$77,000	$43,000	$399,000

Notes:

1. All costs in subtotal are present net worth costs.

OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.*

PRG = preliminary remediation goal.

Table F-8b. Alternative 4, Engineered Barrier Cost Summary. (2 pages)

Waste Site/Group	Duration[2]	Barrier Maintenance Cost/20 years[3]	Barrier Maintenance (Present Worth Cost)[4]	Barrier Performance Monitoring[5] (Present Worth Cost)[4]	Annual Groundwater Monitoring Cost[7]	Present Worth of Groundwater Monitoring[4]	Groundwater Well Replacement Cost/ 30 years[8]	Present Worth of Groundwater Well Replacement[4]	Groundwater Monitoring (Present Worth Cost)[4]	Miscellaneous Costs[6]	Total Present Worth Cost[4]	Total Capital Cost	Total O&M Cost
Process Waste Group													
216-U-1/216-U-2	1000	$9,000	$10,000	$445,000	$2,000	$63,000	$210,000	$134,000	$196,000	$47,000	$1,347,000	$696,000	$13,805,000
216-U-5	141	$3,000	$3,000	$444,000	$2,000	$62,000	$210,000	$132,000	$194,000	-	$1,007,000	$366,000	$2,223,000
216-U-6	141	$3,000	$3,000	$444,000	$2,000	$62,000	$210,000	$132,000	$194,000	-	$994,000	$353,000	$2,222,000
216-U-8	1000	$12,000	$13,000	$445,000	$2,000	$63,000	$210,000	$134,000	$196,000	$141,000	$1,598,000	$944,400	$13,960,000
216-U-12	1000	$5,000	$5,000	$445,000	$2,000	$63,000	$210,000	$134,000	$196,000	-	$1,106,000	$460,000	$13,610,000
216-U-15	141	$1,000	$1,000	$444,000	$2,000	$62,000	$210,000	$132,000	$194,000	-	$899,000	$260,000	$2,209,000
216-U-16	141	$23,000	$26,000	$444,000	$2,000	$62,000	$210,000	$132,000	$194,000	-	$1,998,000	$1,334,000	$2,364,000
216-U-17	141	$7,000	$7,000	$444,000	$2,000	$62,000	$210,000	$132,000	$194,000	-	$1,195,000	$550,000	$2,249,000
241-U-361	128	$1,000	$1,000	$443,000	$2,000	$61,000	$210,000	$131,000	$193,000	$4,762,000	$5,674,000	$5,037,000	$2,042,000
200-W-42/UPR-200-W-163	831	$18,000	$21,000	$445,000	$2,000	$63,000	$210,000	$134,000	$196,000	-	$2,906,000	$2,244,000	$11,921,000
Reverse Well/French Drain Group													
216-U-4/216-U-4A	125	$1,000	$1,000	$443,000					-	-	$695,000	$251,000	$874,000
216-U-4B	125	$1,000	$1,000	$443,000					-	-	$692,000	$248,000	$874,000
Septic System Group													
2607-W5 TANK	129	$1,000	$1,000	$443,000					-	-	$1,927,000	$1,466,000	$990,000
2607-W5 FIELD ACTIVE	129	$7,000	$8,000										
2607-W5 FIELD ABANDONED	129	$8,000	$9,000										

Table F-8b. Alternative 4, Engineered Barrier Cost Summary. (2 pages)

Waste Site/Group	Duration[2]	Barrier Maintenance Cost/20 years[3]	Barrier Maintenance (Present Worth Cost)[4]	Barrier Performance Monitoring[5] (Present Worth Cost)[4]	Annual Groundwater Monitoring Cost[7]	Present Worth of Groundwater Monitoring[4]	Groundwater Well Replacement Cost/ 30 years[8]	Present Worth of Groundwater Well Replacement[4]	Groundwater Monitoring (Present Worth Cost)[4]	Miscellaneous Costs[6]	Total Present Worth Cost[4]	Total Capital Cost	Total O&M Cost
2607-W7 TANK	129	$1,000	$1,000	$443,000					-	-	$1,257,000	$805,000	$934,000
2607-W7 FIELD	129	$7,000	$8,000										
Solid Waste Group													
200-W-56	129	$1,000	$1,000	$443,000					-	-	$695,000	$251,000	$891,000
200-W-57	129	$2,000	$2,000	$443,000					-	-	$781,000	$336,000	$900,000
200-W-71	129	$7,000	$7,000	$443,000					-	-	$1,003,000	$553,000	$928,000
UPR-200-W-8	129	$19,000	$22,000	$443,000					-	-	$1,657,000	$1,192,000	$1,011,000
Unplanned Release Group													
UPR-200-W-19	129	$38,000	$42,000	$443,000					-	-	$2,541,000	$2,056,000	$1,130,000
UPR-200-W-118	129	$20,000	$22,000	$443,000					-	-	$1,596,000	$1,131,000	$1,015,000
Shallow/Surface Waste Site Group													
200-W-77	129	$1,000	$1,000	$443,000					-	-	$696,000	$252,000	$891,000
200-W-85	129	$1,000	$1,000	$443,000					-	-	$705,000	$261,000	$891,000
200-W-87	129	$2,000	$2,000	$443,000					-	-	$785,000	$340,000	$900,000
200-W-89	129	$5,000	$6,000	$443,000					-	-	$928,000	$479,000	$919,000
UPR-200-W-33	129	$1,000	$1,000	$443,000					-	-	$702,000	$258,000	$891,000
UPR-200-W-48	129	$1,000	$1,000	$443,000					-	-	$721,000	$277,000	$894,000
UPR-200-W-55	129	$1,000	$1,000	$443,000					-	-	$695,000	$251,000	$891,000
UPR-200-W-78	129	$1,000	$1,000	$443,000					-	-	$696,000	$252,000	$891,000
UPR-200-W-117/ UPR-200-W-60	$129	$4,000	$4,000	$443,000					-	-	$846,000	$399,000	$909,000

Notes:

2. Duration corresponds to time required to meet PRGs at representative waste site or analogous site with sufficient data for risk assessment (200-W-42/UPR-200-W-163 and 216-U-1&2).
3. Barrier maintenance cost assumes replacement of 6 in. of Layer 1 topsoil and pea gravel over 25% of barrier area with associated revegetation every 20 years.
4. Real discount rate used for present net worth calculation of 3.2% was from Appendix C of OMB Circular No. A-94, which is effective through the end of January 2004.
5. Barrier Performance Monitoring assumes: $50,000/yr for first 5 years, $20,000/yr for the following 10 years, and $20,000/5 yr for the remainder of the duration. Barrier performance monitoring costs are based on actual costs provided by Fluor Hanford for monitoring the 200-BP-1 prototype barrier for fiscal years 2002 through 2004.
6. Miscellaneous cost includes cost of removal of sludge from the 241-U-361 Settling Tank and stabilization of the 216-U-1, 216-U-2, and 216-U-8 Cribs.
7. Annual groundwater monitoring costs assume sampling and analysis of mobile-deep vadose zone contaminants of concern (e.g., Tc-99 and nitrate) at one down-gradient well per waste site at a cost of $2,000 per sampling event.
8. The service life of a groundwater well is assumed to be 30 years. Well replacement costs assume the well will extend to groundwater (255 ft) plus a 10-ft well screen.
9. Costs rounded to nearest $1,000.
10. Construction quality assurance-quality control costs are included in the estimates.

OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.*

PRG = preliminary remediation goal.

APPENDIX G

EXCAVATION OF THE 216-U-1/216-U-2 CRIBS, 216-U-8 CRIB, AND 216-U-12 CRIB

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TERMS

ALARA	as low as reasonably achievable
CFR	*Code of Federal Regulations*
CTA	container transfer area
EPC	exposure-point concentration
ERDF	Environmental Restoration Disposal Facility
RCT	Radiological Control Technician
V&V	Verification and Validation

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APPENDIX G

EXCAVATION OF THE 216-U-1/216-U-2 CRIBS, 216-U-8 CRIB, AND 216-U-12 CRIB

G1.0 INTRODUCTION

In support of the focused feasibility study, this appendix presents an evaluation of worker doses for several maximally exposed receptors involved in the remediation of the selected cribs in the 200-UW-1 Operable Unit.

This worker dose evaluation concentrates solely on the maximally exposed individuals engaged in excavation and removal of contaminated soils from designated waste cribs in the 200-UW-1 Operable Unit.

This evaluation pertains only to the designated waste sites with contaminants at depths exceeding the groundwater protection criteria (i.e., 216-U-1/216-U-2, 216-U-8, and 216-U-12 Cribs). Worker dose evaluations have been conducted only at these waste sites. This evaluation provides the following:

- A brief background history of the site and the technical aspects of the study
- The assumptions used in the analysis
- Descriptions of the processes considered for remediating the site
- Details regarding the receptors being evaluated
- The analysis and the results.

G2.0 BACKGROUND HISTORY AND TECHNICAL ASPECTS

G2.1 DESIGNATED WASTE SITES

Liquid effluents, including acidic process condensate and acidic decontamination waste from the 221-U and 224-U Process Canyon Buildings, were distributed to waste sites through various pipelines. Decontamination waste disposed of to the cribs contained a plethora of differing radionuclides that were considered in this evaluation of receptor doses during excavation activities.

Section G2.0 presents the process history and characterization activities of each waste site in detail. The following is a brief overview of the areas designated for deep excavation remediation.

- **216-U-8 Crib**. This crib received acidic process condensate from the 221-U and 224-U Buildings along with drainage from the 291-U Stack via an underground, vitrified clay pipeline from 1952 through 1960.

- **216-U-12 Crib**. This crib received 291-U-1 Stack drainage, 244-WR Vault waste, and 224-U process condensate via the C-5 Tank from 1960 to 1967. Water contaminated with 3.14 kg of thorium was discharged to the crib in 1965. The crib also received corrosive process condensate and miscellaneous storm drain waste from the 224-U Building from 1981 through 1987.

- **216-U-1 and 216-U-2 Cribs**. These cribs received overflow from the 241-U-361 Settling Tank and from the 224-U Facility and equipment decontamination waste and reclamation waste from the 221-U Canyon. The 241-U-361 Settling Tank received cell drainage from the 5-6 Tank in the 221-U Canyon and waste from the 224-U Building until the uranium recovery process operations shut down in 1957.

Table G-1 describes the source terms used in this study for the 216-U-1/216-U-2, 216-U-8, and 216-U-12 Cribs. The source terms were obtained from the risk assessment in Appendix C.

G2.2 OPERATIONS SUMMARY

To remove the contaminated soils, an excavator will be positioned on top of the contaminated area (that is, the overburden at ground level) and move down as it proceeds, excavating the contaminated area to a depth of approximately 200 ft. The excavation is planned on the basis of a 1.5 to 1 slope (horizontal-vertical) with a 10-ft bench every 25 ft of depth. As the soils are being excavated, a laborer will stand above the excavator on a bench and spray to suppress dust in accordance with normal industrial practices. Radiological control technicians (RCT) will perform frequent radiological surveys inside the pit, but because RCTs are assumed to work in the pit less than full-time, the doses for this receptor will be bounded by the doses calculated for the laborer.

The excavated soils will be placed in a plastic-lined, Environmental Restoration Disposal Facility (ERDF)-compatible roll-on/roll-off container located adjacent to the excavator. An in-pit shuttle truck driver will load the container to a nominal volume of 320 ft^3 (BHI-01558, *116-N-1 Trench Level II ALARA Review*), then move the container to a nearby radiological survey location. There, the liner will be folded and tack-welded closed, and the container will be surveyed to ensure that ERDF waste acceptance criteria are satisfied. In addition, laborers will install a container cover to prevent dust from blowing as the container is transported on public roads. Installation of the cover and completion of the radiological surveys is assumed to take about 3 to 5 minutes. (Because of the short exposure time for both the laborer and RCT, an exposure assessment will not be performed for these receptors, as doses will be bounded by those calculated for the in-pit receptors.) The container then will be hauled a short distance to the container transfer area (CTA) for staging. A different truck will pick up the container and drive it to the ERDF for final disposal. Again, the exposure times during transport from CTA to the ERDF are minimal and shielding features associated with the vehicle will protect the driver from direct radiation. Therefore, an exposure assessment is not considered for this receptor.

G2.3 POTENTIALLY EXPOSED RECEPTORS

Based on the operations summary provided in the previous section, the following three maximally exposed receptors are identified for consideration.

- Excavator operator located in the pit removing contaminated soils
- Haul truck drivers transporting contaminated materials to the CTA
- Laborer providing dust suppression in the pit during excavation operations.

Although multiple exposure assessments and scenarios can be envisioned and evaluated for all personnel involved in the excavation operations, it is only necessary to evaluate the maximally exposed receptors. The results of their evaluation then bounds all other scenarios.
Other potential receptors are the following:

- Haul truck drivers transporting contaminated materials to the CTA and ERDF
- Laborer tack welding and installing transportation dust covers on the shuttle trucks
- RCTs performing radiological surveys in the pit, during conveyance, and while the bulldozer operator spreads the excavated material in the ERDF
- Bulldozer Operator spreading excavated materials within the confines of the ERDF.

G3.0 ASSUMPTIONS

1. The source terms obtained from the risk assessment (Appendix C) and provided in Table G-1 are used in the analysis. The radionuclides are assumed to be uniformly distributed throughout the waste site at the reported concentrations.

2. A soil density of 1.8 g/cm^3 (115 lb/ft^3) is assumed for the waste cribs. This is an averaged value for the waste sites, based on the soil densities provided in Appendix D and the strata thickness identified in Appendix C.

3. Selected waste site dimensions, volumes, and excavation durations are provided in Table G-2. The average waste site dimension and volume are used as the preferred geometry for the analysis (see Figure G-1). The calculations that bound the analysis are performed at three locations across the top of the rectangular volume: the centerline of the rectangle, the side of the rectangle, and leading edge of the rectangle, as depicted in Figure G-1.

4. Excavator Operator - The excavator operator is assumed to be 5 ft above the waste and bottom-shielded with 0.5 in. of steel (cab construction material) and 1 in. of lead (added). (This shielding is assumed because of the long exposure times to the excavator operator.)

5. Laborer Spraying for Dust - A laborer will stand adjacent to the excavator operator on clean soil at the edge of the excavation to spray the excavated soils to suppress dust in accordance with normal industrial practices. The laborer is assumed to be positioned at

the edge of the trench 100 percent of the time. Doses will be calculated at approximately 3 ft above the ground at the mid-plane of the laborer's torso.

6. In Pit Shuttle Truck Driver – The in-pit shuttle truck driver will be assumed to rotate into and out of the pit routinely to keep the excavator operator working at peak efficiency. The operator is assumed to be bottom shielded with 0.5 in. of steel (cab construction material) and 1 in. of lead (added). This shielding is assumed based on the long exposure times to the excavator operator. The operator is assumed to be 5 ft above the level of the waste.

7. ERDF Container - The excavated soil will be placed in a plastic-lined, ERDF-compatible roll-on/roll-off container located adjacent to the excavator. The container will be loaded to a nominal volume of 320 ft^3 (BHI-01558).

8. Seal and Cover ERDF Container - After being loaded and moved to a nearby radiological survey location, the container's liner will be folded and tack-welded closed, and the container will be surveyed by an RCT to ensure that ERDF waste acceptance criteria are satisfied. Also, laborers will install a container cover to prevent dust from blowing as the container is transported on public roads. Sealing and covering the ERDF container and completing the radiological surveys is assumed to take about 3 to 5 minutes. Because of these short exposure times for both laborers and RCTs, exposure assessments will not be performed for these receptors; their doses will be bounded by those of the laborer tasked with dust suppression.

9. Shuttle Truck – Once its liner is tack-welded and the cover installed, the ERDF container is then hauled a short distance to the CTA for staging and later pick up. A different truck will pick up the container and drive it to the ERDF for final disposal. Because the exposure times during transport from the CTA to the ERDF are minimal, the shuttle truck driver's dose will be bounded by that calculated for the in-pit shuttle drivers.

10. It is assumed that normal radiological air monitoring practices will be implemented during excavation operations to ensure that worker exposures are maintained below the Derived Air Concentration Guide presented in Title 10, *Code of Federal Regulations* (CFR), Part 20, Subpart 835, "Occupational Radiation Protection," for the worst case radionuclide identified in the contaminated area being excavated. Therefore, inhalation exposures to workers will not be evaluated.

11. Based on the operations summary and the duration of the receptors assumed residence time (see Table G-3), the following three receptors have been identified as the maximally exposed receptors. The calculations for these workers will thus bound the doses incurred by any other receptor involved in this soil remediation project.

    - Excavator operator is located within the pit removing contaminated soils
    - Shuttle truck drivers are transporting contaminated materials to the CTA
    - Laborer is providing dust suppression in the pit during excavation operations.

G4.0 RESULTS OF THE ANALYSIS

G4.1 MICROSHIELD SHIELDING CODE

For all of the dose calculations, the MicroShield,[1] Version 6.02, shielding code (*MicroShield Shielding Code* [Grove Engineering] was chosen as the preferred shielding code because it provides the user with the flexibility to choose between a multitude of geometric configurations that, in most cases, closely approximate the configuration being modeled. Specifically, the code provides the following:

- More versatile geometries that generally allow offsets from the main axis of symmetry
- Increased number of shields and a great deal of flexibility in their application
- Sensitivity analysis for dimensional variations within a single analysis
- Photon energies between 15 KeV and 15 MeV
- Several energy grouping methods
- User-defined materials
- Radioactive decay of the source with complete generation of decay-chain daughters
- Several energy grouping methods.

MicroShield v6.02 has been verified and validated in accordance with Grove Engineering's Quality Assurance Plan, which implements the requirements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." Grove Engineering has made a verification and validation report available to provide users with a report that can readily be reviewed or audited by independent authorities. The report offers a compendium of the technical basis for MicroShield and consolidates information sources used over the years in its development.

G4.2 RESULTS

Tables G-4 through G-6 provide the results of the analysis for review. The associated MicroShield input and output files, which provide the receptors' locations and dose rates based on the concentrations provided in Table G-1, are included as an attachment to this analysis.

G5.0 CONCLUSIONS

The goal of this analysis was to evaluate doses to the maximally exposed receptors during the remediation of the 216-U-1/216-U-2, 216-U-8, and 216-U-12 waste cribs within the confines of the 200-UW-1 Operable Unit. As expected, for all receptors and their respective locations in the

[1] MicroShield is a trademark of Grove Engineering, Rockville, Maryland.

waste crib the highest doses were calculated at the center, with lower doses calculated at the sides.

As shown in Table G-7, doses to the excavator operator and the in-pit shuttle truck driver are slightly less than those calculated for the laborer providing dust suppression. The lower doses are expected because of the shielding provided by the cab and the added lead. On comparison of the final results, the laborer would be considered the maximally exposed receptor in all cases analyzed.

Although the calculated doses to all receptors are high for the 216-U-1/216-U-2 and 216-U-8 Cribs, the analysis assumed that only one person would be performing each task (i.e., one laborer, one excavator operator, and one in-pit shuttle truck driver), when in reality, many personnel would be performing the work. For example, the analysis assumed that only one laborer would be performing work 6 hours per day for the entire exhumation period, but most as low as reasonably achievable (ALARA) exposure goals for U.S. Department of Energy sites would limit worker doses to 500 to 1,000 mrem/year. Based on these goals, multiple laborers would be required to work at the site to share the doses incurred, and additional radiological controls would have to be implemented to maintain those set ALARA exposure goals.

Additional radiological controls may include but are not limited to preventing the need for the laborer to enter the active exhumation area by using a water cannon from the edge of the clean area, where shielding would be provided by the metal structural frame of the cannon. Additional lead shielding could be added to the cannon's main structural frame and to the cab of the excavator and in-pit shuttle truck.

G6.0 REFERENCES

10 CFR 20, Part 835, "Occupational Radiation Protection," Title 10, *Code of Federal Regulations*, Part 20, Part 835, as amended.

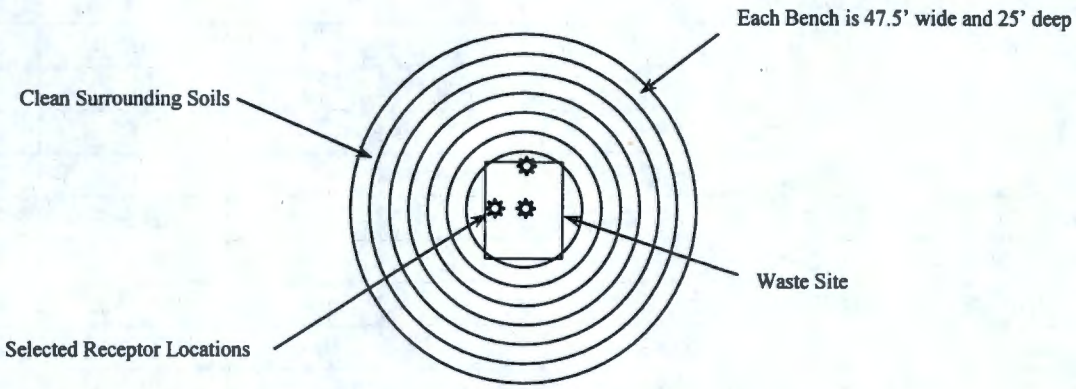
10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," Title 10, *Code of Federal Regulations*, Part 50, as amended.

BHI-01558, 2001, *116-N-1 Trench Level II ALARA Review*, Rev.0, Bechtel Handford, Inc., Richland Washington.

Grove Engineering, *MicroShield Shielding Code*, Version 6.02, Grove Engineering, Rockville, Maryland.

Figure G-1. Excavation Configuration for Deep Soils Based on a 1.5:1 Slope.

Top View



Side View

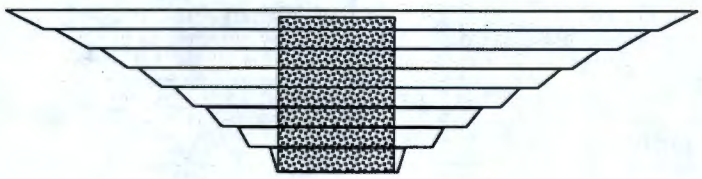


Table G-1. Exposure Point Concentrations for the Designated Waste Site.

Constituent Name	216-U-1/216-U-2 EPC[a]		216-U-12 EPC[b]		216-U-8 EPC[c]	
	(pCi/g)	µCi/cm^3[d]	(pCi/g)	µCi/cm^3[(D)]	(pCi/g)	µCi/cm^3[d]
Americium-241	3.46E+00	6.22E-06	-	-	9.19E-01	1.65E-06
Barium-137m[e]	1.04E+05	1.87E-01	-	-	8.63E+04	1.55E-01
Cesium-134	4.93E+00	8.87E-06	-	-	-	-
Cesium-137	1.10E+05	1.99E-01	-	-	9.12E+04	1.64E-01
Cobalt-60	3.51E-01	6.32E-07	-	-	-	-
Curium-244	6.70E-02	1.21E-07	-	-	5.20E-01	9.36E-07
Europium-152	5.41E-02	9.73E-08	-	-	7.80E-02	1.40E-07
Europium-154	9.63E-01	1.73E-06	-	-	8.67E-02	1.56E-07
Europium-155	3.82E-02	6.88E-08	-	-	1.23E+00	2.22E-06
Iodine-129	1.60E+00	2.88E-06	-	-	3.17E+04	5.70E-02
Neptunium-237	3.04E-01	5.47E-07	-	-	9.20E-02	1.66E-07
Plutonium-238	5.09E-01	9.16E-07	-	-	7.66E-02	1.38E-07
Plutonium-239/240	1.80E+02	3.23E-04	-	-	4.95E+00	8.91E-06
Potassium-40	1.37E+01	2.47E-05	1.30E+01	2.34E-05	1.54E+01	2.77E-05
Radium-226	7.44E-01	1.34E-06	5.60E-01	1.01E-06	1.10E+00	1.97E-06
Radium-228	4.33E-01	7.79E-07	2.92E-01	5.26E-07	6.42E-01	1.16E-06
Selenium-79	1.00E+01	1.80E-05	-	-	9.47E+00	1.70E-05
Sodium-22	1.77E-01	3.18E-07	-	-	-	-
Strontium-90	1.41E+05	2.55E-01	-	-	4.20E+02	7.56E-04
Technetium-99	3.29E+01	5.92E-05	4.88E-01	8.78E-07	2.52E+01	4.54E-05
Thorium-228	1.14E-01	2.06E-07	3.24E-02	5.84E-08	3.72E-01	6.70E-07
Thorium-232	8.97E-01	1.61E-06	8.90E-01	1.60E-06	1.26E+00	2.26E-06
Uranium-233/234	1.09E+01	1.97E-05	8.71E-01	1.57E-06	1.18E+02	2.13E-04
Uranium-234	8.80E+00	1.58E-05	2.50E-01	4.50E-07	9.63E+00	1.73E-05
Uranium-235	2.45E+01	4.41E-05	1.30E-01	2.33E-07	1.09E+01	1.96E-05
Uranium-238	7.80E+02	1.40E-03	9.54E-01	1.72E-06	6.65E+01	1.20E-04
Yttrium	1.41E+05	2.55E-01	-	-	4.20E+02	7.56E-04

Notes:

[a]Values provided from Appendix C, Table C-11.
[b]Values provided from Appendix C, Table C-9.
[c]Values provided from Appendix C, Table C-8.
[d]Based on an average bulk density of 1.8 g/cm^3.
[e]Missing from source term information but must be included, because barium-137m and yttrium-90 are in secular equilibrium with cesium-137 and strontium-90 parents.
- = no value provided.
EPC = exposure-point concentration.

Table G-2. Selected Waste Site Dimensions, Volumes, and Excavation Durations.[a]

Waste Site/Group	Site-Specific Required Inputs					
	Non-Contaminated Soil Volume (ft^3)	Contaminated Soil Volume (ft^3)	Waste Site Dimensions Length/Width (linear ft)	Top Excavation Length/Width (linear ft)[b]	Depth of Excavation (linear ft)	Estimated Excavation Duration per Waste Site (months)
Process Waste Group						
216-U-1/ 216-U-2	183,230,234	3,549,600	174/102	934/862	200	16
216-U-8	186,775,814	4,972,800	222/112	982/872	200	16
216-U-12	178,524,253	1,962,090	150/60	910/820	200	13
Average	**182,843,434**	**3,494,830**	**182/91**	**942/851**	**200**	**15**

Notes:

[a] Values obtained from Appendix F.

[b] Dimensional size required to excavate waste site plus surrounding clean soils and maintain a 1.5:1 slope with a 10-ft bench at each 25-ft level.

Table G-3. Summary of Exposed Receptors and Exposure Scenarios.

Exposure Scenario	Soil Concentration ($\mu Ci/cm^3$)	Distance To Source (ft)	Shielding (in.)	Exposure Time[a] (hrs/day)	Days/Yr	Excavation Duration per Waste Pit (yrs)[b]	Total Exposure Time per Waste Pit (hrs)[c]
Excavator operator	Table G-1	5	0.5 (steel) 1.0 (lead)	6	260	1.25	2,700
In-pit shuttle truck drivers	Table G-1	5	0.5 (steel) 1.0 (lead)	2[d]	260	1.25	900
Laborer (dust suppression)	Table G-1	3	None	6	260	1.25	2,700

Notes:

[a] A 6-hour exposure period is based on an 8-hour work day minus 2 hours of breaks, morning safety meetings, morning equipment maintenance, etc.

[b] Assumed at 15 months per crib. Excavation duration is based on cost model data presented in Appendix F.

[c] Assumes a 52-week per year operation.

[d] Assumes three truck drivers who rotate into the pit to keep excavator operator working at peak efficiency.

Table G-4. Summary of Dose Results for Cribs 216-U-1/216-U-2.

Receptor	Location	Attachment 1 MicroShield File Name	216-U-1/216-U-2 Dose Rate (mR/h)[a]	Total Exposure Time per Waste Pit (hrs)[b]	Person-rem Dose[c]
Excavator operator	Center of waste pit	216-U-1/2 Operators.ms6	4.29E+01	2,700	1.16E+02
	Middle of long rectangular side	216-U-1/2 Operators.ms6	2.14E+01	2,700	5.78E+01
	Middle of short rectangular side	216-U-1/2 Operators.ms6	2.14E+01	2,700	5.78E+01
In-pit shuttle truck drivers	Center of waste pit	216-U-1/2 Operators.ms6	4.29E+01	900	3.86E+01
	Middle of long rectangular side	216-U-1/2 Operators.ms6	2.14E+01	900	1.93E+00
	Middle of short rectangular side	216-U-1/2 Operators.ms6	2.14E+01	900	1.93E+00
Laborer (dust suppression)	Center of waste pit	216-U-1/2 Laborers.ms6	2.94E+02	2,700	7.93E+02
	Middle of long rectangular side	216-U-1/2 Laborers.ms6	1.47E+02	2,700	3.97E+02
	Middle of short rectangular side	216-U-1/2 Laborers.ms6	1.47E+02	2,700	3.97E+02

Notes:

[a]Values obtained from the output files provided in Attachment 1.

[b]Values obtained from Table G-3.

[c]Only one receptor was evaluated.

Table G-5. Summary of Dose Results for Crib 216-U-8.

Receptor	Location	Attachment 1 MicroShield File Name	216-U-8 Dose Rate (mR/h) [a]	Total Exposure Time per Waste Pit (hrs) [b]	Person-rem Dose [c]
Excavator operator	Center of waste pit	216-U-8 Operators.ms6	7.52E-01	2,700	2.03E+00
	Middle of long rectangular side	216-U-8 Operators.ms6	3.76E-01	2,700	1.02E+00
	Middle of short rectangular side	216-U-8 Operators.ms6	3.67E-01	2,700	1.02E+00
In-pit shuttle truck drivers	Center of waste pit	216-U-8 Operators.ms6	7.52E-01	900	6.77E-01
	Middle of long rectangular side	216-U-8 Operators.ms6	3.76E-01	900	3.38E-01
	Middle of short rectangular side	216-U-8 Operators.ms6	3.67E-01	900	3.38E-01
Laborer (dust suppression)	Center of waste pit	216-U-8 Laborers.ms6	3.71E+01	2,700	1.00E+02
	Middle of long rectangular side	216-U-8 Laborers.ms6	1.85E+01	2,700	5.00E+01
	Middle of short rectangular side	216-U-8 Laborers.ms6	1.85E+01	2,700	5.00E+01

Notes:
[a]Values obtained from the output files provided in Attachment 1.
[b]Values obtained from Table G-3.
[c]Only one receptor evaluated.

Table G-6. Summary of Dose Results for Crib 216-U-12.

Receptor	Location	Attachment 1 MicroShield File Name	216-U-12 Dose Rate (mR/h) [a]	Total Exposure Time per Waste Pit (hrs) [b]	Person-rem Dose [c]
Excavator operator	Center of waste pit	216-U-12 Operators.ms6	2.33E-04	2,700	6.29E-04
	Middle of long rectangular side	216-U-12 Operators.ms6	1.16E-04	2,700	3.13E-04
	Middle of short rectangular side	216-U-12 Operators.ms6	1.16E-04	2,700	3.13E-04
In-pit shuttle truck drivers	Center of waste pit	216-U-12 Operators.ms6	2.33E-04	900	2.10E-04
	Middle of long rectangular side	216-U-12 Operators.ms6	1.16E-04	900	1.04E-04
	Middle of short rectangular side	216-U-12 Operators.ms6	1.16E-04	900	1.04E-04
Laborer (dust suppression)	Center of waste pit	216-U-12 Laborers.ms6	1.93E-03	2,700	5.21E-03
	Middle of long rectangular side	216-U-12 Laborers ms6	9.64E-04	2,700	2.60E-03
	Middle of short rectangular side	216-U-12 Laborers ms6	9.64E-04	2,700	2.60E-03

Notes:

[a]Values obtained from the output files provided in Attachment 1.

[b]Values obtained from Table G-3.

[c]Only one receptor was evaluated.

Table G-7. Summary of Dose Results for the Deep Excavation of the 216-U-1/216-U-2, 216-U-8, and 216-U-12 Cribs.

Receptor	Location	216-U-1/216-U-2 Person-rem Dose	216-U-8 Person-rem Dose	216-U-12 Person-rem Dose
Excavator operator	Center of waste pit	1.16E+02	2.03E+00	6.29E-04
	Middle of long rectangular side	5.78E+01	1.02E+00	3.13E-04
	Middle of short rectangular side	5.78E+01	1.02E+00	3.13E-04
In-pit shuttle truck drivers	Center of waste pit	3.86E+01	6.77E-01	2.10E-04
	Middle of long rectangular side	1.93E+00	3.38E-01	1.04E-04
	Middle of short rectangular side	1.93E+00	3.38E-01	1.04E-04
Laborer (dust suppression)	Center of waste pit	7.93E+02	1.00E+02	5.21E-03
	Middle of long rectangular side	3.97E+02	5.00E+01	2.60E-03
	Middle of short rectangular side	3.97E+02	5.00E+01	2.60E-03

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ATTACHMENT G1

MICROSHIELD RUNS

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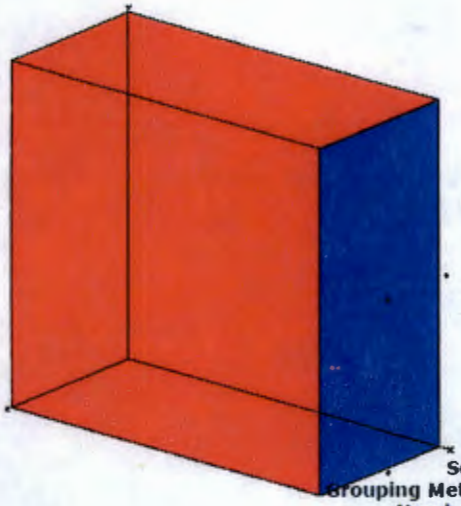
MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-1-2 Operators.ms6
Run Date : August 9, 2004
Run Time : 7:02:38 AM
Duration : 00:00:56

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-1/2 Waste Crib
Description: Excavator and In-pit Shuttle Truck Operators
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6248.4 cm	2773.68 cm	1371.6 cm
	205 ft	91 ft	45 ft
# 2	6248.4 cm	0 cm	1371.6 cm
	205 ft	0.0 in	45 ft
# 3	6248.4 cm	2773.68 cm	0 cm
	205 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.31e+06 ft³	Hanford Soils	1.8
Shield 1	.004 ft	Iron	7.86
Shield 2	.083 ft	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	5.8342e-001	2.1586e+010	6.2200e-006	2.3014e-001
Ba-137m	1.7540e+004	6.4898e+014	1.8700e-001	6.9190e+003
Cm-244	8.3198e-001	3.0783e+010	8.8700e-006	3.2819e-001
Co-60	1.8666e+004	6.9063e+014	1.9900e-001	7.3630e+003
Cs-134	5.9280e-002	2.1933e+009	6.3200e-007	2.3384e-002
Cs-137	1.1349e-002	4.1993e+008	1.2100e-007	4.4770e-003
Eu-152	9.1264e-003	3.3768e+008	9.7300e-008	3.6001e-003
Eu-154	1.6227e-001	6.0039e+009	1.7300e-006	6.4010e-002
Eu-155	6.4532e-003	2.3877e+008	6.8800e-008	2.5456e-003
I-129	2.7013e-001	9.9950e+009	2.8800e-006	1.0656e-001
K-40	2.3168e+000	8.5721e+010	2.4700e-005	9.1390e-001
Na-22	2.9827e-002	1.1036e+009	3.1800e-007	1.1766e-002
Np-237	5.1307e-002	1.8984e+009	5.4700e-007	2.0239e-002
Pu-238	8.5918e-002	3.1790e+009	9.1600e-007	3.3892e-002
Pu-239	3.0296e+001	1.1210e+012	3.2300e-004	1.1951e+001
Ra-226	1.2569e-001	4.6504e+009	1.3400e-006	4.9580e-002
Ra-228	7.3068e-002	2.7035e+009	7.7900e-007	2.8823e-002
Se-79	1.6883e+000	6.2469e+010	1.8000e-005	6.6600e-001
Sr-90	2.3918e+004	8.8497e+014	2.5500e-001	9.4350e+003
Tc-99	5.5528e+000	2.0545e+011	5.9200e-005	2.1904e+000
Th-228	1.9322e-002	7.1492e+008	2.0600e-007	7.6220e-003
Th-232	1.5101e-001	5.5875e+009	1.6100e-006	5.9570e-002
U-233	1.8478e+000	6.8368e+010	1.9700e-005	7.2890e-001
U-234	1.4820e+000	5.4834e+010	1.5800e-005	5.8460e-001
U-235	4.1364e+000	1.5305e+011	4.4100e-005	1.6317e+000
U-238	1.3132e+002	4.8587e+012	1.4000e-003	5.1800e+001

Page : 2
DOS File : 216-U-1-2 Operators.ms6
Run Date: August 9, 2004
Run Time: 7:02:38 AM
Duration : 00:00:56

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Y-90	2.3918e+004	8.8497e+014	2.5500e-001	9.4350e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	30
Y Direction	30
Z Direction	30

Results - Dose Point # 1 - (205,91,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	0.000e+00	1.333e-23	0.000e+00	1.144e-24
0.03	3.823e+13	0.000e+00	2.806e-22	0.000e+00	2.781e-24
0.04	9.023e+12	2.715e-178	2.009e-22	1.201e-180	8.887e-25
0.05	4.418e+08	5.771e-103	4.113e-26	1.537e-105	1.096e-28
0.06	1.253e+10	5.787e-64	4.397e-24	1.149e-66	8.734e-27
0.08	4.693e+09	1.804e-32	1.257e-23	2.855e-35	1.989e-26
0.1	1.589e+10	4.823e-72	1.267e-22	7.379e-75	1.939e-25
0.15	2.364e+10	5.795e-28	9.305e-22	9.543e-31	1.532e-24
0.2	9.504e+10	1.295e-14	8.736e-12	2.285e-17	1.542e-14
0.3	9.239e+07	6.867e-10	6.975e-08	1.303e-12	1.323e-10
0.4	6.406e+07	1.245e-07	4.661e-06	2.427e-10	9.082e-09
0.5	2.031e+09	5.038e-05	1.046e-03	9.889e-08	2.053e-06
0.6	5.841e+14	6.177e+01	8.746e+02	1.206e-01	1.707e+00
0.8	4.466e+09	2.459e-03	2.177e-02	4.677e-06	4.140e-05
1.0	6.906e+14	1.005e+03	6.660e+03	1.853e+00	1.228e+01
1.5	6.906e+14	3.855e+03	1.717e+04	6.485e+00	2.889e+01
TOTALS:	2.020e+15	4.922e+03	2.471e+04	8.459e+00	4.287e+01

Results - Dose Point # 2 - (205,0,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	0.000e+00	8.256e-24	0.000e+00	7.082e-25
0.03	3.823e+13	0.000e+00	1.738e-22	0.000e+00	1.722e-24
0.04	9.023e+12	3.396e-178	1.244e-22	1.502e-180	5.503e-25
0.05	4.418e+08	3.581e-103	2.547e-26	9.538e-106	6.784e-29
0.06	1.253e+10	2.611e-64	2.723e-24	5.186e-67	5.408e-27
0.08	4.693e+09	7.221e-33	7.783e-24	1.143e-35	1.232e-26
0.1	1.589e+10	2.328e-72	7.846e-23	3.562e-75	1.200e-25
0.15	2.364e+10	2.372e-28	5.759e-22	3.907e-31	9.484e-25
0.2	9.504e+10	6.329e-15	4.345e-12	1.117e-17	7.668e-15
0.3	9.239e+07	3.522e-10	3.552e-08	6.680e-13	6.737e-11
0.4	6.406e+07	6.265e-08	2.333e-06	1.221e-10	4.546e-09
0.5	2.031e+09	2.521e-05	5.223e-04	4.948e-08	1.025e-06
0.6	5.841e+14	3.086e+01	4.368e+02	6.024e-02	8.526e-01
0.8	4.466e+09	1.228e-03	1.088e-02	2.336e-06	2.069e-05
1.0	6.906e+14	5.022e+02	3.329e+03	9.257e-01	6.136e+00
1.5	6.906e+14	1.926e+03	8.583e+03	3.241e+00	1.444e+01
TOTALS:	2.020e+15	2.459e+03	1.235e+04	4.227e+00	2.143e+01

Results - Dose Point # 3 - (205,91,0) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	0.000e+00	9.763e-24	0.000e+00	8.374e-25

Page : 3
DOS File : 216-U-1-2 Operators.ms6
Run Date: August 9, 2004
Run Time: 7:02:38 AM
Duration : 00:00:56

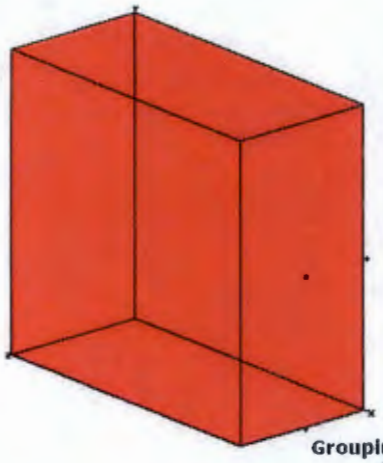
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.03	3.823e+13	0.000e+00	2.055e-22	0.000e+00	2.036e-24
0.04	9.023e+12	1.095e-178	1.471e-22	4.845e-181	6.507e-25
0.05	4.418e+08	2.378e-103	3.011e-26	6.335e-106	8.022e-29
0.06	1.253e+10	2.737e-64	3.219e-24	5.436e-67	6.395e-27
0.08	4.693e+09	9.378e-33	9.203e-24	1.484e-35	1.456e-26
0.1	1.589e+10	2.196e-72	9.277e-23	3.359e-75	1.419e-25
0.15	2.364e+10	2.997e-28	6.812e-22	4.936e-31	1.122e-24
0.2	9.504e+10	6.467e-15	4.356e-12	1.141e-17	7.689e-15
0.3	9.239e+07	3.431e-10	3.487e-08	6.509e-13	6.615e-11
0.4	6.406e+07	6.228e-08	2.331e-06	1.214e-10	4.542e-09
0.5	2.031e+09	2.519e-05	5.230e-04	4.945e-08	1.027e-06
0.6	5.841e+14	3.088e+01	4.373e+02	6.028e-02	8.535e-01
0.8	4.466e+09	1.229e-03	1.088e-02	2.338e-06	2.070e-05
1.0	6.906e+14	5.026e+02	3.330e+03	9.264e-01	6.138e+00
1.5	6.906e+14	1.927e+03	8.585e+03	3.243e+00	1.444e+01
TOTALS:	2.020e+15	2.461e+03	1.235e+04	4.229e+00	2.144e+01

MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-1-2 Laborer.ms6
Run Date : August 4, 2004
Run Time : 9:38:21 AM
Duration : 00:00:56

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-1/2 Waste Crib
Description: laborer
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6187.44 cm	2773.68 cm	1371.6 cm
	203 ft	91 ft	45 ft
# 2	6187.44 cm	0 cm	1371.6 cm
	203 ft	0.0 in	45 ft
# 3	6187.44 cm	2773.68 cm	0 cm
	203 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.31e+06 ft³	Hanford Soils	1.8
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	5.8342e-001	2.1586e+010	6.2200e-006	2.3014e-001
Ba-137m	1.7540e+004	6.4898e+014	1.8700e-001	6.9190e+003
Cm-244	8.3198e-001	3.0783e+010	8.8700e-006	3.2819e-001
Co-60	1.8666e+004	6.9063e+014	1.9900e-001	7.3630e+003
Cs-134	5.9280e-002	2.1933e+009	6.3200e-007	2.3384e-002
Cs-137	1.1349e-002	4.1993e+008	1.2100e-007	4.4770e-003
Eu-152	9.1264e-003	3.3768e+008	9.7300e-008	3.6001e-003
Eu-154	1.6227e-001	6.0039e+009	1.7300e-006	6.4010e-002
Eu-155	6.4532e-003	2.3877e+008	6.8800e-008	2.5456e-003
I-129	2.7013e-001	9.9950e+009	2.8800e-006	1.0656e-001
K-40	2.3168e+000	8.5721e+010	2.4700e-005	9.1390e-001
Na-22	2.9827e-002	1.1036e+009	3.1800e-007	1.1766e-002
Np-237	5.1307e-002	1.8984e+009	5.4700e-007	2.0239e-002
Pu-238	8.5918e-002	3.1790e+009	9.1600e-007	3.3892e-002
Pu-239	3.0296e+001	1.1210e+012	3.2300e-004	1.1951e+001
Ra-226	1.2569e-001	4.6504e+009	1.3400e-006	4.9580e-002
Ra-228	7.3068e-002	2.7035e+009	7.7900e-007	2.8823e-002
Se-79	1.6883e+000	6.2469e+010	1.8000e-005	6.6600e-001
Sr-90	2.3918e+004	8.8497e+014	2.5500e-001	9.4350e+003
Tc-99	5.5528e+000	2.0545e+011	5.9200e-005	2.1904e+000
Th-228	1.9322e-002	7.1492e+008	2.0600e-007	7.6220e-003
Th-232	1.5101e-001	5.5875e+009	1.6100e-006	5.9570e-002
U-233	1.8478e+000	6.8368e+010	1.9700e-005	7.2890e-001
U-234	1.4820e+000	5.4834e+010	1.5800e-005	5.8460e-001
U-235	4.1364e+000	1.5305e+011	4.4100e-005	1.6317e+000
U-238	1.3132e+002	4.8587e+012	1.4000e-003	5.1800e+001
Y-90	2.3918e+004	8.8497e+014	2.5500e-001	9.4350e+003

Buildup
The material reference is : Source

Integration Parameters

Page : 2
DOS File : 216-U-1-2 Laborer.ms6
Run Date: August 4, 2004
Run Time: 9:38:21 AM
Duration : 00:00:56

X Direction	30
Y Direction	30
Z Direction	30

Results - Dose Point # 1 - (203,91,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	4.076e-96	1.427e-23	3.496e-97	1.224e-24
0.03	3.823e+13	5.259e-13	1.152e-12	5.212e-15	1.141e-14
0.04	9.023e+12	2.347e-06	8.316e-06	1.038e-08	3.678e-08
0.05	4.418e+08	6.205e-08	3.351e-07	1.653e-10	8.927e-10
0.06	1.253e+10	3.491e-05	2.549e-04	6.933e-08	5.064e-07
0.08	4.693e+09	1.912e-04	1.840e-03	3.025e-07	2.911e-06
0.1	1.589e+10	2.118e-03	2.239e-02	3.240e-06	3.426e-05
0.15	2.364e+10	1.187e-02	1.184e-01	1.955e-05	1.949e-04
0.2	9.504e+10	9.488e-02	8.288e-01	1.675e-04	1.463e-03
0.3	9.239e+07	2.170e-04	1.475e-03	4.116e-07	2.799e-06
0.4	6.406e+07	2.682e-04	1.501e-03	5.225e-07	2.924e-06
0.5	2.031e+09	1.319e-02	6.325e-02	2.589e-05	1.241e-04
0.6	5.841e+14	5.404e+03	2.291e+04	1.055e+01	4.471e+01
0.8	4.466e+09	7.178e-02	2.536e-01	1.365e-04	4.824e-04
1.0	6.906e+14	1.695e+04	5.256e+04	3.125e+01	9.688e+01
1.5	6.906e+14	3.608e+04	9.078e+04	6.070e+01	1.527e+02
TOTALS:	2.020e+15	5.844e+04	1.662e+05	1.025e+02	2.943e+02

Results - Dose Point # 2 - (203,0,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	9.024e-96	8.742e-24	7.740e-97	7.498e-25
0.03	3.823e+13	2.096e-13	4.589e-13	2.077e-15	4.548e-15
0.04	9.023e+12	1.080e-06	3.852e-06	4.778e-09	1.704e-08
0.05	4.418e+08	3.124e-08	1.697e-07	8.323e-11	4.520e-10
0.06	1.253e+10	1.783e-05	1.302e-04	3.541e-08	2.587e-07
0.08	4.693e+09	9.699e-05	9.292e-04	1.535e-07	1.470e-06
0.1	1.589e+10	1.070e-03	1.125e-02	1.636e-06	1.721e-05
0.15	2.364e+10	5.971e-03	5.930e-02	9.833e-06	9.765e-05
0.2	9.504e+10	4.766e-02	4.149e-01	8.412e-05	7.323e-04
0.3	9.239e+07	1.089e-04	7.384e-04	2.065e-07	1.401e-06
0.4	6.406e+07	1.344e-04	7.509e-04	2.620e-07	1.463e-06
0.5	2.031e+09	6.610e-03	3.165e-02	1.297e-05	6.212e-05
0.6	5.841e+14	2.708e+03	1.146e+04	5.285e+00	2.237e+01
0.8	4.466e+09	3.595e-02	1.269e-01	6.838e-05	2.413e-04
1.0	6.906e+14	8.489e+03	2.629e+04	1.565e+01	4.846e+01
1.5	6.906e+14	1.806e+04	4.541e+04	3.038e+01	7.640e+01
TOTALS:	2.020e+15	2.925e+04	8.317e+04	5.132e+01	1.472e+02

Results - Dose Point # 3 - (203,91,0) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.288e+12	1.827e-96	1.029e-23	1.567e-97	8.828e-25
0.03	3.823e+13	2.721e-13	5.962e-13	2.697e-15	5.909e-15
0.04	9.023e+12	1.184e-06	4.193e-06	5.238e-09	1.854e-08
0.05	4.418e+08	3.098e-08	1.672e-07	8.252e-11	4.455e-10
0.06	1.253e+10	1.743e-05	1.273e-04	3.462e-08	2.529e-07
0.08	4.693e+09	9.553e-05	9.198e-04	1.512e-07	1.455e-06
0.1	1.589e+10	1.059e-03	1.119e-02	1.620e-06	1.713e-05
0.15	2.364e+10	5.934e-03	5.920e-02	9.772e-06	9.748e-05

Page : 3
DOS File : 216-U-1-2 Laborer.ms6
Run Date : August 4, 2004
Run Time: 9:38:21 AM
Duration : 00:00:56

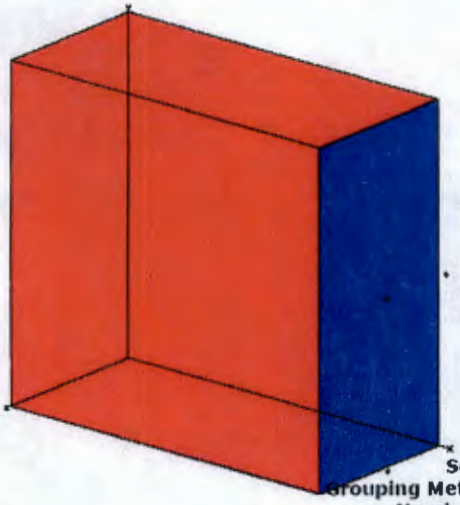
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.2	9.504e+10	4.743e-02	4.144e-01	8.372e-05	7.314e-04
0.3	9.239e+07	1.085e-04	7.377e-04	2.058e-07	1.399e-06
0.4	6.406e+07	1.341e-04	7.503e-04	2.612e-07	1.462e-06
0.5	2.031e+09	6.594e-03	3.162e-02	1.294e-05	6.207e-05
0.6	5.841e+14	2.702e+03	1.145e+04	5.274e+00	2.236e+01
0.8	4.466e+09	3.589e-02	1.268e-01	6.826e-05	2.412e-04
1.0	6.906e+14	8.477e+03	2.628e+04	1.563e+01	4.844e+01
1.5	6.906e+14	1.804e+04	4.539e+04	3.035e+01	7.637e+01
TOTALS:	2.020e+15	2.922e+04	8.312e+04	5.125e+01	1.472e+02

MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-8 Operators.ms6
Run Date : August 9, 2004
Run Time : 7:04:50 AM
Duration : 00:00:56

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-8 Waste Crib
Description: Excavator and In-pit Shuttle Truck Operators
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6248.4 cm	2773.68 cm	1371.6 cm
	205 ft	91 ft	45 ft
# 2	6248.4 cm	0 cm	1371.6 cm
	205 ft	0.0 in	45 ft
# 3	6248.4 cm	2773.68 cm	0 cm
	205 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	9.38e+10 cm³	Hanford Soils	1.8
Shield 1	1.27 cm	Iron	7.86
Shield 2	2.54 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	1.5476e-001	5.7263e+009	1.6500e-006	6.1050e-002
Ba-137m	1.4538e+004	5.3792e+014	1.5500e-001	5.7350e+003
Cm-244	8.7794e-002	3.2484e+009	9.3600e-007	3.4632e-002
Cs-137	1.5383e+004	5.6916e+014	1.6400e-001	6.0680e+003
Eu-152	1.3132e-002	4.8587e+008	1.4000e-007	5.1800e-003
Eu-154	1.4632e-002	5.4139e+008	1.5600e-007	5.7720e-003
Eu-155	2.0823e-001	7.7045e+009	2.2200e-006	8.2140e-002
I-129	5.3464e+003	1.9782e+014	5.7000e-002	2.1090e+003
K-40	2.5982e+000	9.6132e+010	2.7700e-005	1.0249e+000
Np-237	1.5570e-002	5.7610e+008	1.6600e-007	6.1420e-003
Pu-238	1.2944e-002	4.7893e+008	1.3800e-007	5.1060e-003
Pu-239	8.3573e-001	3.0922e+010	8.9100e-006	3.2967e-001
Ra-226	1.8478e-001	6.8368e+009	1.9700e-006	7.2890e-002
Ra-228	1.0880e-001	4.0258e+009	1.1600e-006	4.2920e-002
Se-79	1.5945e+000	5.8998e+010	1.7000e-005	6.2900e-001
Sr-90	7.0910e+001	2.6237e+012	7.5600e-004	2.7972e+001
Tc-99	4.2584e+000	1.5756e+011	4.5400e-005	1.6798e+000
Th-228	6.2844e-002	2.3252e+009	6.7000e-007	2.4790e-002
Th-232	2.1198e-001	7.8433e+009	2.2600e-006	8.3620e-002
U-233	1.9979e+001	7.3921e+011	2.1300e-004	7.8810e+000
U-234	1.6227e+000	6.0039e+010	1.7300e-005	6.4010e-001
U-235	1.8384e+000	6.8021e+010	1.9600e-005	7.2520e-001
U-238	1.1256e+001	4.1646e+011	1.2000e-004	4.4400e+000
Y-90	7.0910e+001	2.6237e+012	7.5600e-004	2.7972e+001

Buildup
The material reference is : Source

Page : 2
DOS File : 216-U-8 Operators.ms6
Run Date: August 9, 2004
Run Time: 7:04:50 AM
Duration : 00:00:56

Integration Parameters

X Direction	30
Y Direction	30
Z Direction	30

Results - Dose Point # 1 - (6248.4,2773.68,1371.6) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	0.000e+00	3.997e-23	0.000e+00	3.429e-24
0.03	1.704e+14	0.000e+00	1.251e-21	0.000e+00	1.240e-23
0.04	2.235e+13	1.473e-191	4.978e-22	6.516e-194	2.202e-24
0.05	6.258e+08	4.276e-110	5.826e-26	1.139e-112	1.552e-28
0.06	2.588e+09	4.297e-69	9.081e-25	8.535e-72	1.804e-27
0.08	4.459e+09	1.141e-34	1.194e-23	1.806e-37	1.890e-26
0.1	8.937e+09	1.225e-73	7.128e-23	1.873e-76	1.090e-25
0.15	1.051e+10	4.866e-29	4.133e-22	8.013e-32	6.806e-25
0.2	4.228e+10	1.608e-15	1.199e-12	2.838e-18	2.116e-15
0.3	1.318e+08	3.514e-10	4.101e-08	6.666e-13	7.780e-11
0.4	3.440e+07	2.668e-08	1.173e-06	5.199e-11	2.285e-09
0.5	3.913e+06	4.148e-08	1.019e-06	8.142e-11	2.000e-09
0.6	4.840e+14	2.303e+01	3.851e+02	4.494e-02	7.516e-01
0.8	2.976e+08	7.958e-05	8.266e-04	1.514e-07	1.572e-06
1.0	3.744e+08	2.802e-04	2.154e-03	5.165e-07	3.970e-06
1.5	1.058e+10	3.346e-02	1.687e-01	5.630e-05	2.839e-04
TOTALS:	6.987e+14	2.306e+01	3.852e+02	4.500e-02	7.519e-01

Results - Dose Point # 2 - (6248.4,0,1371.6) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	0.000e+00	2.475e-23	0.000e+00	2.123e-24
0.03	1.704e+14	0.000e+00	7.746e-22	0.000e+00	7.676e-24
0.04	2.235e+13	2.079e-191	3.083e-22	9.195e-194	1.363e-24
0.05	6.258e+08	2.828e-110	3.608e-26	7.533e-113	9.610e-29
0.06	2.588e+09	2.008e-69	5.623e-25	3.989e-72	1.117e-27
0.08	4.459e+09	4.532e-35	7.393e-24	7.172e-38	1.170e-26
0.1	8.937e+09	5.978e-74	4.413e-23	9.146e-77	6.752e-26
0.15	1.051e+10	1.981e-29	2.559e-22	3.262e-32	4.214e-25
0.2	4.228e+10	7.790e-16	5.914e-13	1.375e-18	1.044e-15
0.3	1.318e+08	1.808e-10	2.096e-08	3.429e-13	3.977e-11
0.4	3.440e+07	1.346e-08	5.883e-07	2.623e-11	1.146e-09
0.5	3.913e+06	2.078e-08	5.091e-07	4.080e-11	9.993e-10
0.6	4.840e+14	1.151e+01	1.923e+02	2.247e-02	3.754e-01
0.8	2.976e+08	3.976e-05	4.129e-04	7.562e-08	7.854e-07
1.0	3.744e+08	1.400e-04	1.076e-03	2.580e-07	1.984e-06
1.5	1.058e+10	1.672e-02	8.433e-02	2.813e-05	1.419e-04
TOTALS:	6.987e+14	1.153e+01	1.924e+02	2.250e-02	3.756e-01

Results - Dose Point # 3 - (6248.4,2773.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	0.000e+00	2.927e-23	0.000e+00	2.510e-24
0.03	1.704e+14	0.000e+00	9.159e-22	0.000e+00	9.077e-24
0.04	2.235e+13	6.052e-192	3.645e-22	2.676e-194	1.612e-24
0.05	6.258e+08	1.734e-110	4.266e-26	4.620e-113	1.136e-28

Page : 3
DOS File : 216-U-8 Operators.ms6
Run Date: August 9, 2004
Run Time: 7:04:50 AM
Duration : 00:00:56

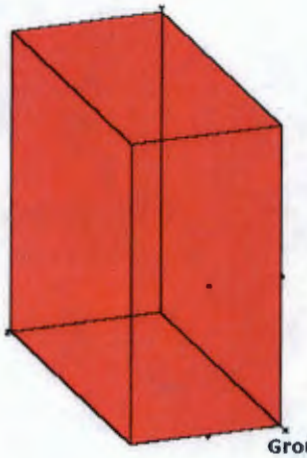
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.06	2.588e+09	1.991e-69	6.649e-25	3.955e-72	1.321e-27
0.08	4.459e+09	5.938e-35	8.743e-24	9.397e-38	1.383e-26
0.1	8.937e+09	5.542e-74	5.219e-23	8.479e-77	7.984e-26
0.15	1.051e+10	2.520e-29	3.026e-22	4.150e-32	4.983e-25
0.2	4.228e+10	8.041e-16	5.984e-13	1.419e-18	1.056e-15
0.3	1.318e+08	1.756e-10	2.050e-08	3.330e-13	3.889e-11
0.4	3.440e+07	1.334e-08	5.866e-07	2.600e-11	1.143e-09
0.5	3.913e+06	2.074e-08	5.095e-07	4.071e-11	1.000e-09
0.6	4.840e+14	1.151e+01	1.925e+02	2.247e-02	3.758e-01
0.8	2.976e+08	3.979e-05	4.133e-04	7.569e-08	7.861e-07
1.0	3.744e+08	1.401e-04	1.077e-03	2.583e-07	1.985e-06
1.5	1.058e+10	1.673e-02	8.437e-02	2.815e-05	1.420e-04
TOTALS:	6.987e+14	1.153e+01	1.926e+02	2.250e-02	3.760e-01

MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-8 Laborer.ms6
Run Date: August 5, 2004
Run Time: 9:01:00 AM
Duration : 00:00:56

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-8 Waste Crib
Description: laborer
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6187.44 cm	2773.68 cm	1371.6 cm
	203 ft	91 ft	45 ft
# 2	6187.44 cm	0 cm	1371.6 cm
	203 ft	0.0 in	45 ft
# 3	6187.44 cm	2773.68 cm	0 cm
	203 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.31e+06 ft³	Hanford Soils	1.8
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	1.5476e-001	5.7263e+009	1.6500e-006	6.1050e-002
Ba-137m	1.4538e+004	5.3792e+014	1.5500e-001	5.7350e+003
Cm-244	8.7794e-002	3.2484e+009	9.3600e-007	3.4632e-002
Cs-137	1.5383e+004	5.6916e+014	1.6400e-001	6.0680e+003
Eu-152	1.3132e-002	4.8587e+008	1.4000e-007	5.1800e-003
Eu-154	1.4632e-002	5.4139e+008	1.5600e-007	5.7720e-003
Eu-155	2.0823e-001	7.7045e+009	2.2200e-006	8.2140e-002
I-129	5.3464e+003	1.9782e+014	5.7000e-002	2.1090e+003
K-40	2.5982e+000	9.6132e+010	2.7700e-005	1.0249e+000
Np-237	1.5570e-002	5.7610e+008	1.6600e-007	6.1420e-003
Pu-238	1.2944e-002	4.7893e+008	1.3800e-007	5.1060e-003
Pu-239	8.3573e-001	3.0922e+010	8.9100e-006	3.2967e-001
Ra-226	1.8478e-001	6.8368e+009	1.9700e-006	7.2890e-002
Ra-228	1.0880e-001	4.0258e+009	1.1600e-006	4.2920e-002
Se-79	1.5945e+000	5.8998e+010	1.7000e-005	6.2900e-001
Sr-90	7.0910e+001	2.6237e+012	7.5600e-004	2.7972e+001
Tc-99	4.2584e+000	1.5756e+011	4.5400e-005	1.6798e+000
Th-228	6.2844e-002	2.3252e+009	6.7000e-007	2.4790e-002
Th-232	2.1198e-001	7.8433e+009	2.2600e-006	8.3620e-002
U-233	1.9979e+001	7.3921e+011	2.1300e-004	7.8810e+000
U-234	1.6227e+000	6.0039e+010	1.7300e-005	6.4010e-001
U-235	1.8384e+000	6.8021e+010	1.9600e-005	7.2520e-001
U-238	1.1256e+001	4.1646e+011	1.2000e-004	4.4400e+000
Y-90	7.0910e+001	2.6237e+012	7.5600e-004	2.7972e+001

Buildup
The material reference is : Source

Integration Parameters

X Direction	30
Y Direction	30
Z Direction	30

Page : 2
DOS File : 216-U-8 Laborer.ms6
Run Date: August 5, 2004
Run Time: 9:01:00 AM
Duration : 00:00:56

Results - Dose Point # 1 - (203,91,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	1.222e-95	4.278e-23	1.048e-96	3.669e-24
0.03	1.704e+14	2.344e-12	5.134e-12	2.323e-14	5.089e-14
0.04	2.235e+13	5.814e-06	2.060e-05	2.571e-08	9.112e-08
0.05	6.258e+08	8.790e-08	4.747e-07	2.342e-10	1.265e-09
0.06	2.588e+09	7.209e-06	5.265e-05	1.432e-08	1.046e-07
0.08	4.459e+09	1.816e-04	1.748e-03	2.874e-07	2.766e-06
0.1	8.937e+09	1.191e-03	1.259e-02	1.823e-06	1.927e-05
0.15	1.051e+10	5.277e-03	5.263e-02	8.690e-06	8.666e-05
0.2	4.228e+10	4.221e-02	3.687e-01	7.449e-05	6.508e-04
0.3	1.318e+08	3.096e-04	2.105e-03	5.873e-07	3.993e-06
0.4	3.440e+07	1.440e-04	8.058e-04	2.806e-07	1.570e-06
0.5	3.913e+06	2.541e-05	1.218e-04	4.987e-08	2.392e-07
0.6	4.840e+14	4.479e+03	1.898e+04	8.742e+00	3.705e+01
0.8	2.976e+08	4.784e-03	1.690e-02	9.099e-06	3.215e-05
1.0	3.744e+08	9.192e-03	2.850e-02	1.694e-05	5.253e-05
1.5	1.058e+10	5.528e-01	1.391e+00	9.300e-04	2.340e-03
TOTALS:	6.987e+14	4.479e+03	1.898e+04	8.743e+00	3.706e+01

Results - Dose Point # 2 - (203,0,45) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	2.705e-95	2.621e-23	2.320e-96	2.248e-24
0.03	1.704e+14	9.342e-13	2.046e-12	9.258e-15	2.028e-14
0.04	2.235e+13	2.676e-06	9.543e-06	1.184e-08	4.221e-08
0.05	6.258e+08	4.425e-08	2.404e-07	1.179e-10	6.403e-10
0.06	2.588e+09	3.682e-06	2.690e-05	7.313e-09	5.342e-08
0.08	4.459e+09	9.214e-05	8.827e-04	1.458e-07	1.397e-06
0.1	8.937e+09	6.017e-04	6.328e-03	9.205e-07	9.681e-06
0.15	1.051e+10	2.654e-03	2.636e-02	4.371e-06	4.341e-05
0.2	4.228e+10	2.120e-02	1.846e-01	3.742e-05	3.258e-04
0.3	1.318e+08	1.553e-04	1.054e-03	2.947e-07	1.999e-06
0.4	3.440e+07	7.219e-05	4.032e-04	1.407e-07	7.857e-07
0.5	3.913e+06	1.273e-05	6.097e-05	2.499e-08	1.197e-07
0.6	4.840e+14	2.244e+03	9.498e+03	4.380e+00	1.854e+01
0.8	2.976e+08	2.396e-03	8.456e-03	4.557e-06	1.608e-05
1.0	3.744e+08	4.603e-03	1.425e-02	8.484e-06	2.628e-05
1.5	1.058e+10	2.767e-01	6.958e-01	4.655e-04	1.171e-03
TOTALS:	6.987e+14	2.244e+03	9.499e+03	4.380e+00	1.854e+01

Results - Dose Point # 3 - (203,91,0) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.185e+13	5.476e-96	3.085e-23	4.697e-97	2.646e-24
0.03	1.704e+14	1.213e-12	2.658e-12	1.202e-14	2.634e-14
0.04	2.235e+13	2.934e-06	1.039e-05	1.298e-08	4.594e-08
0.05	6.258e+08	4.388e-08	2.369e-07	1.169e-10	6.311e-10
0.06	2.588e+09	3.599e-06	2.629e-05	7.149e-09	5.222e-08
0.08	4.459e+09	9.075e-05	8.738e-04	1.436e-07	1.383e-06
0.1	8.937e+09	5.955e-04	6.296e-03	9.111e-07	9.633e-06
0.15	1.051e+10	2.638e-03	2.632e-02	4.344e-06	4.333e-05
0.2	4.228e+10	2.110e-02	1.844e-01	3.724e-05	3.254e-04
0.3	1.318e+08	1.548e-04	1.053e-03	2.936e-07	1.997e-06
0.4	3.440e+07	7.199e-05	4.029e-04	1.403e-07	7.850e-07
0.5	3.913e+06	1.270e-05	6.092e-05	2.493e-08	1.196e-07

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DOS File : 216-U-8 Laborer.ms6
Run Date: August 5, 2004
Run Time: 9:01:00 AM
Duration : 00:00:56

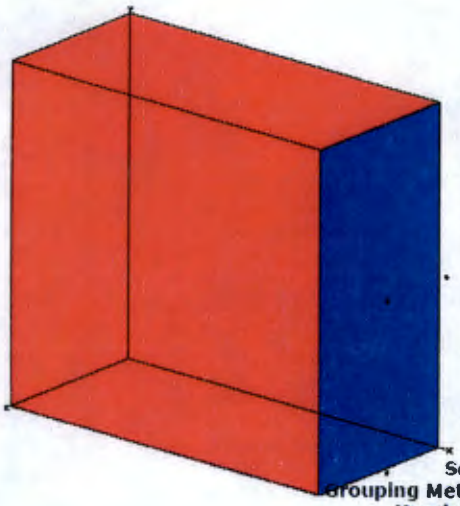
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6	4.840e+14	2.239e+03	9.491e+03	4.371e+00	1.853e+01
0.8	2.976e+08	2.392e-03	8.451e-03	4.549e-06	1.607e-05
1.0	3.744e+08	4.596e-03	1.425e-02	8.472e-06	2.626e-05
1.5	1.058e+10	2.764e-01	6.954e-01	4.650e-04	1.170e-03
TOTALS:	6.987e+14	2.240e+03	9.492e+03	4.371e+00	1.853e+01

MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-12 Operators.ms6
Run Date : August 9, 2004
Run Time: 7:06:30 AM
Duration : 00:00:32

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-12 Waste Crib
Description: Excavator and In-pit Shuttle Truck Operators
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6248.4 cm	2773.68 cm	1371.6 cm
	205 ft	91 ft	45 ft
# 2	6248.4 cm	0 cm	1371.6 cm
	205 ft	0.0 in	45 ft
# 3	6248.4 cm	2773.68 cm	0 cm
	205 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	5.72e+09 in³	Hanford Soils	1.8
Shield 1	.5 in	Iron	7.86
Shield 2	1.0 in	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
K-40	2.1948e+000	8.1209e+010	2.3400e-005	8.6580e-001
Ra-226	9.4735e-002	3.5052e+009	1.0100e-006	3.7370e-002
Ra-228	4.9337e-002	1.8255e+009	5.2600e-007	1.9462e-002
Tc-99	8.2354e-002	3.0471e+009	8.7800e-007	3.2486e-002
Th-228	5.1401e-003	1.9018e+008	5.4800e-008	2.0276e-003
Th-232	1.5007e-001	5.5528e+009	1.6000e-006	5.9200e-002
U-233	1.4726e-001	5.4487e+009	1.5700e-006	5.8090e-002
U-234	4.2209e-002	1.5617e+009	4.5000e-007	1.6650e-002
U-235	2.1855e-002	8.0862e+008	2.3300e-007	8.6210e-003
U-238	1.6133e-001	5.9692e+009	1.7200e-006	6.3640e-002

Buildup
The material reference is : Source

Integration Parameters

X Direction	30
Y Direction	30
Z Direction	30

Results - Dose Point # 1 - (2460,1092,540) in

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	0.000e+00	4.443e-27	0.000e+00	3.811e-28

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DOS File : 216-U-12 Operators.ms6
Run Date: August 9, 2004
Run Time: 7:06:30 AM
Duration : 00:00:32

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.05	1.843e+06	1.259e-112	1.716e-28	3.354e-115	4.571e-31
0.06	1.634e+07	2.713e-71	5.733e-27	5.388e-74	1.139e-29
0.08	4.209e+07	1.077e-36	1.127e-25	1.704e-39	1.784e-28
0.1	8.137e+07	1.115e-75	6.489e-25	1.706e-78	9.928e-28
0.15	1.275e+08	5.903e-31	5.014e-24	9.722e-34	8.257e-27
0.2	6.144e+08	2.337e-17	1.742e-14	4.124e-20	3.075e-17
0.3	2.338e+05	6.233e-13	7.273e-11	1.182e-15	1.380e-13
1.5	8.665e+09	2.740e-02	1.382e-01	4.611e-05	2.325e-04
TOTALS:	1.198e+10	2.740e-02	1.382e-01	4.611e-05	2.325e-04

Results - Dose Point # 2 - (2460,0,540) in

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	0.000e+00	2.751e-27	0.000e+00	2.360e-28
0.05	1.843e+06	8.328e-113	1.062e-28	2.218e-115	2.830e-31
0.06	1.634e+07	1.268e-71	3.550e-27	2.518e-74	7.051e-30
0.08	4.209e+07	4.278e-37	6.979e-26	6.769e-40	1.104e-28
0.1	8.137e+07	5.443e-76	4.018e-25	8.327e-79	6.147e-28
0.15	1.275e+08	2.403e-31	3.105e-24	3.957e-34	5.113e-27
0.2	6.144e+08	1.132e-17	8.594e-15	1.998e-20	1.517e-17
0.3	2.338e+05	3.206e-13	3.718e-11	6.082e-16	7.052e-14
1.5	8.665e+09	1.369e-02	6.906e-02	2.304e-05	1.162e-04
TOTALS:	1.198e+10	1.369e-02	6.906e-02	2.304e-05	1.162e-04

Results - Dose Point # 3 - (2460,1092,0) in

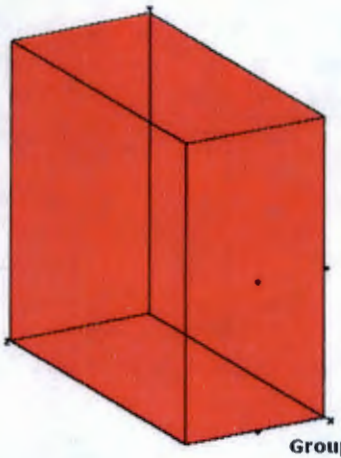
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	0.000e+00	3.253e-27	0.000e+00	2.790e-28
0.05	1.843e+06	5.108e-113	1.256e-28	1.361e-115	3.347e-31
0.06	1.634e+07	1.257e-71	4.197e-27	2.497e-74	8.337e-30
0.08	4.209e+07	5.605e-37	8.252e-26	8.869e-40	1.306e-28
0.1	8.137e+07	5.046e-76	4.751e-25	7.720e-79	7.269e-28
0.15	1.275e+08	3.058e-31	3.671e-24	5.035e-34	6.045e-27
0.2	6.144e+08	1.169e-17	8.696e-15	2.062e-20	1.535e-17
0.3	2.338e+05	3.113e-13	3.636e-11	5.906e-16	6.897e-14
1.5	8.665e+09	1.370e-02	6.909e-02	2.305e-05	1.162e-04
TOTALS:	1.198e+10	1.370e-02	6.909e-02	2.305e-05	1.162e-04

MicroShield v6.02 (6.02-00014)
CH2M_Hill

Page : 1
DOS File : 216-U-12 Laborer.ms6
Run Date: August 5, 2004
Run Time: 8:49:02 AM
Duration : 00:00:32

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 216-U-12 Waste Crib
Description: laborer
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	6.1e+3 cm	200 ft
Width	2.8e+3 cm	91 ft
Height	5.5e+3 cm	182 ft

Dose Points

	X	Y	Z
# 1	6187.44 cm	2773.68 cm	1371.6 cm
	203 ft	91 ft	45 ft
# 2	6187.44 cm	0 cm	1371.6 cm
	203 ft	0.0 in	45 ft
# 3	6187.44 cm	2773.68 cm	0 cm
	203 ft	91 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	9.38e+10 cm³	Hanford Soils	1.8
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
K-40	2.1948e+000	8.1209e+010	2.3400e-005	8.6580e-001
Ra-226	9.4735e-002	3.5052e+009	1.0100e-006	3.7370e-002
Ra-228	4.9337e-002	1.8255e+009	5.2600e-007	1.9462e-002
Tc-99	8.2354e-002	3.0471e+009	8.7800e-007	3.2486e-002
Th-228	5.1401e-003	1.9018e+008	5.4800e-008	2.0276e-003
Th-232	1.5007e-001	5.5528e+009	1.6000e-006	5.9200e-002
U-233	1.4726e-001	5.4487e+009	1.5700e-006	5.8090e-002
U-234	4.2209e-002	1.5617e+009	4.5000e-007	1.6650e-002
U-235	2.1855e-002	8.0862e+008	2.3300e-007	8.6210e-003
U-238	1.6133e-001	5.9692e+009	1.7200e-006	6.3640e-002

Buildup
The material reference is : Source

Integration Parameters

X Direction	30
Y Direction	30
Z Direction	30

Results - Dose Point # 1 - (6187.44,2773.68,1371.6) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	1.358e-99	4.755e-27	1.165e-100	4.078e-28
0.05	1.843e+06	2.589e-10	1.398e-09	6.896e-13	3.724e-12
0.06	1.634e+07	4.551e-08	3.324e-07	9.040e-11	6.602e-10
0.08	4.209e+07	1.714e-06	1.650e-05	2.712e-09	2.611e-08
0.1	8.137e+07	1.085e-05	1.147e-04	1.659e-08	1.754e-07
0.15	1.275e+08	6.402e-05	6.385e-04	1.054e-07	1.051e-06

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DOS File : 216-U-12 Laborer.ms6
Run Date : August 5, 2004
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Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.2	6.144e+08	6.133e-04	5.358e-03	1.083e-06	9.457e-06
0.3	2.338e+05	5.491e-07	3.733e-06	1.042e-09	7.082e-09
1.5	8.665e+09	4.527e-01	1.139e+00	7.616e-04	1.916e-03
TOTALS:	1.198e+10	4.534e-01	1.145e+00	7.628e-04	1.927e-03

Results - Dose Point # 2 - (6187.44,0,1371.6) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	3.007e-99	2.913e-27	2.579e-100	2.499e-28
0.05	1.843e+06	1.303e-10	7.078e-10	3.472e-13	1.886e-12
0.06	1.634e+07	2.324e-08	1.698e-07	4.617e-11	3.373e-10
0.08	4.209e+07	8.697e-07	8.332e-06	1.376e-09	1.318e-08
0.1	8.137e+07	5.478e-06	5.761e-05	8.381e-09	8.814e-08
0.15	1.275e+08	3.220e-05	3.198e-04	5.303e-08	5.267e-07
0.2	6.144e+08	3.081e-04	2.682e-03	5.438e-07	4.734e-06
0.3	2.338e+05	2.755e-07	1.869e-06	5.226e-10	3.545e-09
1.5	8.665e+09	2.266e-01	5.698e-01	3.812e-04	9.586e-04
TOTALS:	1.198e+10	2.269e-01	5.728e-01	3.818e-04	9.640e-04

Results - Dose Point # 3 - (6187.44,2773.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.429e+09	6.086e-100	3.429e-27	5.221e-101	2.942e-28
0.05	1.843e+06	1.292e-10	6.977e-10	3.442e-13	1.859e-12
0.06	1.634e+07	2.272e-08	1.660e-07	4.513e-11	3.297e-10
0.08	4.209e+07	8.566e-07	8.247e-06	1.356e-09	1.305e-08
0.1	8.137e+07	5.422e-06	5.733e-05	8.295e-09	8.770e-08
0.15	1.275e+08	3.200e-05	3.192e-04	5.270e-08	5.257e-07
0.2	6.144e+08	3.066e-04	2.679e-03	5.412e-07	4.728e-06
0.3	2.338e+05	2.745e-07	1.867e-06	5.208e-10	3.541e-09
1.5	8.665e+09	2.263e-01	5.695e-01	3.808e-04	9.582e-04
TOTALS:	1.198e+10	2.267e-01	5.726e-01	3.814e-04	9.635e-04

APPENDIX H

HISTOGRAMS FOR THE 216-U-1/216-U-2 CRIBS, 216-U-8 CRIB, AND 216-U-12 CRIB

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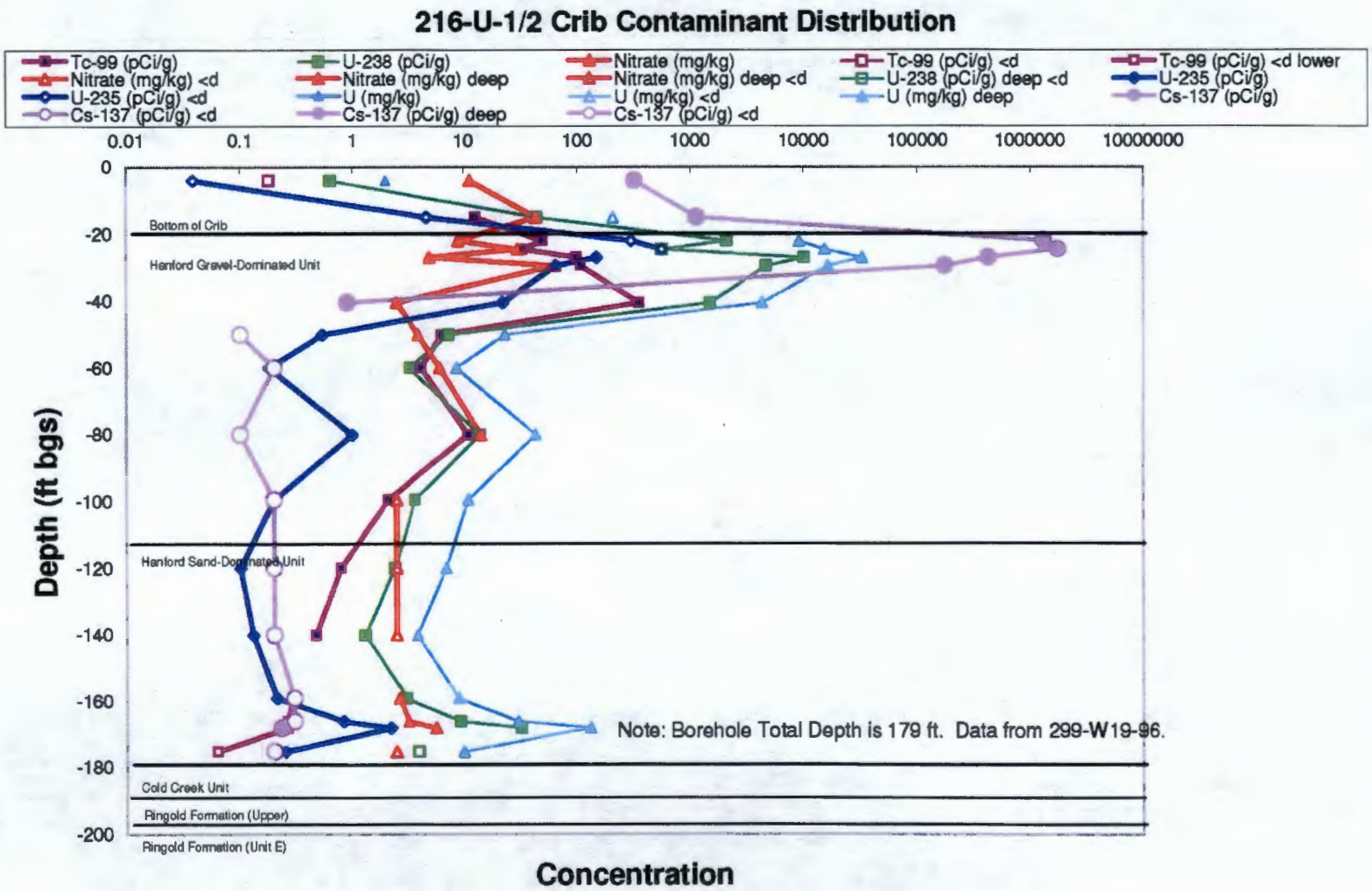


Figure H-1. 216-U-1 and 216-U-2 Cribs Contaminant Distribution.

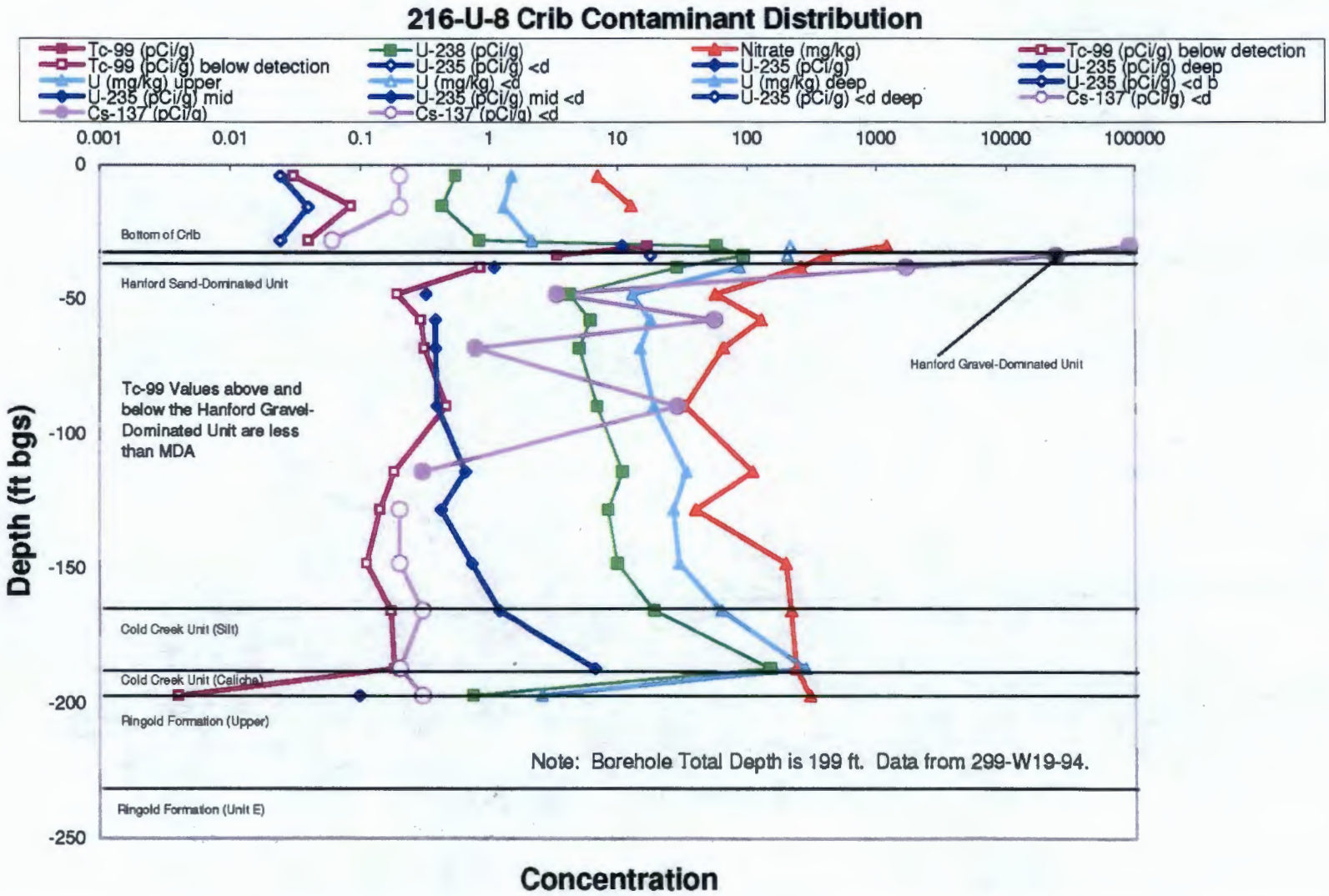


Figure H-2. 216-U-8 Crib Contaminant Distribution.

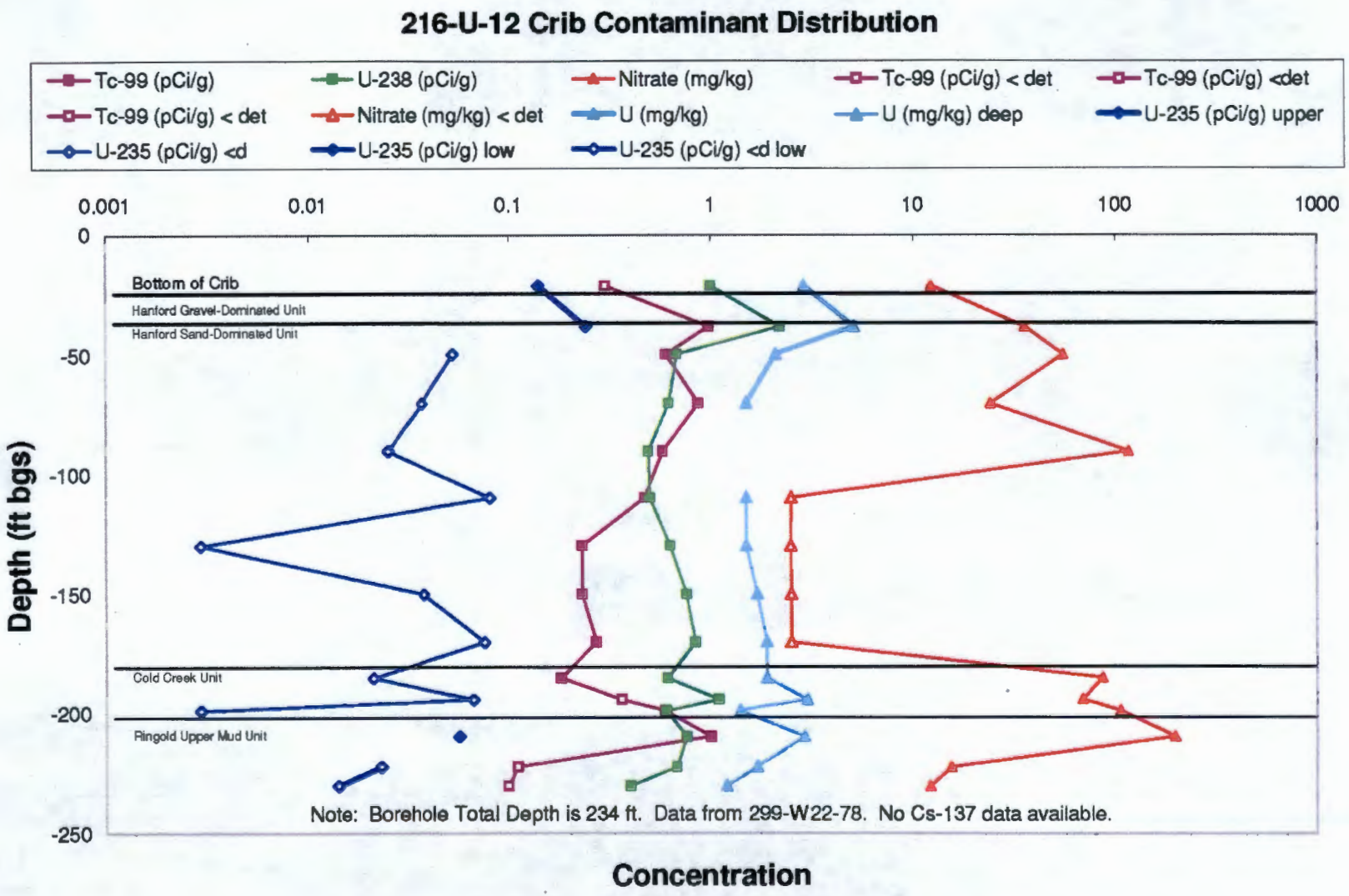


Figure H-3. 216-U-12 Crib Contaminant Distribution.

Figure H-4. Annual Discharge Plot for the 216-U-1 and 216-U-2 Cribs.

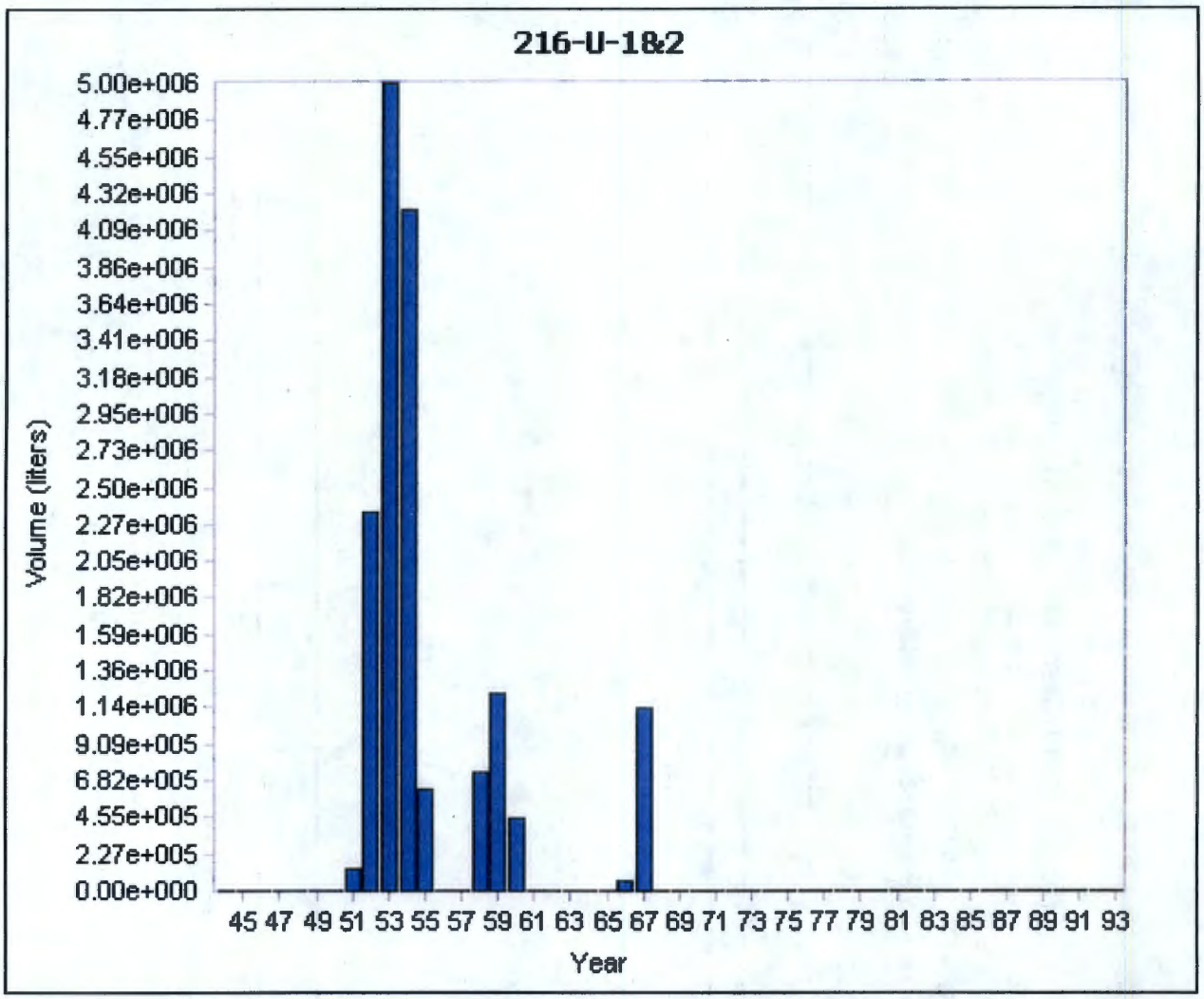


Figure H-5. Annual Discharge Plot for the 216-U-8 Crib.

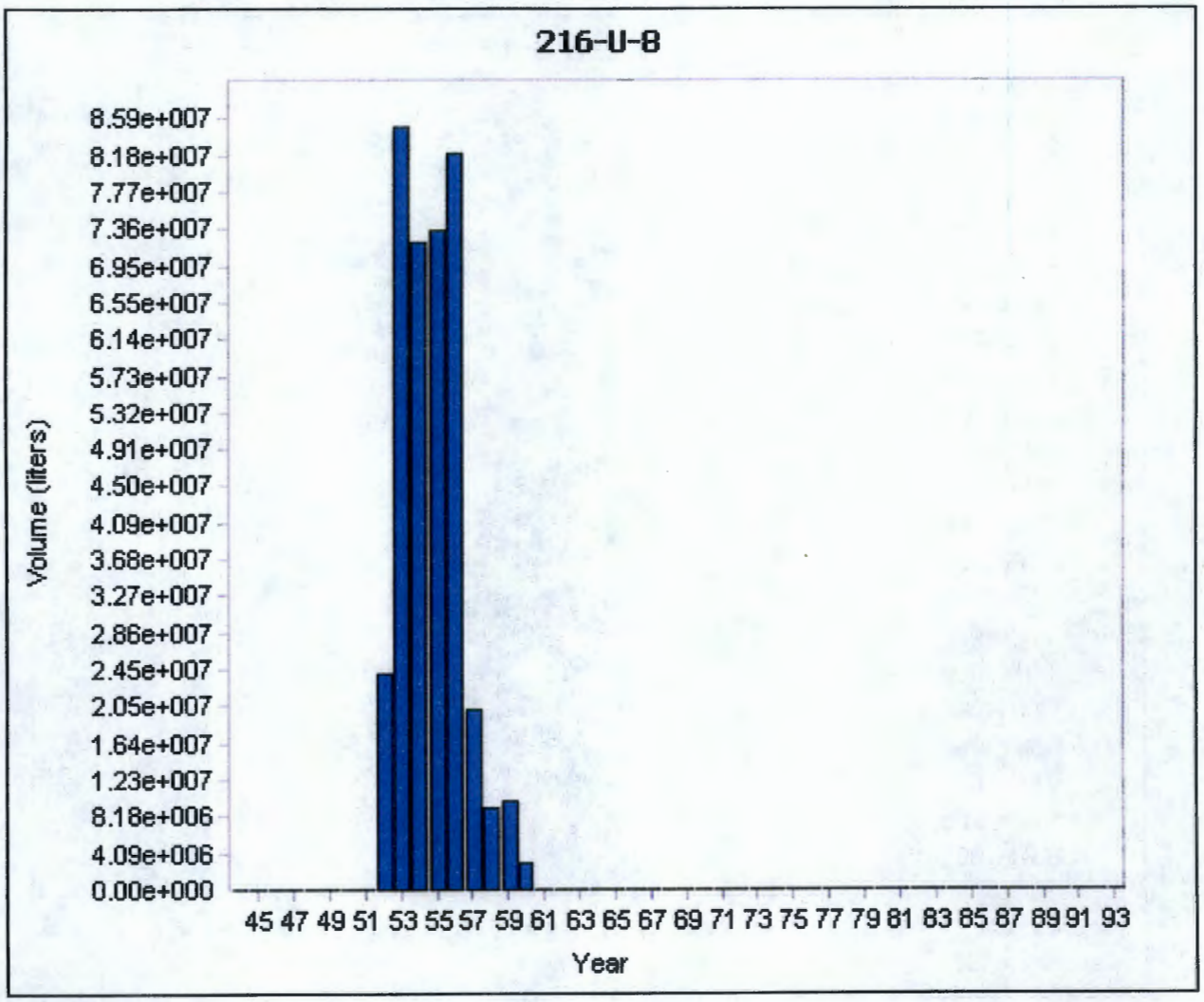
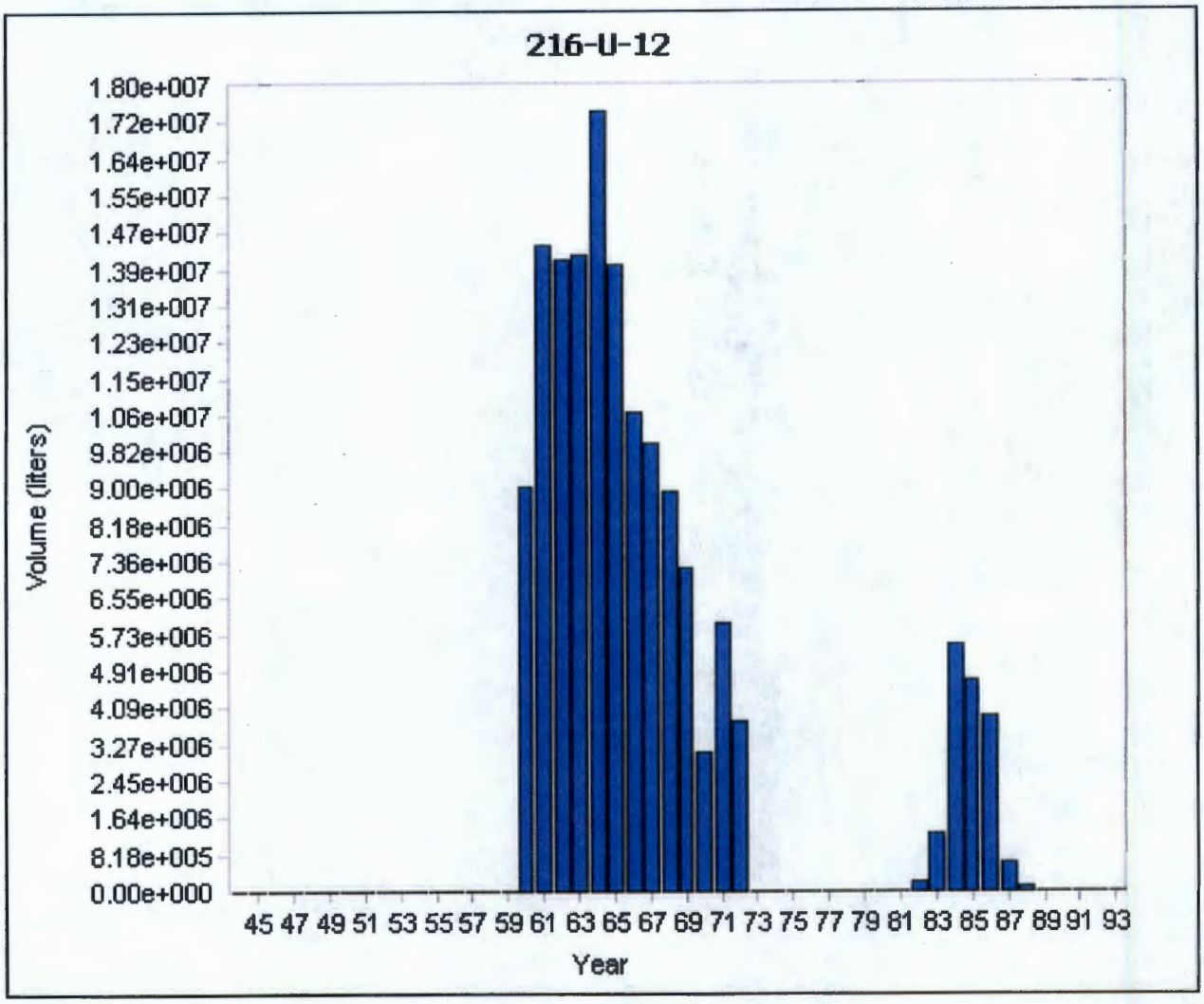


Figure H-6. Annual Discharge Plot for the 216-U-12 Crib.



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	J. M. Steffen	R3-60

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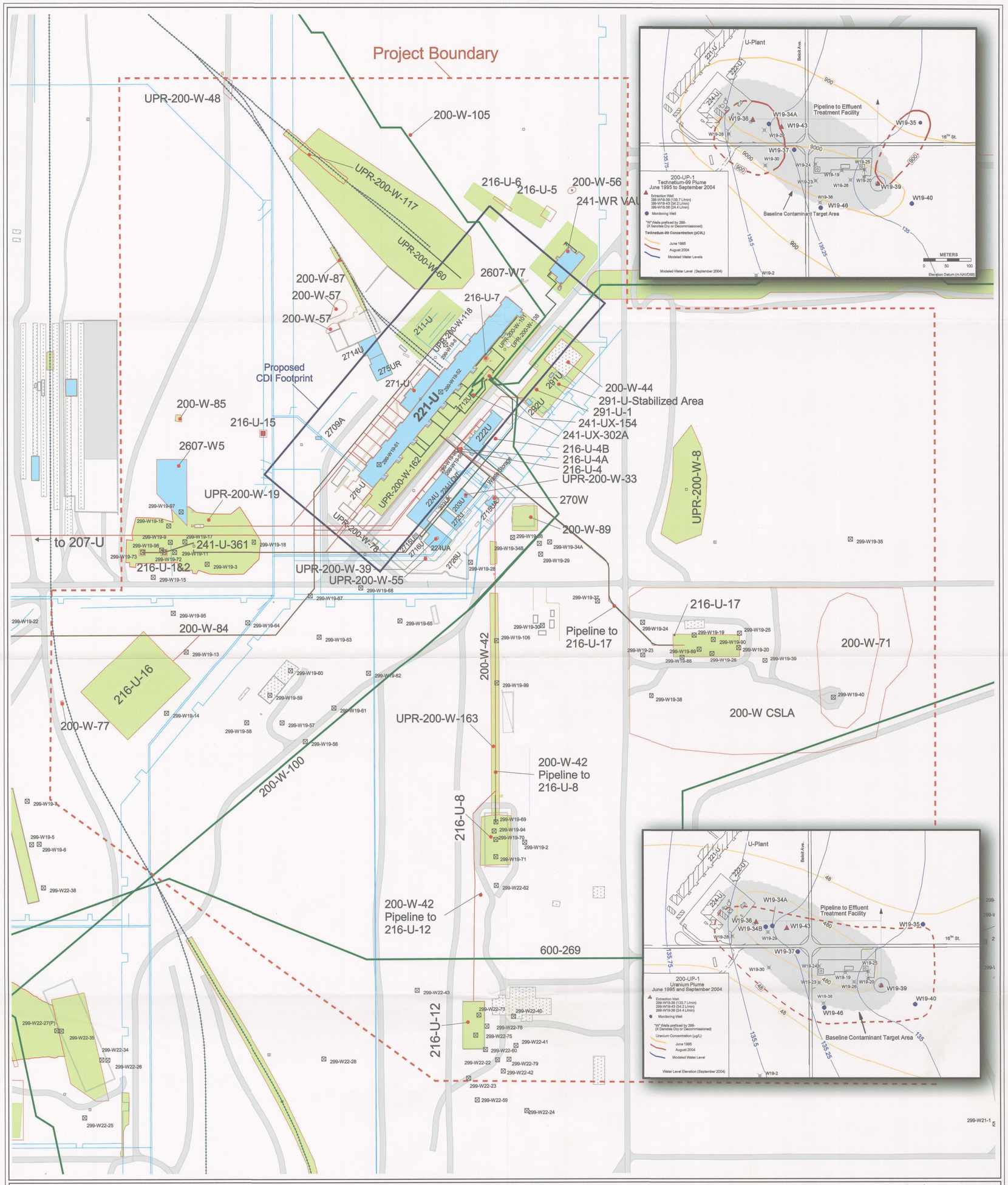

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April 29, 2005

Plate 1. U Plant Area