APPENDIX D

ENGINEERED BARRIERS AND POST-REMEDIATION ACTIVITIES

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to provide additional detail on engineered barriers installed during Phase 1 decommissioning and describe the post-remediation monitoring, maintenance, and institutional control program to be implemented for the WVDP premises following Phase 1 Decommissioning.

INFORMATION IN THIS APPENDIX

This appendix includes information on engineered barrier conceptual designs and the conceptual post-remediation monitoring, maintenance, and institutional control program, organized as follows:

- Section 1 describes the conceptual designs of the engineered barriers to be installed during Phase 1 decommissioning;
- Section 2 describes the conceptual post-remediation site monitoring and maintenance program that will be implemented for the project premises at the conclusion of Phase 1 decommissioning;
- Section 3 describes the conceptual post-remediation site institutional control program that will be implemented for the project premises at the conclusion of Phase 1 decommissioning.

RELATIONSHIP TO OTHER PLAN SECTIONS

Information provided in Section 1 on the project background and Section 7 on decommissioning activities, will help place the information in this appendix into context. The content of Appendix D, like that of other parts of the plan, is consistent with the annotated NRC decommissioning plan checklist in Appendix A, which expresses NRC's expectations for section content.

1.0 Description of Engineered Barriers

This section presents a detailed description of the conceptual designs for the engineered barriers to be installed during Phase 1 decommissioning, supplementing the physical descriptions previously presented in Section 7. Engineered barriers will be installed at the WMA 1 and WMA 2 excavations to facilitate the removal of sub-grade structures, excavate contaminated soil to meet unrestricted release criteria, and to prevent the recontamination of the WMA 1 and WMA 2 excavated areas by the non-source area of the North Plateau Plume.

The final design of the barrier walls and French drain will be prepared by the site decommissioning contractor after Phase 1 decommissioning activities start in 2011. The final design details of the hydraulic barriers and French drain will be provided to the NRC for technical review before their installation, as indicated in Section 1.6 of this plan.

The development of the WMA 1 and WMA 2 hydraulic barrier walls and French drain designs will be supported by the collection of subsurface soil geotechnical data, the installation of groundwater monitoring wells to provide groundwater elevation monitoring data, and groundwater modeling to evaluate the potential impacts these structures have on groundwater flow patterns in WMA 1 and WMA 2 and in surrounding areas such as WMA 3.

According to the NRC's Final Policy Statement (67 FR 22), engineered barriers are generally passive manmade structures or devices intended to improve a facility's ability to meet a site's performance objectives. While institutional controls are designed to restrict access, engineered barriers are usually designed to inhibit water from contacting waste, limit releases, or mitigate doses to intruders.

1.1 Waste Management Area 1

Phase 1 of the WVDP decommissioning will include the removal of all above grade and sub-grade structures of WMA 1 and the removal of the underlying soils associated with the source area of the north plateau groundwater plume to a maximum depth of approximately 50 feet. The removal of the sub-grade structures and the soils of the source area of the plume will require the installation of temporary and permanent subsurface hydraulic barrier walls prior to excavation as described in Section 7. A French drain system will be installed in the backfilled excavation to prevent mounding of groundwater against the permanent barrier wall as described in Section 7. The WMA 1 barrier walls and French drain will be designed to result in minimal changes to groundwater flow patterns and water levels in WMA 3. These barrier walls and the French drain system are described in greater detail below.

1.1.1 Need for Subsurface Engineered Barriers and French Drain

During Phase 1 decommissioning sub-grade structures (building cells, underground piping and tanks) and underlying vadose and saturated soils associated with the source area of the North Plateau Plume in WMA 1 will be removed down into the underlying Lavery till to meet the unrestricted release criteria in 10 CFR 20.1402. Much of the WMA 1 excavation will be within the saturated sand and gravel unit within the north plateau groundwater plume.

Subsurface hydraulic barrier walls will be installed on each side of the WMA 1 excavation to:

- Isolate the excavation from the non-source area of the north plateau groundwater plume,
- Prevent groundwater intrusion into the excavation from the surrounding sand and gravel unit,
- Allow dewatering of saturated soils within the excavation,
- Facilitate removal of sub-grade structures,
- Allow excavation of subsurface soil down into the Lavery till and up to the hydraulic barrier walls,
- Allow final status surveys and NRC confirmatory surveys to be performed in the bottom and sides of the excavation, and
- Prevent recontamination of the remediated and backfilled WMA 1 excavation from the

non-source area of the north plateau groundwater plume until a Phase 2 decommissioning decision is made.[1]

Subsurface soil characterization will be performed in WMA 1 before excavation begins to identify the lateral extent of subsurface soil contamination associated with the source area of the North Plateau Plume. This subsurface soil data will be used to locate the temporary interlocking sheet piling which will be driven through the uncontaminated sand and gravel unit into the underlying Lavery till on the upgradient and cross-gradient sides of the WMA 1 excavation to prevent groundwater intrusion into the excavation from upgradient sources. A permanent hydraulic barrier of slurry wall type construction will be installed on the downgradient side of the excavation in soil contaminated by the north plateau groundwater plume to act as an intrusion barrier to prevent the migration of Sr-90 contaminated groundwater from the non-source area of the north plateau groundwater plume into the WMA 1 excavation.

The permanent downgradient hydraulic barrier will:

- Prevent recontamination of the remediated and backfilled WMA 1 excavation from the non-source area of the plume until a Phase 2 decommissioning decision is made, and
- Minimize groundwater recharge to the non-source area of the plume, thereby minimizing hydraulic heads and groundwater velocity.

A French drain system will be installed adjacent and hydraulically upgradient of the permanent hydraulic barrier wall once the WMA 1 excavation has been backfilled to maintain groundwater elevations near their current levels. The French drain system will:

- Prevent groundwater mounding against, and potential overtopping of, the permanent downgradient hydraulic barrier wall;
- Maintain hydraulic heads on the upgradient side of the barrier wall that coincide with the elevation of the French drain system, that are higher than groundwater levels downgradient of the barrier wall. This will create a hydraulic gradient towards the non-source area of the north plateau groundwater plume, preventing seepage from the plume through the wall into the backfilled excavation; and
- In conjunction with the permanent downgradient hydraulic barrier, minimize groundwater recharge to the non-source area of the North Plateau Plume thereby minimizing hydraulic heads and groundwater velocity across the North Plateau.

1.1.2 Hydraulic Barrier Walls and French Drain System

The WMA 1 excavation will require the installation of approximately 2,250 linear feet of subsurface hydraulic barrier wall comprised of temporary interlocking steel sheet piling on the upgradient and cross-gradient sides of the excavation and a permanent hydraulic barrier wall on the downgradient side of the excavation before excavation begins as shown on Figure D-1.

Temporary Sheet Pile Barrier Walls

Approximately 1,500 feet of conventional interlocking sheet piles will be installed in uncontaminated soils along the upgradient and cross-gradient sides of the excavation boundary before excavation begins (Figure D-1). The piles will be driven a minimum of two feet into the underlying Lavery till to prevent groundwater from migrating beneath the piles into the WMA 1 excavation.

[1] The recontamination potential is low since groundwater flows northeast away from WMA 1.

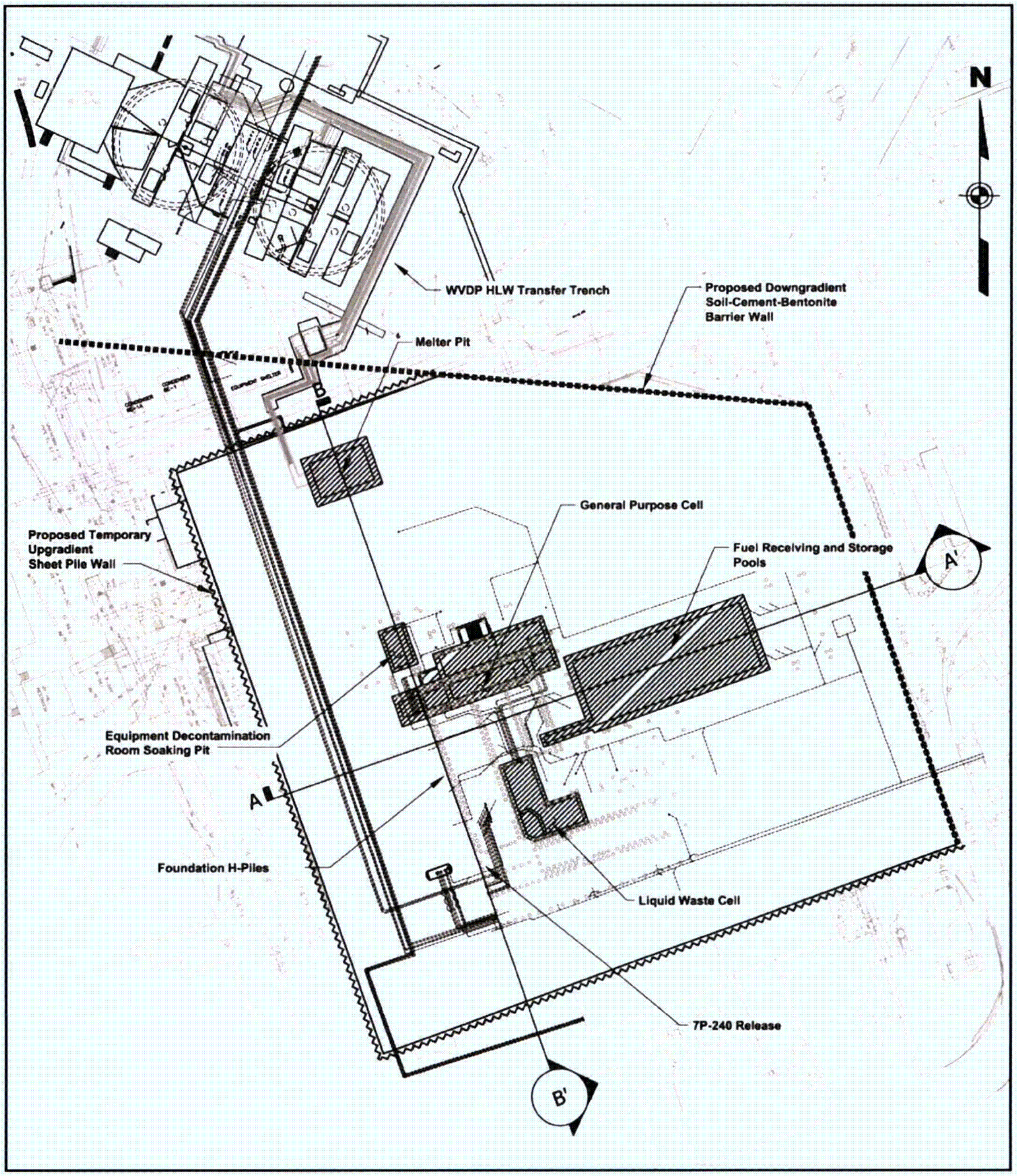


Figure D-1. Plan View of the WMA 1 Excavation

Contaminated soil exceeding the subsurface soil cleanup criteria specified in Section 5 will be excavated leaving a soil cut-back slope against the sheet pile walls containing soil with radionuclide concentrations below the subsurface soil clean-up criteria.[2] The soil cut-backs along the sheet pile walls will be surveyed during the Phase 1 final status surveys as specified in Sections 7 and 9 of this plan. The sheet pile barrier wall will be removed as specified in Section 7 once the final status survey, the independent verification survey, and backfilling of the

[2] Figure 7-8 in Section 7 of this plan shows typical excavation slopes.

WMA 1 excavation is completed to allow a return to typical groundwater flow patterns within the sand and gravel unit.

Permanent Downgradient Hydraulic Barrier Wall

The permanent hydraulic barrier wall constructed on the downgradient side of the WMA 1 excavation (Figure D-1) will be a vertical soil-cement-bentonite slurry wall installed using slurry wall trenching technology. This hydraulic barrier technology was selected because of its long history of successful usage. This wall will prevent migration of Sr-90 contaminated groundwater from the non-source area of the North Plateau Plume into the WMA 1 excavation both during excavation and after backfilling the excavation with clean fill.

The hydraulic barrier wall downgradient of the WMA 1 excavation will be installed under a carefully planned and rigorous quality control-quality assurance program as described in Section 8.

The soil-cement-bentonite barrier wall will be a mixture of 85 percent soil, five percent Portland cement, and 10 percent bentonite. The Portland cement will provide internal stability to the barrier wall and it will have an initial maximum design hydraulic conductivity of 6.0E-06 cm/s.

The soil-cement-bentonite barrier wall will be approximately 750 feet long, two to 13 feet wide, and will be up to 50 feet deep with an average depth of 27 feet. The wall will extend through the sand and gravel unit and a minimum of two feet into the Lavery till to minimize groundwater flow beneath the bottom of the wall.

Approximately 225 feet of barrier wall outside of the excavation boundary will be two to three feet thick. The remaining 525 feet of barrier wall within the boundary of the excavation will be at least 13 feet thick to allow the excavation of subsurface soils up to and into the barrier wall. The thickness will allow an excavation cut back slope of 1:2 (horizontal to vertical), which is typical of what can be achieved in most stiff clayey soils. The barrier wall material within the excavation cut-back slope will be surveyed during the Phase 1 final status survey.[3]

The upper three feet of the barrier wall will be constructed of clean backfill similar to the surrounding sand and gravel unit. This material will allow vehicular traffic over the barrier wall without damaging the underlying barrier wall.

French Drain System

A French drain system will be installed upgradient of the permanent hydraulic barrier wall during the backfilling of the WMA 1 excavation (Figure D-1). The French drain will be installed to keep groundwater levels at their current level on the upgradient side of the barrier wall to prevent groundwater mounding against the wall, prevent potential overtopping of the wall, and promote groundwater flow towards the non-source area of the north plateau groundwater plume.

The French drain will be constructed by excavating a trench, approximately four feet wide and 10 feet deep, placing perforated pipe into the bottom of the trench, and backfilling the trench with permeable granular materials. The northwest and southeast portions of the French drain will meet at a concrete manhole located near the mid-point of the barrier wall. The French

[3] As explained in Section 7 of this plan, any soil found to exceed cleanup goals will be removed only within the confines of the planned excavation, that is, within the confines of the downgradient hydraulic barrier wall and the sheet piles.

drain will be sloped to the southeast to discharge by gravity flow to a surface water drainage discharging to Erdman Brook.

1.2 Waste Management Area 2

The Phase 1 decommissioning activities in WMA 2 will include the removal of Lagoons 1 through 3, the Neutralization Pit, Interceptors, Solvent Dike, and surrounding contaminated soils within a single excavation down into the underlying Lavery till. Most of this excavation is cross gradient to the non-source area of the North Plateau Plume (Figure D-2). The removal of the lagoons, sub-grade structures, and surrounding soils will require the installation of a permanent subsurface hydraulic barrier wall prior to excavation to facilitate removal activities and to prevent potential recontamination of the area from the non-source area of the north plateau groundwater plume as described in Section 7. The barrier wall for WMA 2 is described in greater detail below.

1.2.1 Need for Subsurface Engineered Barriers

Lagoons 1 through 3, sub-grade structures, and surrounding contaminated vadose and saturated soils will be removed to a depth of approximately 14 feet to meet the unrestricted release criteria in 10 CFR 20.1402. Most of the WMA 2 excavation may be impacted by migration of Sr-90 contaminated groundwater from the adjacent non-source area of the north plateau groundwater plume. The need for a subsurface hydraulic barrier wall for the 4.2-acre excavation area across WMA 2 is the same as the rationale described earlier in Section 1.1.1 of this Appendix for the excavation of WMA 1.

A permanent hydraulic barrier of slurry wall type construction will be installed on the northwest and northeast side of the WMA 2 excavation to act as an intrusion barrier to prevent the migration of Sr-90 contaminated groundwater from the non-source area of the north plateau groundwater plume into the WMA 2 excavation. This permanent downgradient hydraulic barrier will prevent recontamination of the remediated and backfilled WMA 2 excavation from the non-source area of the north plateau plume until a Phase 2 decommissioning decision is made.

1.2.2 Hydraulic Barrier Wall

Before excavation activities begin in WMA 2 a permanent subsurface hydraulic barrier wall will be installed on the northwest side of the WMA 2 excavation as shown on Figure D-3.

Permanent Hydraulic Barrier Wall

The permanent hydraulic barrier wall constructed on the northwest and northeast side of the WMA 2 excavation will be a vertical soil-cement-bentonite slurry wall installed using slurry wall trenching technology. This hydraulic barrier technology was selected because of its long history of successful usage. This wall will prevent migration of Sr-90 contaminated groundwater from the non-source area of the north plateau plume into the WMA 2 excavation both during excavation and after the excavation has been backfilled with clean fill.

The hydraulic barrier wall installed northwest of the WMA 2 excavation will be installed under a carefully planned and rigorous quality control-quality assurance program as described in Section 8. The barrier wall will be approximately 1,100 feet long, sufficiently wide to provide the stability necessary to permit excavation close to the edge of the excavation, and up to 20 feet deep, with an average depth of 16 feet. The wall will extend through the sand and gravel unit and a minimum of two feet into the Lavery till to minimize groundwater flow beneath the bottom of the wall.

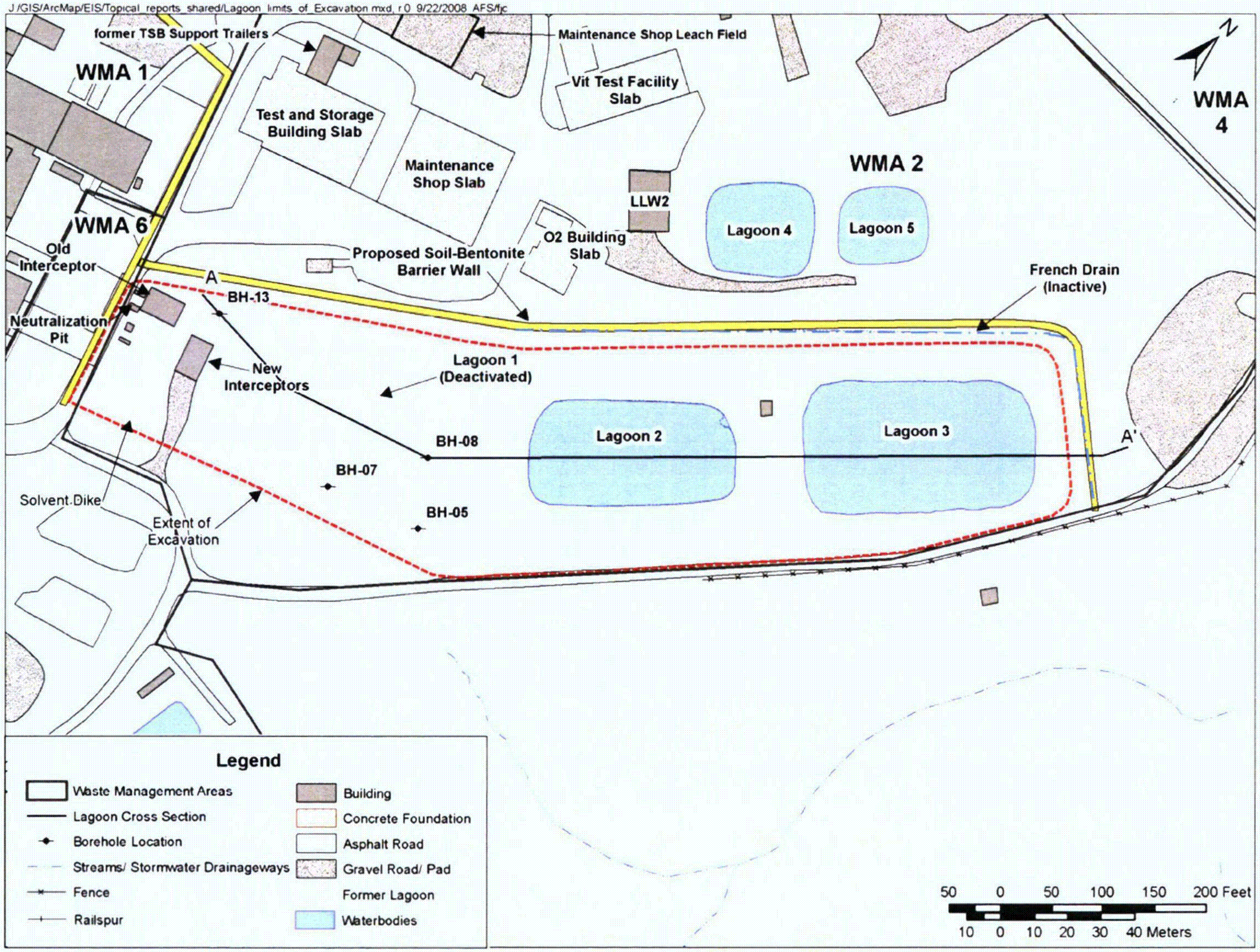


Figure D-2. Plan View of the WMA 2 Excavation

The upper three feet of the barrier wall will be constructed of clean backfill similar to the surrounding sand and gravel unit. This material will allow vehicular traffic over the barrier wall without damaging the underlying barrier wall.

1.3 Durability of Engineered Barriers

The materials used in the construction of the soil-cement-bentonite slurry walls are common natural geologic construction materials that exhibit long-term durability within the natural environment. The engineered barriers are expected to retain their design effectiveness until the start of Phase 2 of the decommissioning at a minimum. Their continued use will be among the factors evaluated in determining the approach to Phase 2 of the decommissioning.

The low-permeability bentonite used in the slurry wall construction is a natural geologic material exhibiting demonstrated long-term mineralogical and geologic stability (Mitchell 1986 and Mitchell 1993). Chemical contaminants that might degrade the physical characteristics and/or compromise the hydraulic conductivity of soil-bentonite slurry walls include:

- Concentrated solutions of organic fluids (Mille, et al. 1992 and Khera and Tirumala 1992),
- Organic groundwater contaminants (Evans, et al. 1985b and Grube 1992), and
- Acidic or highly alkaline solutions (Evans, et al. 1985a and Fang et al. 1992).

However, these conditions are not present within the project premises.

The backfill to be used for slurry wall construction will be a mixture of soil, Portland cement, and commercial sodium bentonite. The soil can be any material that could be classified as CL, CL/ML or ML/CL by the Unified Soil Classification System. The soil backfill will be natural geologic materials similar to the sand and gravel unit in the North Plateau. Uncontaminated sand and gravel from the trench excavation may also be used as soil backfill for the slurry wall. The sodium bentonite will be added at a rate recommended by the vendor to achieve a hydraulic conductivity on the order of 1 E-08 to 1 E-06 cm/s.

The geotechnical stability of the soil-cement-bentonite slurry wall has been evaluated under combined static and seismic loading conditions. The evaluation results indicate that the soil-cement-bentonite slurry wall will provide the necessary strength to withstand damage from static and seismic loads predicted to occur during a hypothetical earthquake generating a horizontal acceleration of 0.20 g in the soil, with an approximate factor of safety of greater than 1.3 to greater than 3.0 (URS 2000).

The French drain will be constructed of natural (stone backfill) and man-made (perforated drain pipe, geotextile) materials. The French drain trench backfill will be designed to minimize silting of the drainpipe. The French drain will be periodically monitored and maintained until the start of Phase 2 decommissioning to ensure it is functioning properly.

1.4 Engineered Barriers and Groundwater Flow

Groundwater flow in the sand and gravel unit is currently to the northeast across the north plateau through WMA 1 and parallel to WMA 2 (Figure D-2). The permanent hydraulic barrier wall and French drain to be installed on the downgradient side of the WMA 1 excavation will be nearly perpendicular to the current groundwater flow path in the sand and gravel unit in the north plateau.

1.4.1 Conceptual Model

A three-dimensional near-field groundwater model was developed to simulate groundwater flow conditions near the engineered barriers installed at WMA 1 and WMA 2 using the STOMP computer code (Nichols, et al. 1997)[4]. This model is a revised version of the near-field model described in Appendix E to the Decommissioning EIS. Figure D-3 shows the boundaries of the north plateau near-field model.

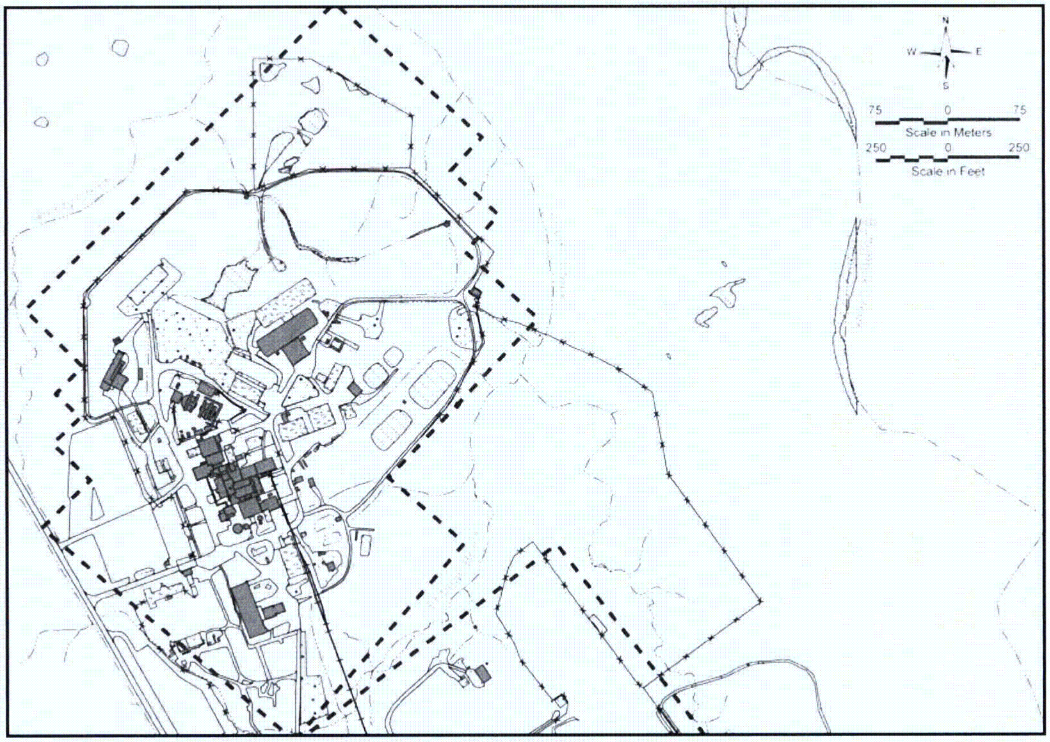


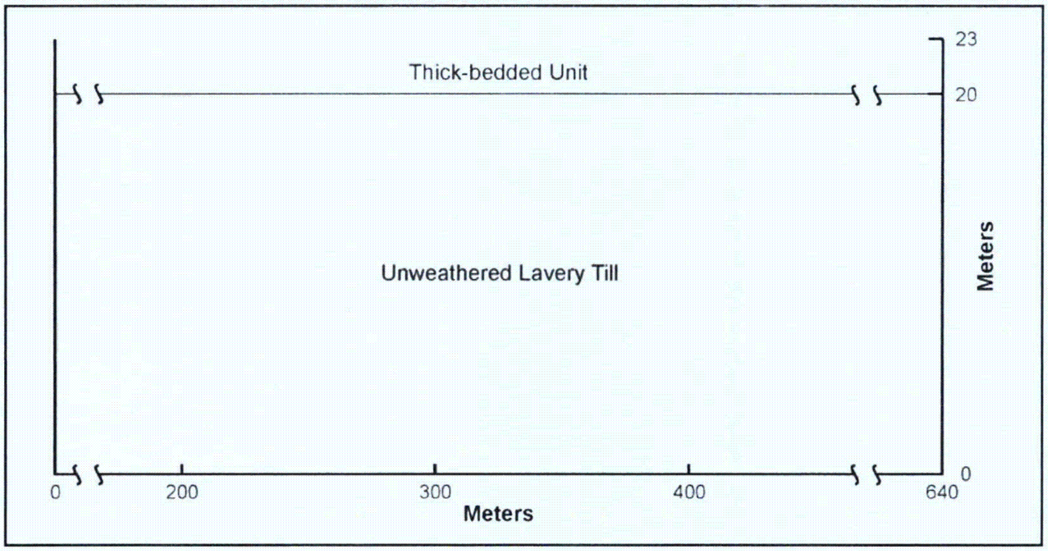
Figure D-3. North Plateau Groundwater Flow Model Boundary

The north plateau model mimics the shape of the lateral extent of the sand and gravel unit. It is oriented from the southwest to the northeast and extends downward from the ground surface to the top of the Kent Recessional Sequence.

Hydrogeologic units represented in the model are the thick-bedded unit, the slack-water sequence and the unweathered Lavery till. Together, the thick-bedded unit and the slack-water sequence comprise the surficial sand and gravel unit. The thick-bedded unit comprises glaciofluvial gravel and alluvial deposits that range from one to six meters in thickness overlying the unweathered Lavery till. The slack-water sequence is a depositional sequence with layers of gravel, sand and silt filling a southwest-to-northeast trending channel in the upper portion of the unweathered Lavery till. The slack-water sequence varies in thickness from zero to five meters with the thickest portions beneath the Process Building. The unweathered Lavery till is a glacial till with a thickness range of 10 to 17 meters in the model volume.

[4] STOMP (Subsurface Transport Over Multiple Phases) solves the relevant conservation equations for the flow of both liquid and gas (air with water vapor) phases in a porous matrix confined in a cylindrical shape. This computer code was developed by DOE's Pacific Northwest National Laboratory.

The hydrogeologic units incorporated into the north plateau near-field flow model are represented in Figures D-4 through D–8. The slack-water sequence appears in the northeastern portion of the model as shown in Figures D-6 through D–8. The hydraulic conductivities of these units are assumed constant over the model domain with values of 2.5 E-03, 5.3 E-03, and 6.0 E-08 centimeters per second for the thick-bedded unit, slack-water sequence, and unweathered Lavery till, respectively. Two variants of the north plateau near-field model were developed to simulate current north plateau groundwater flow conditions and to evaluate north plateau groundwater flow conditions associated with the hydraulic barriers to



be installed during Phase 1.

Figure D-4. Cross Section of North Plateau Near-Field Model – Southwest to Northeast Distance of 0 to 80 Meters

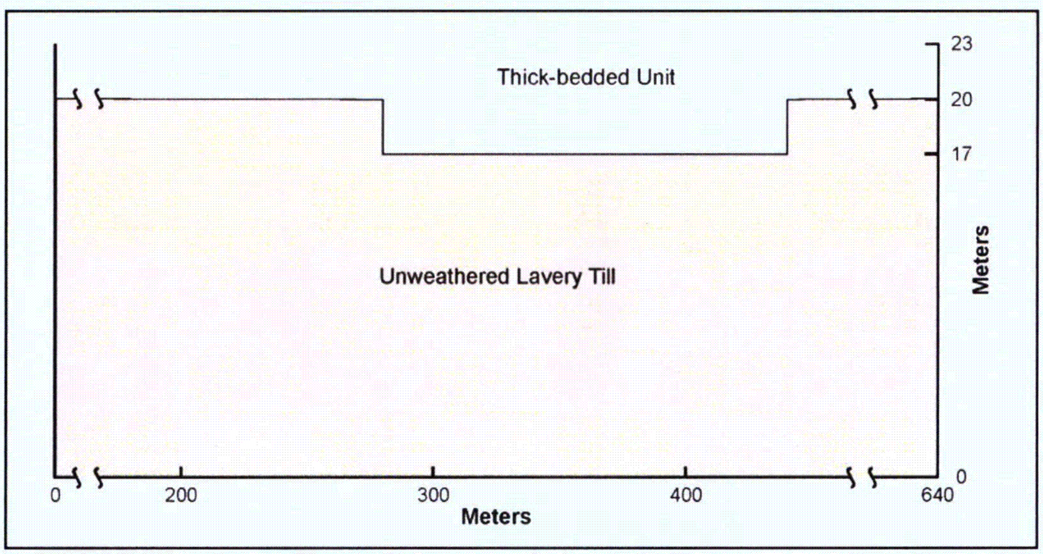


Figure D-5. Cross Section of North Plateau Near-Field Model – Southwest to Northeast Distance of 80 to 120 Meters

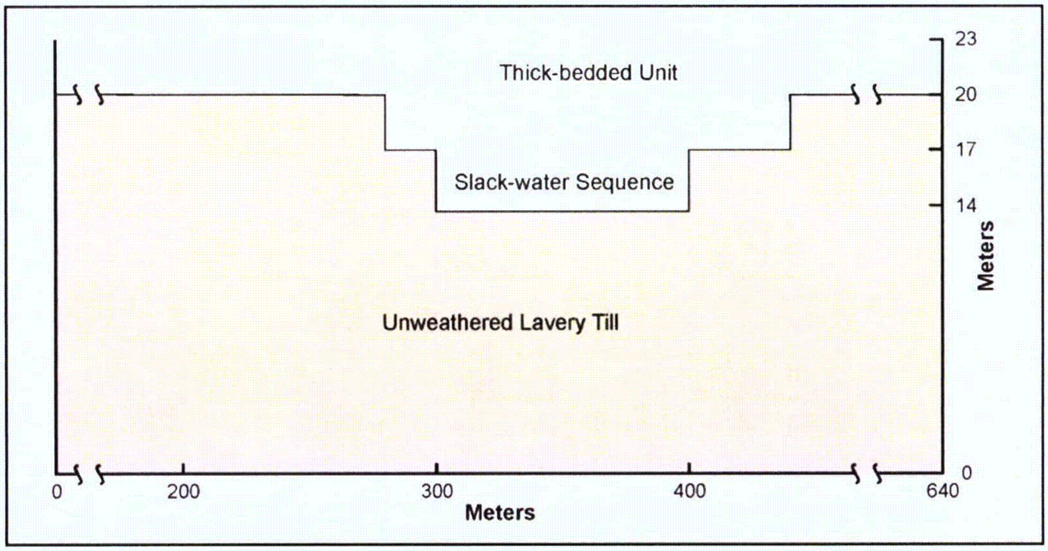


Figure D-6. Cross Section of North Plateau Near-Field Model – Southwest to Northeast Distance of 120 to 250 Meters

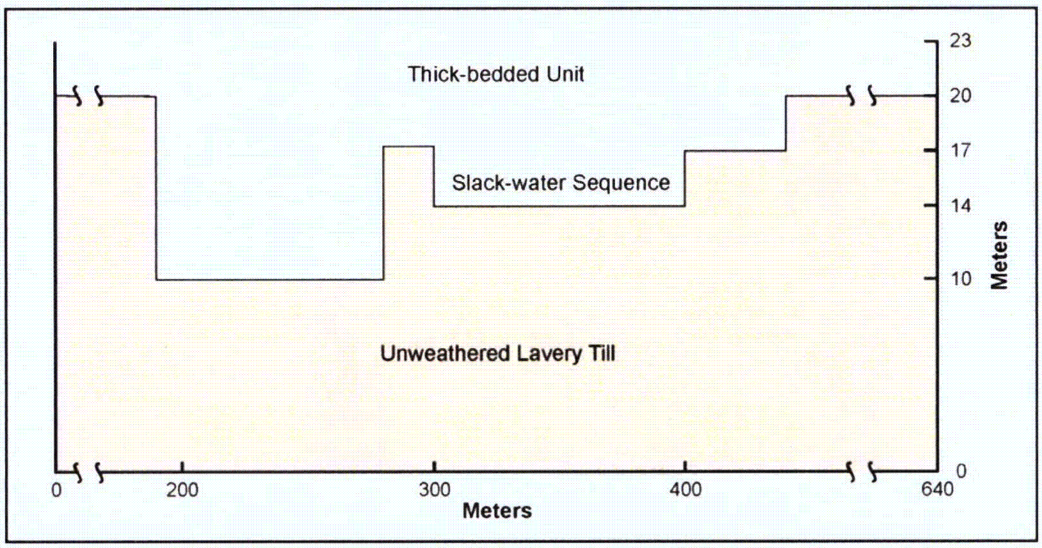


Figure D-7. Cross Section of North Plateau Near-Field Model – Southwest to Northeast Distance of 250 to 310 Meters

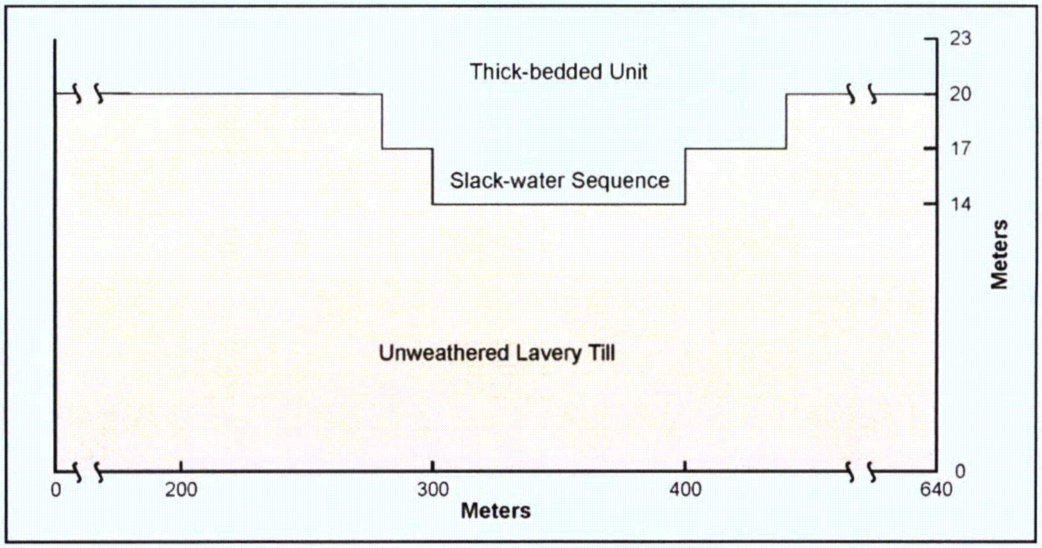


Figure D-8. Cross Section of North Plateau Near-Field Model – Southwest to Northeast Distance of 310 to 820 Meters

1.4.2 Modeling Current Conditions

To simulate current conditions, the horizontal portion of the near-field groundwater model grid comprised rectangular blocks with 81 blocks in the southwest-to-northwest direction and 64 blocks in the southwest-to-southeast direction. Grid blocks with horizontal dimension as large as 50 meters were used along the west and north boundaries while grid block horizontal dimensions range from 1 to 10 meters over most of the model domain. For the vertical direction, the upper three meters were represented using 15 0.2-meter-thick layers, the next three meters were represented using six 0.5-meter-thick layers, and the bottom 17 meters were represented using 17 1.0-meter-thick layers. With these dimensions, the model utilized approximately 174,000 grid blocks.

Boundary conditions applied for the near-field model are consistent with site observations and with those applied for the site-wide model. At the bottom of the unweathered Lavery till, atmospheric pressure was applied representing the presence of a water table in the Kent Recessional Sequence. On the sides of the model, no flow conditions were applied for the unweathered Lavery till. On the southwest side of the model, lateral recharge into the thick-bedded unit of 20 cubic meters per day was applied. On the northwest, southeast, and northeast sides of the model, atmospheric pressure conditions were applied for the thick-bedded unit and slack-water sequence to represent seepage to Quarry Creek, Erdman Brook, and Franks Creek, respectively.

Evaluation of simulated pressures and measured conditions in target groundwater wells showed that a uniform recharge of 26 centimeters per year produced the closest match to existing conditions. Table D-1 compares measured hydraulic heads in wells screened in the sand and gravel unit from the north plateau with predicted hydraulic heads generated by the near-field model for three different recharge rates. Figure D-9 shows the resulting plot of water table elevation in the thick bedded unit for a recharge of 26 centimeters per year. These water table elevations are consistent with the measured heads and the predictions of the site-wide groundwater model described in Appendix E to the Decommissioning EIS. Table D-2 shows the modeled flow balance.

Table D-1. North Plateau Near-field Flow Model Calibration for Head[(1)]

Groundwater Well	Measured Head (ft)	Predicted Head (ft) at Specified Recharge		
		18 cm/y	26 cm/y	34 cm/y
103	1391.4	1386.8	1391.6	1394.5
104	1385.5	1379.6	1383.1	1385.7
116	1380.5	1372.4	1376.8	1379.4
203	1394.4	1400.2	1401.6	1404.2
205	1393.1	1397.9	1399.2	1401.2
301	1410.7	1401.9	1406.8	1410.6
401	1410.3	1401.5	1406.4	1409.5
406/86-08	1393.5	1394.1	1397.4	1400.0
601	1377.3	1376.9	1378.9	1380.9
603	1391.9	1395.0	1397.0	1399.6
604	1391.6	1389.7	1391.9	1394.6
86-09	1391.8	1391.6	1396.5	1399.8
86-12	1364.8	1343.6	1345.2	1346.8
408	1391.8	1391.0	1394.8	1398.4
501	1391.3	1386.8	1391.5	1394.5
403	1408.0	1401.1	1405.8	1409.1
801	1376.6	1369.3	1373.1	1375.7
804	1369.9	1356.0	1359.2	1360.4
Sum of Squared Residuals (ft^2)[(2)]		1111.4	730.1	831.4

NOTES: (1) This specified recharge is the net inflow at the ground surface that results from the balance of precipitation, evapotranspiration, and run-off.

(2) Sum of squared residuals = (Measured Head – Predicted Head)^2 for each location, then summed.

Table D-2. Summary of Sand and Gravel Unit Flow Balance[(1)]

Inflow		Outflow	
Location	Rate (m^3/y)	Location	Rate (m^3/y)
Recharge at the Ground Surface	107,624	Down Flow to the KRS	9,060
Recharge from Bedrock from the	7,304	Seepage to Quarry Creek	8,456
		Seepage to Erdman Brook	15,238

Table D-2. Summary of Sand and Gravel Unit Flow Balance[1]

Inflow		Outflow	
Location	**Rate (m^3/y)**	**Location**	**Rate (m^3/y)**
Southwest		Seepage to Frank's Creek	66,713
		Seepage to North Plateau Ditch	15,445
Totals	114,928		114,912

NOTE: (1) For a recharge rate of 26 centimeters per year
LEGEND: KRS = Kent Recessional Sequence

The relationship between rate of flow in the slack-water sequence and the thick-bedded unit above the slack-water sequence was investigated through tabulation of groundwater velocities along a flow path extending from the location of the Process Building to the north plateau ditch. Average linear velocities predicted by the near-field model for this path are presented in Table D-3. An effective porosity value of 0.225 was used for the thick-bedded unit and an effective porosity value of 0.35 for the slack-water sequence. For the slack-water sequence and thick-bedded unit above the slack-water sequence, the travel time and average velocity along the flow path are 1.90 years and 161 meters per year and 2.0 years and 157 meters per year, respectively.

Table D-3. Average Linear Velocity for Flow Path Originating at the Process Building

Distance Along Flow Path (m)	Average Linear Velocity (m/y)	
	Slack-water Sequence	**Thick-bedded Unit**
0 to 10	114	105
10 to 63	130	132
63 to 110	143	147
110 to 160	156	161
160 to 210	171	174
210 to 260	192	180
260 to 310	220	176

NOTE: To convert meters per year to feet per year, multiply by 3.2803.

1.4.3 Modeling Conditions Following Phase 1 of the Decommissioning

The near-field groundwater flow model developed to assess current groundwater flow conditions was used to evaluate groundwater flow following the installation of the Phase 1 hydraulic barriers and WMA 1 French drain. The WMA 1 and WMA 2 slurry walls are modeled as one-meter thick extending downward to the unweathered Lavery till with a hydraulic conductivity of 1.0 E-06 cm/s. The WMA 1 hydraulic barrier wall downgradient of the Process Building is oriented parallel to the groundwater elevation contours and perpendicular to groundwater flow as shown in Figure D-9. The segment of barrier wall between the Process Building and the Waste Tank Farm has been modeled parallel to groundwater flow due to the model constraints. The French drain for WMA 1 was modeled as one-meter thick with a depth of three meters and a hydraulic conductivity of 10 cm/s.

The cross-sectional structure of the aquifer is that represented in Figures D-4, D-5, D-6, D-7, and D-8 with the same vertical discretization as the current conditions case.

Figure D-9 shows the distribution of hydraulic heads predicted following completion of Phase 1 of the decommissioning. The results indicate an overall increase in water table elevation of several feet across the large backfilled WMA 1 and WMA 2 excavations formerly occupied by the Process Building and the lagoons, respectively.

The higher groundwater elevations in the backfilled WMA 1 excavation suggest that groundwater would flow through the WMA 1 slurry wall to the northeast, towards the non-source area of the north plateau groundwater plume. However, a significant volume of this flow would be diverted by the French drain and discharged to Erdman Brook (Table D-4). Groundwater elevations coincide on either side of the slurry wall separating the backfilled WMA 1 excavation from the Waste Tank Farm, suggesting little potential for groundwater flow from the backfilled WMA 1 excavation toward the Waste Tank Farm.

Groundwater elevations coincide with the bottom of the French drain near the WMA 1 barrier wall. Groundwater elevations on the downgradient side of the WMA 1 barrier wall are approximately 10 feet lower than on the upgradient side, resulting in a steep hydraulic gradient across the barrier wall and a shallower gradient along the non-source area of the north plateau groundwater plume.

Groundwater levels in the backfilled WMA 2 excavation are several feet higher than modeled in the current conditions scenario and would be below grade across the backfilled WMA 2 excavation. Groundwater elevations are up to 10 feet lower on the north plateau plume side of the WMA 2 barrier wall, suggesting groundwater flow to the northwest and northeast through the WMA 2 slurry wall towards the non-source area of the north plateau groundwater plume and to the southeast towards Erdman Brook.

Table D-4 summarizes the modeled flow balance. Table D-5 shows the average linear velocities predicted by the near-field model for conditions after Phase 1.

Table D-4. Summary of Sand and Gravel Unit Flow Balance After Phase 1[(1)]

Inflow		Outflow	
Location	**Rate (m^3/y)**	**Location**	**Rate (m^3/y)**
Recharge at the Ground Surface	107,624	Down Flow to the KRS	8,909
Recharge from Bedrock from the Southwest	7,304	Seepage to Quarry Creek	8,780
		Seepage to Erdman Brook (TBU)	14,915
		French Drain to Erdman Brook	21,698
		Seepage to Frank's Creek	46,791
		Seepage to North Plateau Ditch	13,783
Total	114,928		114,876

NOTE: (1) For a recharge rate of 26 centimeters per year.

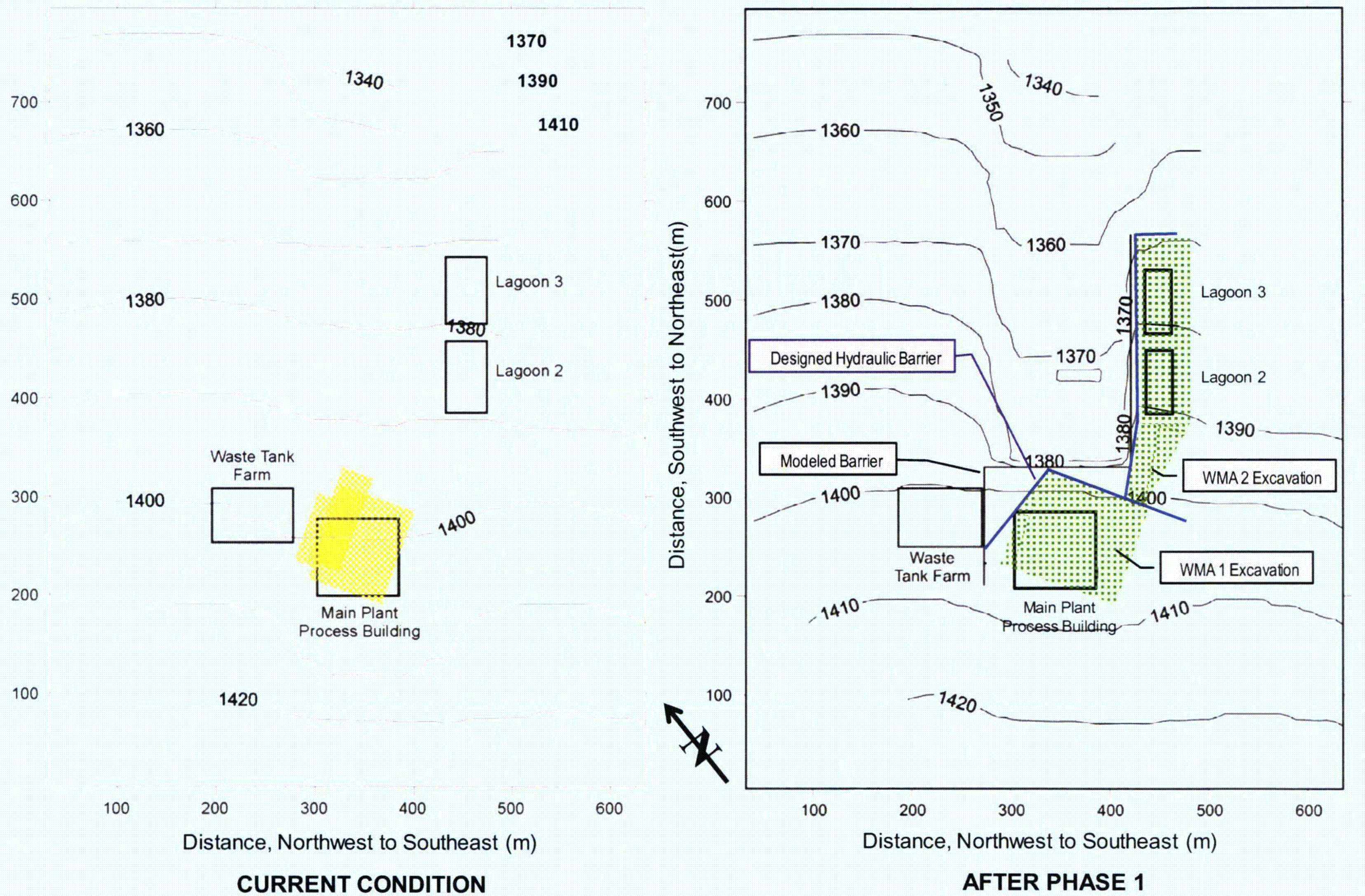


Figure D-9. Groundwater Flow Associated with the WMA 1 and WMA 2 Engineered Barriers

Table D-5. Average Linear Velocity for Flow Path Originating at the Process Building Area After Phase 1

Distance Along Flow Path (m)	Average Linear Velocity (m/y)	
	Slack-water Sequence	Thick-bedded Unit
0 to 40	81.0	81.2
40 to 80	79.2	82.2
80 to 120	22.5	1.9
120 to 160	61.2	1.8
160 to 200	104.3	1.9
200 to 240	95.6	6.0
240 to 280	112.6	84.7
280 to 320	131.3	111.5

NOTE: To convert meters per year to feet per year, multiply by 3.2803.

In calculation of linear velocities shown in Table D-5, the value of effective porosity of 0.35 was used for the slack-water sequence while the moisture content of the thick-bedded unit was used to reflect unsaturated conditions that develop along the flow path north of the location of the slurry wall. For the slack-water sequence and thick-bedded unit above the slack-water sequence, the travel time and average velocity along the flow path are 6.37 years and 50 meters per year and 70 years and 4.6 meters per year, respectively.

1.4.4 Groundwater Modeling Predictions for Conditions Following Phase 1

The revised near-field groundwater model for the north plateau suggests that the engineered barriers to be installed during Phase 1 decommissioning would have the following effect on groundwater flow in the north plateau:

- Groundwater flow patterns upgradient of the WMA 1 barrier wall and French drain would be similar to current flow patterns in the sand and gravel unit shown in Figure D-9.
- Water table elevations in WMA 1 would be approximately 10 feet higher on the upgradient side of the northeastern segment of the WMA 1 barrier wall compared to water levels immediately downgradient of this wall segment.
- This steep hydraulic gradient suggests that groundwater would preferentially flow from the backfilled WMA 1 excavation to the northeast across the barrier wall into the non-source area of the north plateau plume, rather than from the non-source area of the plume into the backfilled WMA 1 excavation.
- Groundwater elevations coincide on either side of the northwestern segment of the WMA 1 barrier wall separating the backfilled WMA 1 excavation from the Waste Tank Farm, suggesting low potential for groundwater flow across the barrier wall from either the backfilled excavation or Waste Tank Farm.

- Flow contours southeast of the WMA 1 barrier wall suggest that groundwater would flow to the east into the area of the backfilled WMA 2 excavation, as discussed in Section 1.4.3 of this appendix.
- Downgradient of the WMA 1 barrier wall groundwater flow in the sand and gravel unit would continue to the northeast across the north plateau. However, the upgradient diversion of groundwater flow by the barrier wall system would result in an overall reduction in the hydraulic gradient of the non-source area of the north plateau groundwater plume.
- Groundwater elevations in the backfilled WMA 2 excavation are expected to be up to 10 feet higher than present in the non-source area of the north plateau groundwater plume.
- Higher groundwater elevations within the backfilled WMA 2 excavation suggests groundwater would flow across the WMA 2 barrier wall to the northwest and northeast toward the non-source area of the north plateau groundwater plume and also to the southeast toward Erdman Brook.

2.0 Conceptual Post-Remediation Site Monitoring and Maintenance

DOE will be responsible for maintaining institutional controls and for monitoring and maintenance of the project premises until the completion of Phase 2 of the WVDP decommissioning.

This section describes the post-remediation site monitoring and maintenance program to be implemented by the DOE at the project premises following the completion of Phase 1 decommissioning. The Phase 1 program will include monitoring and maintenance associated with engineered barriers installed within the project premises and monitoring of environmental media within and outside the project premises. This monitoring and maintenance program will continue until the start of Phase 2 of the decommissioning, when the program requirements will be re-evaluated. DOE concludes that this program will be adequate to control and maintain the project premises because it is similar to the successful program currently in use and because it appropriately addresses all facilities of importance.

2.1 Monitoring and Maintenance of Engineered Barriers and Systems

The performance of the engineered barriers installed at WMA 1 and WMA 2 during Phase 1 decommissioning will be routinely monitored up to the start of Phase 2 of the decommissioning to ensure they function as designed. Systems and engineered barriers installed during work leading to the interim end state, such the Tank and Vault Drying System at WMA 3 and the geomembrane cover and slurry wall at WMA 7, will also be routinely monitored and maintained as part of the DOE monitoring and maintenance program. Corrective actions will be implemented to correct any observed defects or irregularities with these engineered barrier and systems.

2.1.1 North Plateau Subsurface Barrier Walls and French Drain

The monitoring and maintenance program will monitor the performance and condition of the subsurface hydraulic barriers installed at WMA 1 and WMA 2, and the French drain at WMA 1. This program will include routine inspections of these systems for signs of degradation or loss of performance.

Hydraulic Barrier Walls

A series of nested piezometers screened at different depth intervals will be installed at regular intervals upgradient and downgradient of the permanent hydraulic barrier walls installed downgradient of the WMA 1 and northwest of the WMA 2 excavations (Figure D-10) to monitor their performance. These piezometers will be spaced at intervals at least equal to the maximum lateral spacing recommended by the U.S. Environmental Protection Agency (EPA 1998). Water levels in these piezometers will be routinely monitored to identify any changes in water levels that may indicate the development of defects within the barrier walls that require corrective action. Groundwater will be routinely sampled and analyzed for radiological indicator parameters (gross alpha, gross beta, tritium) and for Sr-90 to evaluate the effectiveness of the barrier walls in preventing recontamination of WMA 1 and WMA 2. Changes in groundwater concentrations of these radiological indicator parameters may identify defects associated with the barrier walls that require corrective action to limit the potential recontamination of the backfilled WMA 1 and WMA 2 excavations.

If groundwater monitoring suggests repairs to the walls are required, these repairs will be accomplished through grouting, consistent with past industry experience and practice (e.g., EPA 1998).

French Drain

Monitoring and maintenance activities associated with the French drain installed upgradient of the WMA 1 hydraulic barrier wall will include monitoring of groundwater levels in piezometers installed on the upgradient and downgradient sides of the French drain following installation.

The need for and extent of repairs to the French drain, if any, will be determined based on analysis of the groundwater level data, which will be evaluated to identify evidence for any localized defect(s) in the French drain.

2.1.2 Waste Tank Farm Tank and Vault Drying System

The Tank and Vault Drying System installed in WMA 3 during the work to establish the interim end state will be routinely monitored and maintained during the Phase 1 period to ensure its continued operation as designed. The major components of the system – such as the blowers, heaters, and dehumidifier units – will be inspected and repaired or replaced as necessary to ensure continued operation of the system.

2.1.3 Waste Tank Farm Dewatering Well

As specified in Section 7 of this plan, the existing dewatering well will continue to be used to artificially lower the water table to minimize in-leakage of groundwater into the tank vaults. The water from this well will be collected, sampled, treated if necessary using a portable wastewater treatment system, and released to Erdman Brook through a State Pollutant Discharge Elimination System-permitted outfall.

2.1.4 NRC-licensed Disposal Area Engineered Barriers

The geomembrane cover and the hydraulic barrier wall installed at the NDA during work to establish the interim end state will be routinely monitored and maintained throughout Phase 1.

Geomembrane Cover

The geomembrane cover will be routinely inspected for signs of deterioration or damage to the membrane. The seams connecting the geomembrane panels will be inspected to evaluate their condition. The geomembrane cover will be repaired to remedy any defects or irregularities identified during these inspections.

Hydraulic Barrier Wall

A monitoring and maintenance program similar to that described for the barrier walls installed at WMA 1 and WMA 2 will be implemented for the hydraulic barrier wall installed upgradient of the NDA. Twenty-one piezometers were installed upgradient and downgradient of the barrier wall during its construction. Water levels in these piezometers will be routinely monitored during Phase 1 to evaluate the performance of the barrier wall in limiting groundwater flow into the NDA.

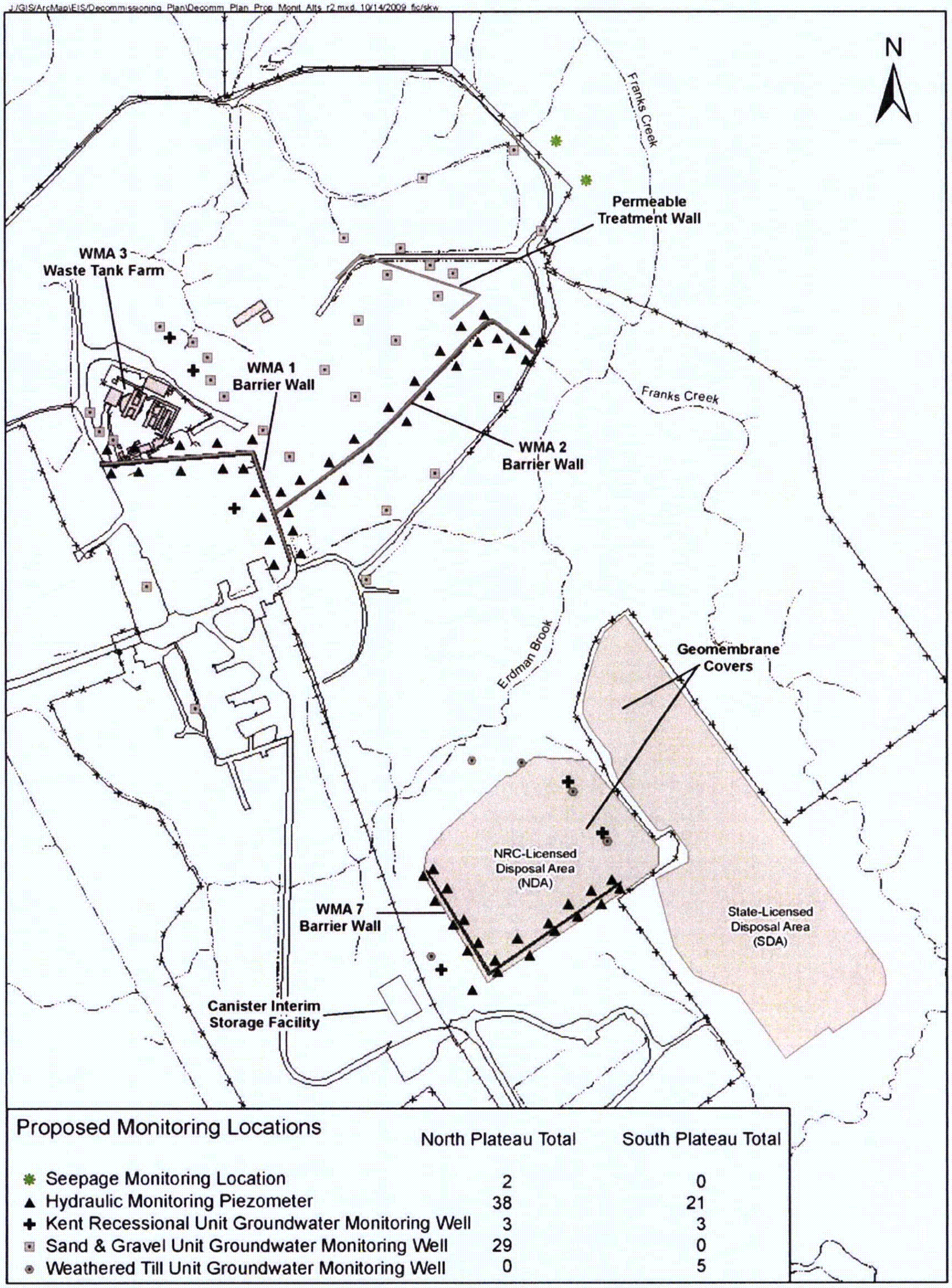


Figure D-10. Groundwater Monitoring Locations within the Project Premises during the Phase 1 Institutional Control Period

2.1.5 Security Features

The features important to security on the project premises and to security of the new Canister Interim Storage Facility during the period before Phase 2 of the decommissioning will be periodically inspected and maintained in good repair. These features include the security fences, signs, and security lighting described in Section 3.2 of this appendix.

2.2 Environmental Monitoring

The Phase 1 decommissioning activities will include the removal of the following facilities:

- Above-ground and below-grade facilities in WMA 1 and the underlying source area of the north plateau groundwater plume within a single excavation down into the underlying Lavery till;
- Lagoons 1, 2, and 3, the Neutralization Pit, Interceptors, Solvent Dike, and surrounding contaminated soils in WMA 2 within a single excavation down into the underlying Lavery till; and
- Most remaining facilities and concrete slabs down to a maximum depth of two feet.

The following facilities and contamination areas within the project premises will not be considered during Phase 1 decommissioning but will be addressed during Phase 2:

- The Waste Tank Farm in WMA 3, including the Permanent Ventilation System Building and the Supernatant Treatment System Support Building;
- The Construction Demolition Debris Landfill in WMA 4;
- The NDA in WMA 7; and
- The non-source area of the north plateau groundwater plume.

The DOE will implement an environmental monitoring program to monitor closed and remaining facilities and the non-source area of the north plateau groundwater plume as part of its management of the project premises during the Phase 1 institutional control period. Environmental monitoring will include onsite groundwater, storm water, and air monitoring, and onsite and offsite surface water, sediment, and radiation monitoring as described below. Annual reports will be issued summarizing the monitoring results. These reports will include analyses of the data collected, along with conclusions about trends and compliance with regulatory limits.

2.2.1 Groundwater Monitoring Within the Project Premises

Groundwater within the project premises will be monitored during the Phase 1 institutional control period in accordance with the DOE WVDP Groundwater Monitoring Plan in effect at the time. Offsite groundwater monitoring will not be performed as this monitoring program was discontinued in 2007. The onsite grounding monitoring program for the project premises is described below and shown on Figure D-10. A total of 40 groundwater wells will be routinely monitored along with 59 piezometers.

WMA 1 - Process Building and Vitrification Facility Area

Groundwater in the sand and gravel unit in the backfilled WMA 1 excavation will be monitored using the network of piezometers installed to monitor the effectiveness of the hydraulic barrier wall and French drain described in Section 2.1.1 of this Appendix. A monitoring well screened in the sand and gravel unit will also be installed in the upgradient portion of the WMA 1 excavation to provide information on groundwater quality flowing into the backfilled excavation.

An additional monitoring well screened in the Kent Recessional Sequence will be installed immediately upgradient of the WMA 1 hydraulic barrier wall to monitor groundwater in this unit and to evaluate potential migration of groundwater from the source area of the north plateau groundwater plume that was removed during Phase 1 decommissioning.

Groundwater from these piezometers and monitoring wells will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and for Sr-90 during the Phase 1 institutional control period.

WMA 2 - Low-Level Waste Treatment Facility Area

Groundwater in the sand and gravel unit in the backfilled WMA 2 excavation will be monitored using the network of piezometers installed to monitor the effectiveness of the hydraulic barrier wall and French drain described in Section 2.1.1 of this Appendix. Three monitoring wells screened in the sand and gravel unit will also be installed on the southeastern boundary of the WMA 2 excavation to provide information on groundwater flow and quality in this area.

Groundwater from these piezometers and monitoring wells will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and for Sr-90 during the Phase 1 institutional control period.

WMA 3 - Waste Tank Farm Area

Groundwater in the sand and gravel unit and the Kent Recessional Sequence will be routinely monitored at WMA 3 during the Phase 1 institutional control period. Eight wells will be screened in the sand and gravel unit with three wells upgradient and five wells downgradient of the Waste Tank Farm. Two wells screened in the Kent Recessional Sequence will be installed downgradient of the Waste Tank Farm.

Groundwater from these wells will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and for Sr-90 during the Phase 1 institutional control period.

WMA 4 - Construction Demolition Debris Landfill Area

Groundwater in the sand and gravel unit at WMA 4 will be routinely monitored at six locations, including four monitoring wells around the Construction and Demolition Debris Landfill, and at two groundwater seep locations along the edge of the north plateau outside of the WVDP fence line.

Groundwater at WMA 4 will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and for Sr-90.

WMA 6 - Central Project Premises

Groundwater in the sand and gravel unit at WMA 6 will be routinely monitored at two well locations, including one well upgradient of the rail spur and the other well downgradient of the rail spur and the removed Demineralizer Sludge Ponds and Equalization Basin.

Groundwater at these locations will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium).

WMA 7 – NDA

Groundwater in the weathered Lavery till and Kent recessional unit at WMA 7 will be routinely monitored by five wells screened in the weathered Lavery till and three wells screened in the Kent Recessional Sequence. One well cluster will be located upgradient of the NDA and will include a well screened in the weathered Lavery till and one screened in the Kent Recessional Sequence. Two well clusters, each with a well screened in the weathered Lavery till and Kent Recessional Sequence, will be located downgradient of the burial area. The two remaining wells screened in the weathered Lavery till will be located downgradient of the burial area.

Groundwater at WMA 7 will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and annually for specific radionuclides (Cs-137, Sr-90, Am-241, and Pu isotopes).

Non-Source Area of the North Plateau Plume

Groundwater in the sand and gravel unit will be routinely monitored at 11 well locations within the non-source area of the north plateau groundwater plume. These wells are located along the length of the plume from the WMA 1 barrier wall to the Construction and Demolition Debris Landfill in WMA 4. Three wells are located downgradient of the Permeable Treatment Wall to evaluate its effectiveness in reducing Sr-90 concentrations in groundwater from the sand and gravel unit.

Groundwater in the non-source area of the north plateau groundwater plume will be sampled semiannually for radiological indicator parameters (gross alpha, gross beta, and tritium) and for Sr-90.

2.2.2 Surface Water, Sediment, and Storm Water Monitoring

Surface water and associated stream sediments will be routinely monitored both within and outside the project premises during the Phase 1 institutional control period. The monitoring locations are currently part of the DOE WVDP annual environmental monitoring program. These locations have been uniquely sited to monitor surface water releases from the WVDP and the Center. Several of the locations have been actively monitored since the implementation of the program in 1982 providing a significant historical record of surface waters leaving the WVDP and the Center.

Eight surface water-sampling locations within the project premises will be routinely monitored during the Phase 1 institutional control period (Figure D-11). These locations monitor streams both within (WNDNKEL, WNSP005, WNNDADR, WNFRC67, WNERB53) and leaving the project premises (WNSW74A, WNSWAMP, and WNSP006). Sediment samples will be collected from three locations where surface waters leave the project premises (SNSW74A, SNSWAMP, and SNSP006).

Surface water will be routinely collected and analyzed from three sampling locations outside of the project premises (Figure D-12). These locations will monitor surface water quality in Buttermilk Creek and Cattaraugus Creek where these streams leave the Center (WFFELBR, WFBCTCB) and where Buttermilk Creek enters the Center (WFBCBKG). Sediment samples will be collected from all three off-site locations (SFBCSED, SFTCSED, SFCCSED).

Surface water and sediment samples will be collected from these locations semi-annually and will be analyzed for radiological indicator parameters (gross alpha, gross beta, and tritium).

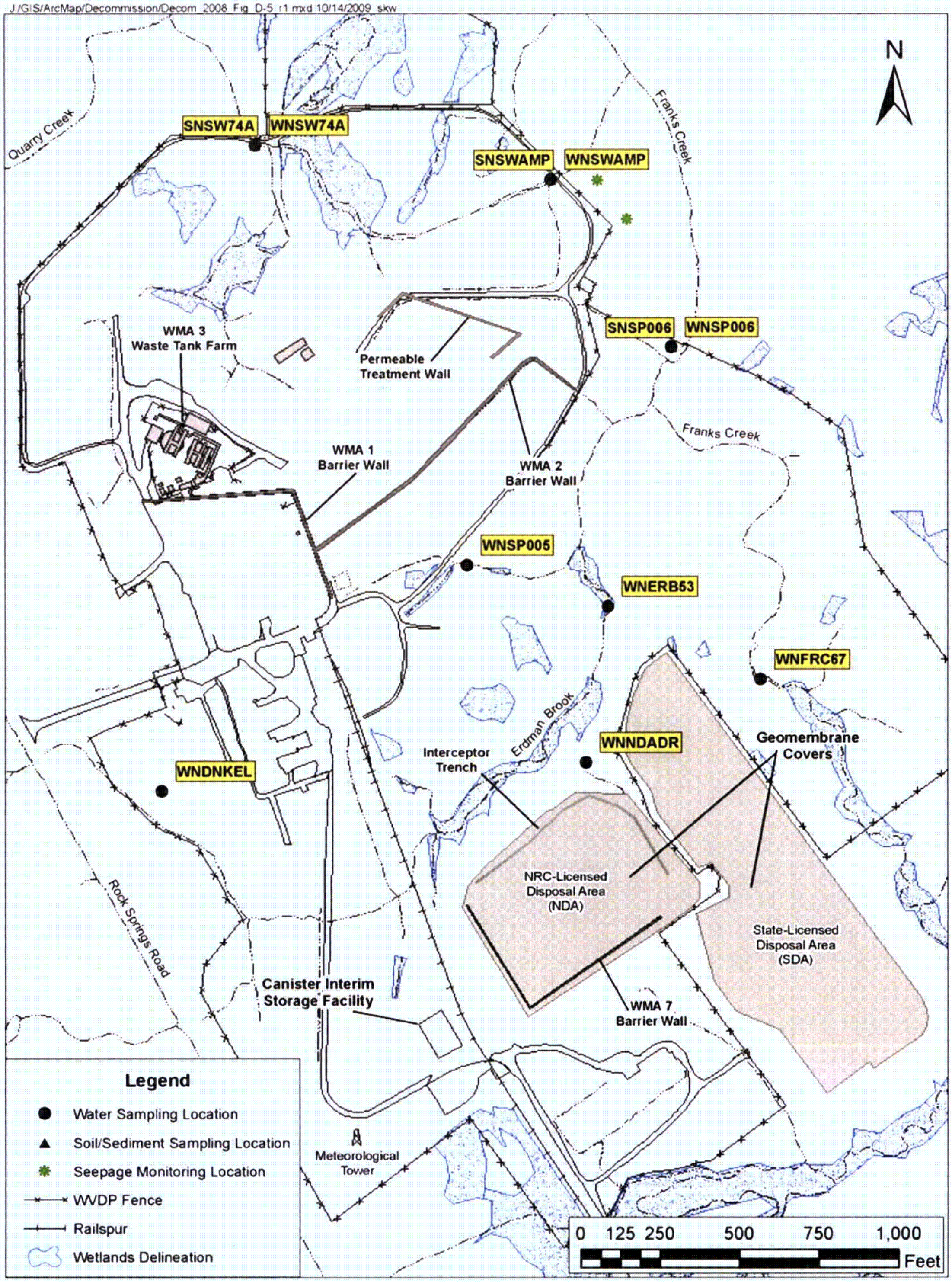


Figure D-11. Surface Water and Sediment Sampling Locations on the Project Premises during the Phase 1 Institutional Control Period

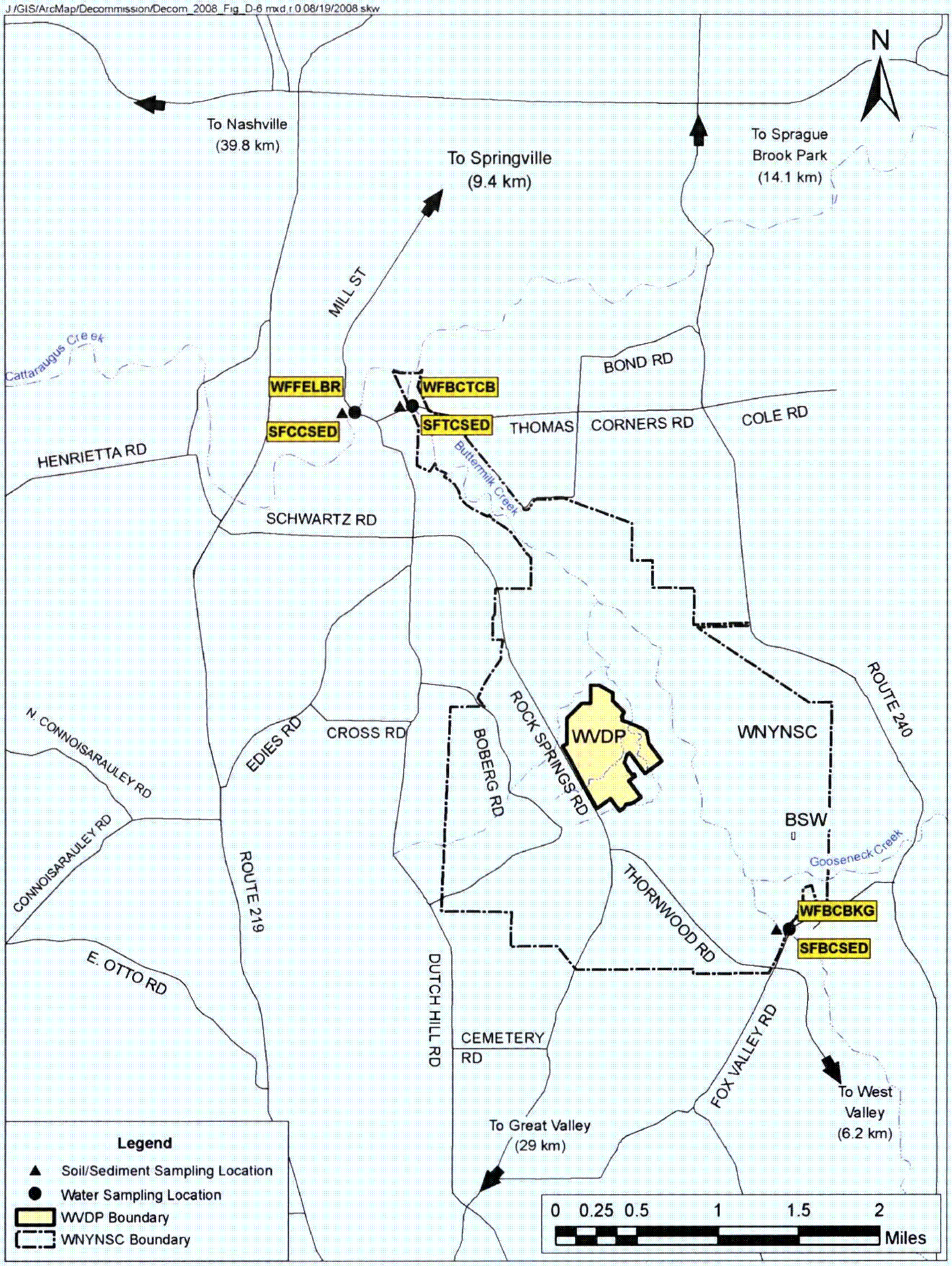


Figure D-12 – Offsite Surface Water and Sediment Sampling Locations during the Phase 1 Institutional Control Period

The New York State Pollutant Discharge Elimination System permit issued to the DOE WVDP requires periodic sampling from storm water outfalls located within the project premises. Sampling from these outfalls during storm events is designed to assess specific chemicals in storm water discharges that may originate from industrial or construction activity runoff from locations within the project premises. The planned storm water sampling locations are identified on Figure D-13. Sampling will be performed semi-annually for the non-radiological parameters specified in the New York State Pollutant Discharge Elimination System permit.

2.2.3 Air Monitoring

The stack discharge from the Permanent Ventilation System Building in the Waste Tank Farm in WMA 3 will be the only air monitoring location to be routinely monitored within and outside of the project premises during the Phase 1 institutional control period (Figure D-14).

The Permanent Ventilation System ventilates the Supernatant Treatment System Valve Aisle and Tanks 8D-1, 8D-2, 8D-3, and 8D-4 in WMA 3. The air discharged from these facilities passes though high-efficiency particulate air filters before discharge through the Permanent Ventilation System Building stack. Air discharged from the Tank and Vault Drying System will also be treated in the Permanent Ventilation System Building.

Air discharges from this location will be analyzed for radiological indicator parameters (gross alpha, gross beta, and tritium) and specific radionuclides (Cs-137, Sr-90, I-129, Am-241, and U and Pu isotopes).

2.2.4 Direct Radiation Monitoring

Direct radiation monitoring using thermoluminescent dosimeters will be performed at 19 locations within and outside of the project premises. These monitoring locations are currently part of the DOE WVDP annual environmental monitoring program and were sited to monitor both on-site and off-site radiation exposure from facilities within the project premises and the State-Licensed Disposal Area. Several of these locations have been actively monitored since 1982.

Eight monitoring locations will be within the project premises (Figure D-15) and eleven stations will be located on the perimeter of the Center (Figure D-16). All locations will be routinely monitored for gamma radiation exposure on a quarterly monitoring schedule.

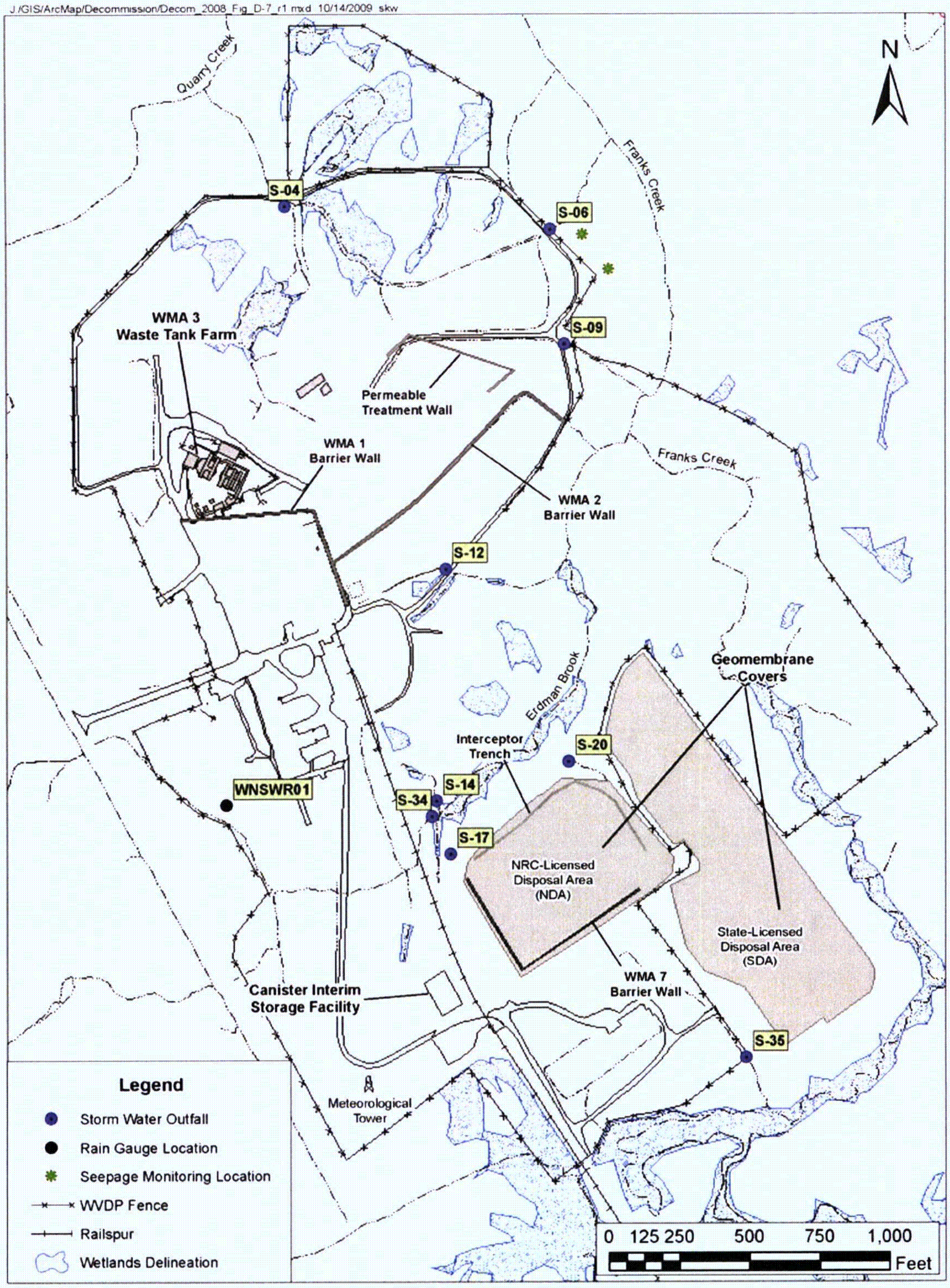


Figure D-13. Storm Water Sampling Locations on the Project Premises during the Phase 1 Institutional Control Period

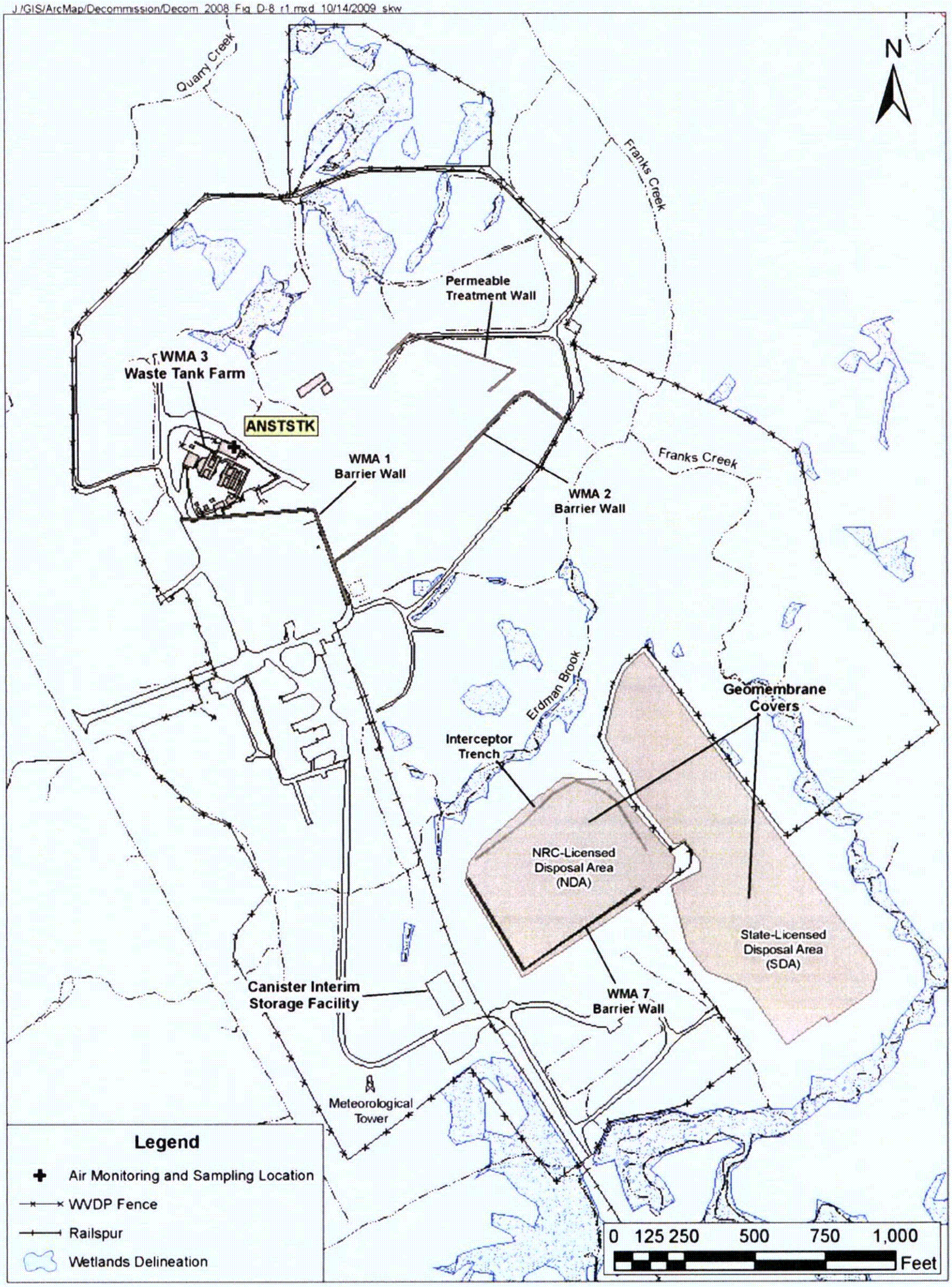


Figure D-14. Air Monitoring Locations on the Project Premises during the Phase 1 Institutional Control Period

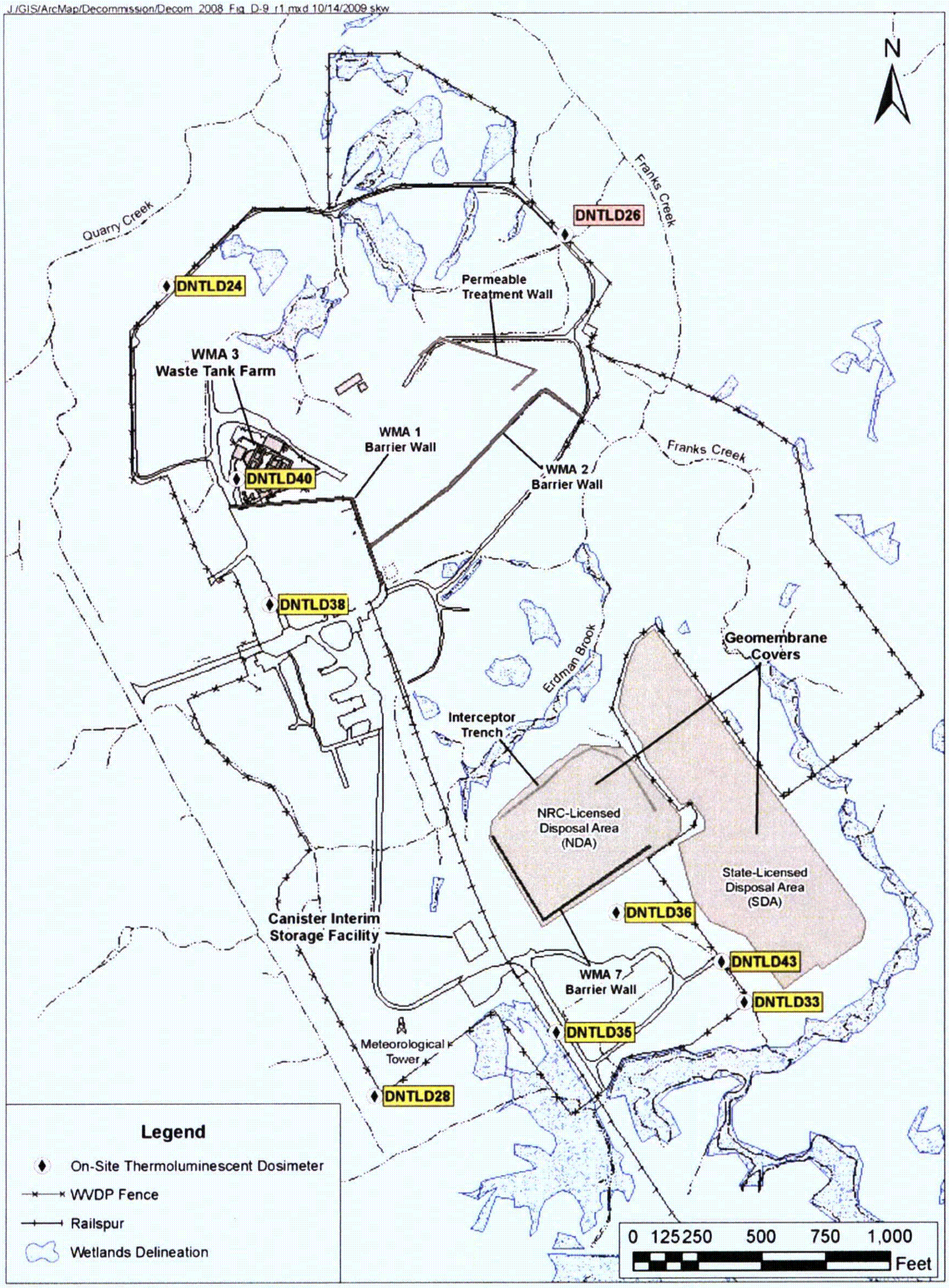


Figure D-15 – Direct Radiation Monitoring Locations on the Project Premises during the Phase 1 Institutional Control Period

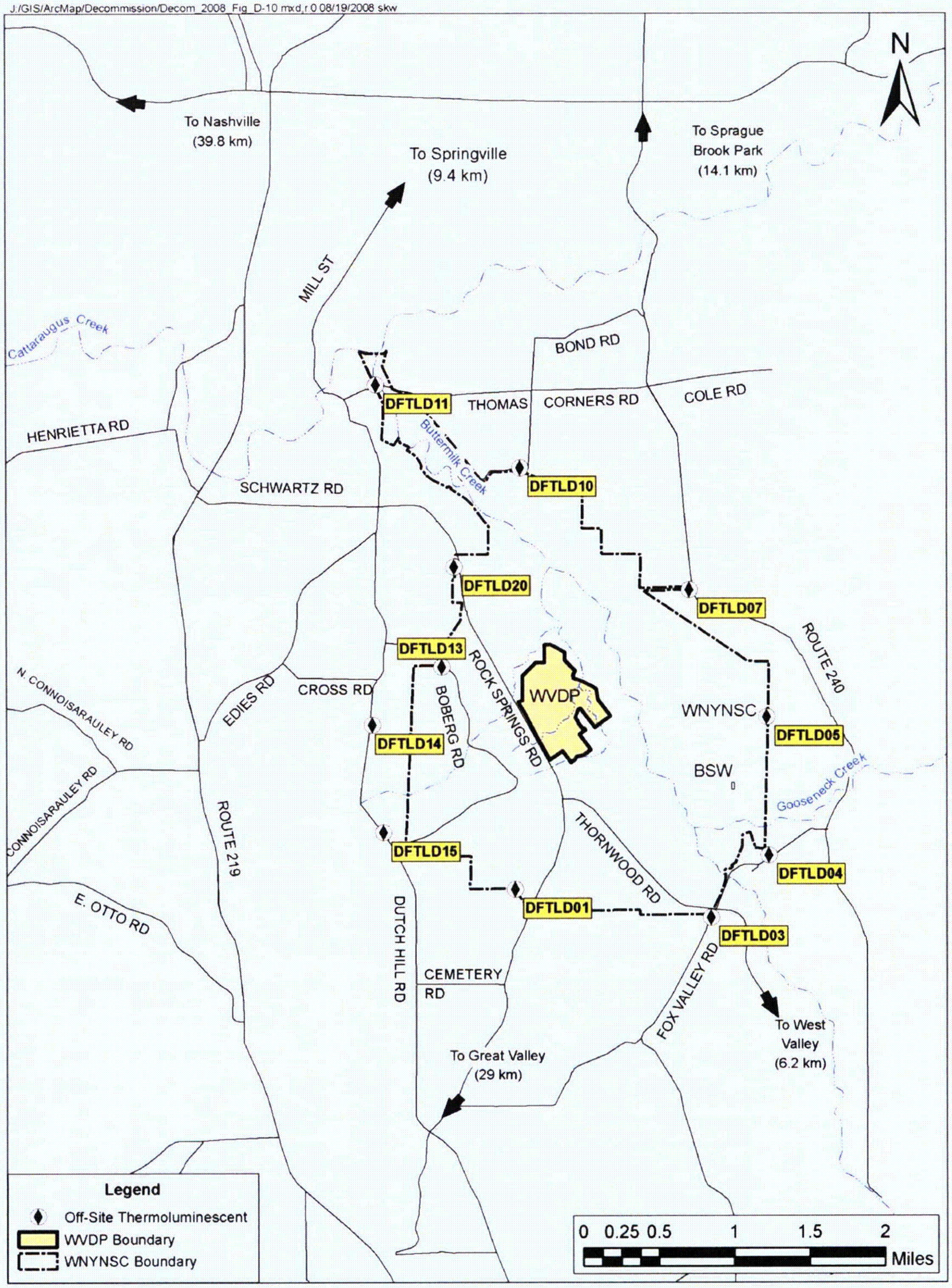


Figure D-16. Offsite Direct Radiation Monitoring Locations during the Phase 1 Institutional Control Period

3.0 Phase 1 Institutional Control Program

This section describes the institutional control program that will be implemented for the project premises during and following the completion of the Phase 1 remedial activities.

3.1 Government Control of the Project Premises

NYSERDA is the current owner of the project premises property and will remain owner following Phase 1 activities. As stipulated in the Cooperative Agreement with NYSERDA, DOE shall remain in exclusive use and possession of the project premises and project facilities throughout the remainder of the project term (DOE and NYSERDA 1981). DOE will therefore continue control of the project premises during the implementation of the Phase 1 decommissioning activities and during the Phase 1 institutional control period. In this capacity, DOE carries the full authority of the federal government in enforcing institutional controls over the project premises.

DOE will be responsible for operating and maintaining facilities within the project premises such as the Waste Tank Farm, the NDA, and the non-source area of the north plateau groundwater plume in a safe manner. DOE will continue to implement the environmental radiation protection program for the project premises as required by DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. NRC will also be involved in a regulatory oversight capacity over the project premises, which will remain under NRC license.

3.2 Institutional Control Design Features

The institutional control program for the project premises will prevent its unacceptable use and protect against inadvertent intrusion into the site. DOE in its capacity as the steward of the site will ensure that institutional controls are maintained at the project premises during Phase 1 decommissioning and during the Phase 1 institutional control period. These institutional controls will include:

- Security fencing and signage along the perimeter of the project premises to prevent inadvertent intrusion into the site and to notify individuals that access is forbidden without permission from the DOE,
- A full time security force to prevent unauthorized access into the project premises,
- Authorized personnel and vehicle access into the project premises will be limited to designated gateways through the perimeter security fence
- The environmental monitoring program implemented at the project premises during the Phase 1 institutional control period will ensure that operations at the site protect members of the public and the environment from radiation risk.

Additional institutional controls will be provided for the new Canister Interim Storage Facility on the south plateau. These will include measures such as security fencing around the area and appropriate security lighting.

4.0 References

Code of Federal Regulations and Federal Register Notices

10 CFR 20 Subpart E, *Radiological Criteria for License Termination.*

67 FR 22, *Decommissioning Criteria for the West valley Demonstration Project (M-32) at the West Valley Site; Final Policy Statement*, U.S. Nuclear Regulatory Commission, Washington, D.C., February 1, 2002.

DOE Orders

DOE Order 5400.5, Change 2, *Radiation Protection of the Public and the Environment.* U.S. Department of Energy, Washington, D.C., January 7, 1993.

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APPENDIX E

DOSE MODELING PROBABILISTIC UNCERTAINTY ANALYSES

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to describe probabilistic uncertainty analyses performed to evaluate the degree of conservatism in key input parameters for the conceptual models used to develop derived concentration guideline levels (DCGLs) for surface soil, subsurface soil, and streambed sediment, along with the results of these analyses.

INFORMATION IN THIS APPENDIX

This appendix provides the following information:

- Section 1 provides introductory information to help place the discussions that follow into context.
- Section 2 defines key terms used in the discussions.
- Section 3 summarizes the probabilistic analysis capabilities of the RESRAD computer code used in the analyses.
- Section 4 describes criteria used for selecting parameters for uncertainty analysis.
- Section 5 describes how parameter distributions were selected.
- Section 6 describes correlation of parameters.
- Section 7 describes the uncertainty analysis results for each of the three conceptual models, including DCGLs expressed as the peak-of-the-mean (50^{th} percentile) and 95^{th} percentile.
- Section 8 describes parameter output rank correlations.
- Section 9 provides conclusions and describes actions taken on the analysis results.
- Attachment 1 contains copies of representative probabilistic output plots.
- Attachment 2 contains the electronic files developed in performing the analyses.

RELATIONSHIP TO OTHER PLAN SECTIONS

This appendix provides supporting information for Section 5. Information provided in *Section 5 and in Section 1 on the project background will help place the information* in this appendix into context.

1.0 Introduction

1.1 Purpose

The probabilistic uncertainty analyses discussed in this appendix were performed to evaluate the degree of conservatism in key input parameters for the conceptual models used in developing DCGLs for surface soil, subsurface soil, and streambed sediment that are described in Section 5 of this plan. The DOE letter that forwarded Revision 0 of this plan to NRC for review (DOE 2008) noted that this matter was still under evaluation when Revision 0 was completed.

These probabilistic uncertainty analyses supplement the deterministic sensitivity analyses described in Section 5 of this plan. They compute the total uncertainty in the DCGLs resulting from the uncertainty in or the variability of the input parameters. They also help determine the relative importance of the contributions of different input parameters to the total uncertainty in the DCGLs.

These analyses thereby provide additional perspective on the relationships between conceptual model input parameters and estimated dose, along with sets of DCGLs expressed in probabilistic terms. This information supports a risk-informed approach to establishing cleanup goals for Phase 1 of the decommissioning.

1.2 Background

The DCGLs for surface soil, subsurface soil, and streambed sediment were developed using the basic RESRAD deterministic approach in which the analysis is performed by assigning each parameter a single value, as described in Section 5 of this plan. As noted in Section 5, RESRAD was selected as the mathematical model for DCGL development due to its extensive use by DOE and by NRC licensees in developing DCGLs and evaluating doses from residual radioactivity at decommissioned sites.

General NRC Guidance on Uncertainty and Sensitivity Analyses

NRC guidance on uncertainty and sensitivity analyses appears in Appendix I to NUREG-1757, Volume 2 (NRC 2006). NRC concludes that while the deterministic modeling approach has the advantage of being simple to implement and easy to communicate to a non-specialist audience, it has significant limitations:

- It does not allow consideration of the effects of unusual combinations of input parameters;
- It does not provide information on uncertainty in the results, which would be helpful to the decision-maker; and
- It often leads to overly conservative evaluations because it has to rely on the use of pessimistic estimates of each parameter of the model to ensure a bounding dose estimate, that is, results that are likely to overestimate the actual peak dose.

The first two limitations apply to the deterministic dose analysis described in Section 5, which did not include evaluation of different parameter combinations or estimates of uncertainty. And while DOE used conservative model input parameters in many cases, it is difficult to demonstrate that the results of the deterministic dose analysis are bounding.

NRC encourages the use of probabilistic techniques to evaluate and quantify the magnitude and effect of uncertainties in dose assessments, and the sensitivity of the calculated risks from individual parameter values and modeling assumptions. Probabilistic uncertainty analysis provides more information to the decision-maker than deterministic analysis, as it characterizes a range of potential doses and the likelihood that a particular dose may be exceeded. (NRC 2006)

Uncertainty analyses in the RESRAD probabilistic modules use Latin hypercube sampling[1], a modified Monte Carlo method, allowing for the generation of representative input parameter values from all segments of the input distributions. Input variables for the models are selected randomly from probability distribution functions for each parameter of interest. Parameter distribution functions may be either independent or correlated to other input variable distributions. The analysis is then performed hundreds of times to obtain a distribution of doses resulting from each set of randomly selected input parameters.

The results of a probabilistic uncertainty analysis provide a distribution of doses illustrating the effects of random combinations of input parameters. It should be recognized that some percentage of the calculated distribution of doses may exceed the regulatory limit, which is expressed as a (deterministic) single value. Compliance can be stated in terms of a metric of the distribution such as the mean falling below the limit, or only a percentage of calculated doses exceeding the limit. (NRC 2006)

NRC indicates that when using probabilistic dose modeling, the "peak-of-the-mean" dose distribution should be used for demonstrating compliance with its License Termination Rule in 10 CFR Part 20, Subpart E (NRC 2006).

Specific NRC Guidance for Phase 1 of the WVDP Decommissioning

DOE and NRC held two scoping meeting on DOE's dose modeling plans. The NRC summary of the second meeting (NRC 2008) included the following statements:

> "NRC indicated that it might not be acceptable to use the mean or most likely value for those parameters that have the largest impact on dose in a deterministic analysis (e.g., for parameters such as K_ds that have a large parameter range and uncertainty)."
>
> "NRC warned of the potential pitfalls of performing a deterministic analysis with a sensitivity analysis in lieu of a probabilistic assessment. Depending on the combination and range of parameter values selected and models employed (e.g., mass balance versus non-dispersion model in RESRAD), key radionuclides and pathways, the results of the sensitivity analysis could be misleading and the full range of uncertainty difficult to determine. Selection of parameter values should be guided by conservative assumptions when uncertainty is large and cannot be reduced. To determine the impact of a particular parameter value on the dose results, DOE must identify key risk drivers and perform a comprehensive sensitivity analysis to ensure that its selection of parameter values in its deterministic analysis errors on the side of conservatism."

DOE identified key risk (i.e., dose) drivers and included a comprehensive sensitivity analysis in Section 5.2.4 of Revision 1 to the plan. The analyses described in this appendix, complete DOE actions on these matters.

[1] The Latin hypercube method is a modified Monte Carlo method; see Section 2 below for definitions of terms such as these. NRC supported development of the probabilistic version of RESRAD for use in determining compliance with its License Termination Rule (Yu, et al. 2000). RESRAD probabilistic modeling capabilities are discussed in Section 3 below.

1.3 Analyses and Associated Electronic Files

The probabilistic dose analyses discussed herein were performed using the probabilistic modules of RESRAD Version 6.4 (LePoire, et al. 2000; Yu, et al. 2000; Yu, et al. 2001) making use of the stratified sampling of the Latin hypercube method.

For the surface soil model, three groups of results were generated for 1000 sets of input parameters, with calculated statistical parameters (minimum, maximum, mean, percentiles) output by RESRAD for each of the three input parameter datasets. For the subsurface and streambed sediment models, use of the mass balance groundwater option results in long computation times for multiple parameter input sets. Therefore, only a single set of 1000 input values for each parameter was used for the subsurface soil and sediment evaluation where simulation times were extensive.

Included in the electronic files of Attachment 1 are the RESRAD input and output files for surface soil ("RESRAD PROB SURF.zip"), subsurface soil ("RESRAD PROB SUBS.zip"), and sediment ("RESRAD PROB SED.zip"), and a Word file containing output plots of dose over time for each radionuclide in each media ("PROB Dose Plots.doc").

1.4 Products of the Probabilistic Uncertainty Analyses

The primary products of these analyses are as follows:

- Sets of peak-of-the-mean $DCGL_W$ values for surface soil, subsurface soil, and streambed sediment, that is, values that have a 50 percent probability that the specified concentration for each radionuclide would correspond to a dose of 25 mrem in the year of peak dose;
- Sets of 95^{th} percentile $DCGL_W$ values for surface soil, subsurface soil, and streambed sediment, that is, values that have a 95 percent probability that the specified concentration for each radionuclide would correspond to a dose of 25 mrem in the year of peak dose;
- Preliminary dose estimates for the remediated Waste Management Area (WMA) 1 excavation expressed as the peak of the mean (50^{th} percentile) and the 95^{th} percentile; and
- Preliminary dose estimates for the remediated WMA 2 excavation expressed as the peak of the mean and the 95^{th} percentile.

> As discussed in Section 9.2 of this appendix, the results of the probabilistic uncertainty analyses indicate that some input parameters used in the deterministic modeling to develop DCGLs may not be sufficiently conservative to ensure bounding results.

2.0 Key Terms

Because of the technical nature of the discussions in this appendix, some readers may find the following definitions to be useful. These definitions are tailored to the use of the terms in this appendix.

Behavioral parameter. Any conceptual model input parameter whose value would depend on the receptor's behavior within the scenario definition. For the same group of receptors, a behavioral parameter value could change if the scenario changed, e.g., parameters for recreational use could be different from those for residential use. (See also **metabolic parameter** and **physical parameter**.)

Correlation. A measure of the strength of the relationship between two variables (e.g., conceptual model input parameters) used to predict the value of one variable given the value of the other.

Correlation coefficient. Correlation coefficients (R values) are expressed on a scale from -1.0 to +1.0, with the strongest correlations being at both extremes and providing the best predictions. Negative values reflect inverse relationships. (See also **partial rank correlation coefficient**.)

Deterministic analysis. In a deterministic analysis, each input parameter is assumed to be an exactly known single value, as are the analysis results.

Empirical distribution. An empirical distribution is a parameter distribution well defined by available data to the extent that additional sampling would not be expected to significantly change the distribution's shape.

Latin hypercube sampling. A modified **Monte Carlo method** used to generate random samples of input parameters in the probabilistic version of RESRAD.

Lognormal distribution. In a lognormal distribution, the logarithm of the parameter has a **normal distribution**. A lognormal distribution is defined by two parameters, the logarithmic mean and its standard deviation.

Mean. The arithmetic mean as used here is the mathematical average of a set of numbers. The mean is calculated by adding a set of values and dividing the total by the number of values in the set.

Metabolic parameter. A parameter representing the metabolic characteristics of the potential receptor that is independent of scenario. (Metabolic parameters were not included in the evaluation discussed in this appendix.)

Monte Carlo method. A technique which obtains a probabilistic approximation to the solution of a problem by using statistical sampling techniques. Monte Carlo methods rely on repeated random sampling to compute their results, and are often used to simulate complex physical and mathematical systems.

Normal distribution. Probability values in a normal distribution follow a bell shaped curve centered about a mean value with the width of the "bell" described by the standard deviation. In a bounded normal distribution, upper and lower limits to the range are specified.

Overall coefficient of determination. This coefficient, denoted by R^2, provides an indication of the variability in the overall radionuclide dose accounted for by the selected input parameters. It varies between 0 and 1; the higher the value, the greater the influence. A value of 0 indicates the selected parameters do not influence the calculated dose at all.

Partial rank correlation coefficient. The partial rank correlation coefficient measures the strength of the relationship between variables after any confounding influences of other variables have been removed. (See also **rank correlation coefficient.**)

Peak of the mean. The highest dose value in a plot of the estimated mean dose over time.

Physical parameter. Any parameter whose value would not change if a different group of receptors was considered. Physical parameters are site-specific factors determined by the source, its location, and geological or physical characteristics of the site.

Probabilistic analysis. In a probabilistic analysis, statistical distributions are defined for input parameters to account for their uncertainty, and the analysis results reflect the resulting uncertainty, e.g., a distribution of values rather than a single value. Such analyses use a random sampling method to select parameter values from a distribution. Results of the calculations appear in the form of a distribution of values.

Probability density function. A graphical representation of the probability distribution of a continuously random variable illustrating the range of possible values and the relative frequency (probability) of each value within the range. Uncertainty in a conceptual model input parameter is represented by the probability density function for that parameter. Probability distribution functions provided for in RESRAD include empirical, uniform, triangular, normal, and lognormal.

Rank correlation coefficient. A correlation coefficient between two variables that is used for determining the relative importance of input parameters in influencing the resultant dose.

Regression analysis. A mathematical method of modeling the relationships among three or more variables used to predict the value of one variable given the values of the others.

Triangular distribution. In a triangular distribution of a continuous random variable, the graph of the probability density function forms a triangle, with a range defined by minimum and maximum values and a mode value which is the most frequent (probable) value.

Uniform distribution. In a uniform distribution, each value within the range has the same probability of occurrence.

3.0 *The Probabilistic Version of* RESRAD

The probabilistic RESRAD code is an extended and enhanced version of RESRAD. RESRAD Version 6.4, which was used for the dose analyses described in Section 5 of this plan, provides both deterministic and probabilistic analysis capabilities.

The probabilistic version of RESRAD was developed for use in site-specific dose modeling in support of NRC's License Termination Rule compliance process for decontamination and decommissioning of NRC-licensed sites. Probabilistic analysis capabilities were incorporated into RESRAD in external software modules integrated into the code. Three reports describe these probabilistic analyses capabilities and how they are applied:

- NUREG/CR-6676, *Probabilistic Dose Analysis Using Parameter Distributions Developed for RESRAD and RESRAD-BUILD Codes* (Kamboj, et al. 2000);

- NUREG/CR-6692, *Probabilistic Modules for the RESRAD and RESRAD-Build Computer Codes, User Guide* (LePoire, et al. 2000); and
- NUREG/CR-6697, *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes* (Yu, et al. 2000).

Three basic types of input parameters are considered in probabilistic analyses: physical parameters, behavioral parameters, and metabolic parameters[2]. Certain parameters fall into more than one category, e.g., inhalation rate is both a behavioral parameter and a metabolic parameter.

The probabilistic modules in RESRAD Version 6.4 provide default values and distributions for various parameters. Default probability distributions include normal, lognormal, uniform, triangular, and empirical. These default distributions are based primarily on the quantity of relevant data available in reviewed technical literature.[3] For three parameters of interest in this plan – cover depth, precipitation rate, and well pumping rate – a default distribution type is not provided.

In a RESRAD probabilistic analysis, the results from all input samples are analyzed and presented in a statistical format in terms of the average value, standard deviation, minimum value, and maximum value. The cumulative probability distribution of the output is presented in both tabular and graphical forms.

The basic process includes the following steps:

- Identifying parameters for probabilistic evaluation;
- Defining distributions of key parameters;
- Assigning correlations between input parameters, which is done to limit the occurrence of unrealistic physical conditions;
- Verifying that simulation input values reflect the desired correlations by visual inspection of scatter plots of correlated parameters;
- Determining parameters with highest rank correlation coefficients in the results, i.e., those that most influence dose; and
- Confirming output parameter correlations with scatter plots of parameter input values versus calculated dose.

Figure E-1 illustrates the process.

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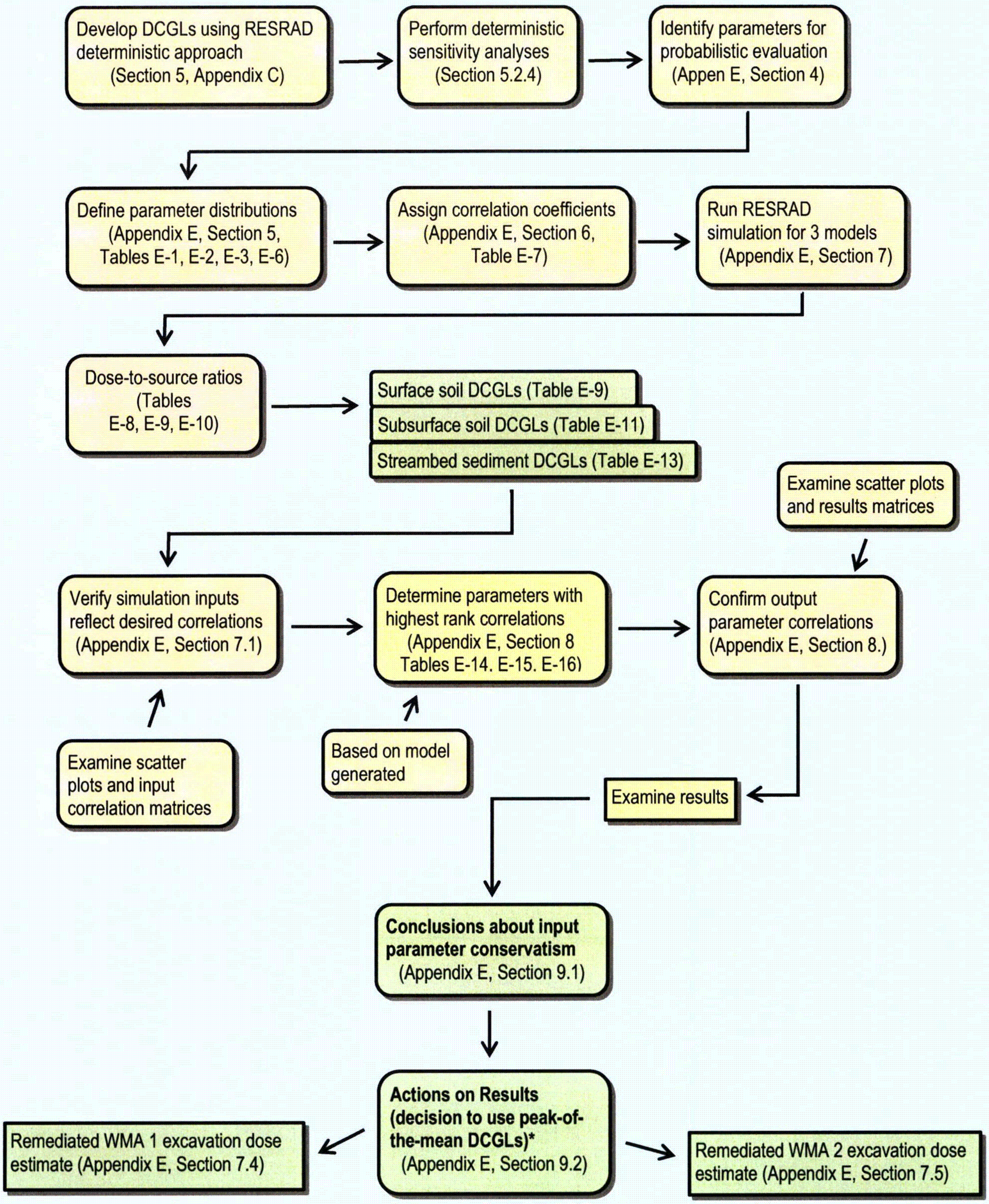
[2] Metabolic parameters were not included in this evaluation because the deterministic values represent means for the generic population, which would be independent of site conditions (Kamboj, et al. 2000).

[3] Parameter distributions developed for use with RESRAD and RESRAD-BUILD and their bases are described in Attachment C to NUREG/CR-6697 (Yu, et al. 2000).



*For surface soil and streambed sediment. See Section 5.2.8 for subsurface soil DCGLs.

Figure E-1. Probabilistic Uncertainty Analysis Process

4.0 Key Parameter Selection

The main criteria used for identifying key parameters to be evaluated involved the expected parameter influence on dose variability. That is, key parameters are those that have the largest effect on the dose analysis results.

Section 5.2.4. of this plan describes the results of sensitivity analyses for key input parameters for each of the three conceptual models. Tables E-1, E-2, and E-3 identify key parameters for the three conceptual models described in Section 5 of the plan, along with their assigned distributions, which are discussed in the next section.

Section 5.2.4 identifies Sr-90 and Cs-137 as likely to be the primary dose drivers for surface soil, subsurface soil and sediment exposure pathways. However, all eighteen radionuclides of interest were evaluated in the probabilistic analyses for the sake of completeness.

Other factors considered in parameter selection included the availability of site-specific information that could be used to define the distributions and NRC guidance on potentially significant parameters. Preference was also given to including parameters for which input correlations with other input variables could be defined, and where ambiguous input correlations with other input parameters was limited. Additionally, a number of parameters were used to establish a site-specific dilution factor (See Appendix C) corroborated by the detailed three dimensional flow model. These parameters were not varied with the exception of hydraulic conductivity, well pumping rate and length parallel to aquifer flow. For these parameters the probabilistic evaluation included values that would vary the dilution factor within a reasonable site-specific range.

Initial probabilistic simulations included parameters such as soil density, total porosity, and effective porosity for the contaminated, unsaturated, and saturated zones. These parameters consistently had correlation coefficients below 0.25. Because the correlation of these parameters with other more significant input parameters (i.e. hydraulic conductivity) was not clear, these parameters were dropped from subsequent analysis. Additional information regarding parameter input correlation is provided in Section 6.0.

5.0 Parameter Distribution Selection

This section first addresses the statistical distributions of model input parameters other than K_d values and then addresses K_d values.

5.1 Parameters Other Than Distribution Coefficients

Distributions selected for the input parameters are presented in Tables E-1, E-2, and E-3, and were based on applicable guidance in NUREG/CR-6676 (Kamboj, et al. 2000) and NUREG/CR-6697 (Yu, et al. 2000). Site specific parameters were generally assigned triangular distributions centered on the most likely value (e.g., source thickness, contaminated length parallel to aquifer flow).

Table E-1 identifies parameters of interest and their assigned distributions for the surface soil conceptual model that were varied during the analyses and the distribution used for each parameter, except for distribution coefficients and the plant, meat and milk biotransfer factors. The distribution coefficients for all ten elements associated with the radionuclides of interest were also varied using bounded lognormal distributions.

Table E-1. Input Parameter Distributions for Surface Soil Model (Other than K_d and Biotransfer Factor Values)(1)(2)

RESRAD Parameter	Parameter Description	Units	Distribution	Parameters(3)			
THICK0	Contaminated zone thickness	m	triangular	0.5	1	3	
LCZPAQ	Length parallel to aquifer flow	m	triangular	100	165	200	
HCSZ	Saturated zone hydraulic conductivity	m/y	triangular	630	1400	2200	
UW	Well pumping rate	m^3/y	bounded normal	5900	1270	2618	7586
RI	Irrigation rate	m/y	bounded normal	0.47	0.12	0.14	0.64
FIND	Indoor time fraction	none	triangular	0.45	0.66	0.8	
FOTD	Outdoor time fraction	none	triangular	0.1	0.25	0.45	
HCUZ(1)	Unsaturated zone hydraulic conductivity	m/y	triangular	63	140	220	
HCCZ	Contaminated zone hydraulic conductivity	m/y	triangular	63	140	220	
DROOT	Root depth	m	triangular	0.3	0.9	3	
PRECIP	Precipitation rate	m/y	bounded normal	1.03	0.13	0.86	1.36
THICK0	Contaminated zone thickness	m	triangular	0.5	1	3	
SHF1	External gamma shielding factor	none	triangular	(4)	(4)	(4)	

NOTES: (1) Values in RESRAD file "SUMMARY.REP".

(2) Radionuclide specific K_d values were varied (see Table E-6) and plant, meat, milk transfer factors were assigned the RESRAD default distribution.

(3) Parameters for the distributions are: TRIANGULAR - minimum, mode, maximum and BOUNDED NORMAL - mean, standard deviation, minimum, maximum.

(4) Radionuclide specific distribution. Dose drivers Cs-137 and U-232 were evaluated.

In general, site-specific physical parameters in Table E-1 were described with triangular distributions across the range of values associated with the site, including hydraulic conductivity, and indoor/outdoor time fraction, etc. Depth of roots was assigned a triangular distribution ranging from 0.3 meter (onions, lettuce) to three meters (alfalfa), centered on 0.9 m (corn).

Precipitation was based on a normal distribution described by statistical parameters (mean = 1.03 meter, standard deviation = 0.13 meter) that were calculated from meteorological data collected over the last 30 years in Buffalo, New York (http://www.weatherexplained.com/Vol-4/2001-Buffalo-New-York-BUF.html). The precipitation data was then used to assign a distribution for the irrigation rate, assuming that a total of 1.5 m/y of applied water was needed, and the well pumping rate was assigned a distribution based on the irrigation volume needed. These parameters were also correlated to ensure this relationship in the input values.

The total onsite fraction of 0.91 equates to a total of 33 days each year, or 15 hours each week, away from the site inclusive of time spent taking livestock/crops to market, assisting on neighboring farms, or other travel off-site (vacation, family occasions, religious services, etc.).

The plant-soil, meat-soil, and milk-soil bioaccumulation factors were simulated using the RESRAD default lognormal-N distributions, and were correlated (R = -0.87) with the K_d as described in Section 6.0.

Table E-2 identifies parameters of interest and their assigned distributions for the subsurface soil conceptual model, except for distribution coefficients and the plant, meat and milk biotransfer factors, that were varied during the analyses and the distribution used for each parameter. The distribution coefficients for all ten elements associated with the radionuclides of interest were also varied using bounded lognormal distributions.

Table E-2. Input Parameter Distributions for Subsurface Soil Model (Other than K_d and Biotransfer Factor Values)(1)(2)

RESRAD Parameter	Parameter Description	Units	Distribution	Parameters(3)			
UW	Well pumping rate	m^3/y	bounded normal	5900	1270	2618	7586
RI	Irrigation rate	m/y	bounded normal	0.47	0.12	0.14	0.64
FIND	Indoor time fraction	none	triangular	0.45	0.66	0.8	
FOTD	Outdoor time fraction	none	triangular	0.1	0.25	0.45	
DROOT	Root depth	m	triangular	0.3	0.9	3	
PRECIP	Precipitation rate	m/y	bounded normal	1.03	0.13	0.86	1.36
SHF1	External gamma shielding factor	none	triangular	(4)	(4)	(4)	

NOTES: (1) Values in RESRAD file "SUMMARY.REP".

(2) Radionuclide specific K_d values were varied (see Table E-6) and plant, meat, milk transfer factors were assigned the RESRAD default distribution.

(3) Parameters for the distributions are: TRIANGULAR - minimum, mode, maximum and BOUNDED NORMAL - mean, standard deviation, minimum, maximum.

(4) Radionuclide specific distribution. Dose drivers Cs-137 and U-232 were evaluated

Because the subsurface soil model is based on the well drilling scenario, only a limited amount of material is available from the excavation (approximately 30 m^3). The parameter ranges and correlation described below were selected assuming deterministic values for the contaminated zone area and depth. The sensitivity of the models to specific area and thickness combinations was evaluated in Section 5 of the body of this plan. Note that the subsurface soil evaluation is based on the mass balance groundwater model.

The plant-soil, meat-soil, and milk-soil bioaccumulation factors were simulated using the RESRAD default lognormal-N distributions, and were correlated (R = -0.87) with the K_d as described in Section 6.0.

Table E-3 identifies parameters of interest and their assigned distributions for the streambed sediment conceptual model, except for distribution coefficients and the plant and meat biotransfer factors, that were varied during the analyses and the distribution used for each parameter. The distribution coefficients for all ten elements associated with the radionuclides of interest were also varied using bounded lognormal distributions

Table E-3. Input Parameter Distributions for Streambed Sediment Model (Other than K_d and Biotransfer Factor Values)[(1)(2)]

RESRAD Parameter	Parameter Description	Units	Distribution	Parameters[(3)]			
HCCZ	Contaminated zone hydraulic conductivity	m/y	triangular	63	140	220	
PRECIP	Precipitation rate	m/y	bounded normal	1.03	0.13	0.86	1.36
FOTD	Outdoor time fraction	none	triangular	0.006	0.012	0.024	

NOTES: (1) Values in RESRAD file "SUMMARY.REP"..

(2) Radionuclide specific K_d values were varied (see Table E-6) and plant, meat, fish transfer factors were assigned the RESRAD default distribution.

(3) Parameters for the distributions are: TRIANGULAR - minimum, mode, maximum and BOUNDED NORMAL - mean, standard deviation, minimum, maximum.

Soil parameters were varied over the same ranges used for the soil models. Parameter values for the fraction of time outdoors were taken from the deterministic sensitivity analysis described in Section 5 of the plan for likely recreational exposures.

The plant-soil and meat-soil bioaccumulation factors were simulated using the RESRAD default lognormal-N distributions, and were correlated (R = -0.87) with the K_d as described previously. Fish transfer factors were also simulated using the RESRAD default lognormal-N distributions, however no correlations were included.

5.2 Distribution Coefficients

Table C-2 of this plan identifies the distribution coefficients (K_d values) used in the dose analyses described in Section 5 of the body of this plan. Section 3.7.8 and Table 3-20 of this plan provide information on measurements of the distribution coefficients in soils at the site. However, these data are not sufficient to establish a site-specific distribution of the K_d parameter for each of the 10 chemical elements represented in the 18 radionuclides of interest in dose modeling.

Sheppard and Thibault (Sheppard and Thibault 1990) and NUREG/CR-6697 (Yu, et al. 2000) recommend that the K_d parameter be described as a lognormal distribution. Table E-4 summarizes data on K_d values from two key sources compared to the values used in the dose modeling described in Section 5 of this plan. Table E-5 provides a summary of the parameters describing the lognormal distributions as given in these reports.

Consideration of the data in Table E-5 from the two sources led to the distribution parameters in Table E-6, which were used in the uncertainty analyses. The distributions were bounded based on the values presented in Table E-6 to constrain unreasonably large or small values, which is consistent with the approach suggested in NUREG-6697 (Attachment C). The values in the table were established as follows:

- When Sheppard and Thibault sand values were used for K_d in the basic RESRAD analysis, then the Sheppard and Thibault sand distribution was used in the uncertainty analysis; and
- For cases when WVDP site-specific values are available, a distribution was selected so that the distribution mean [exp(μ)] provides a closer approximation to the K_d used in the basic RESRAD analyses.

Table E-4. Summary of Data on K_d Parameter (mL/g) for the 10 Elements of Interest

Element	RESRAD Default	Geometric Mean and Range [Sheppard and Thibault 1990]				Range [EPA 1999] [EPA 2004]	Values Used in Section 5 Modeling	
		Sand	Loam	Clay	Organic		Surface Soil, Unsaturated Zone, Saturated Zone	Subsurface Soil and Sediment in Contaminated Zone
Am	20	1,900 8.2 – 300,000	9,600 400 – 48,309	8,400 25 – 400,000	112,000 6,398 – 450,000	8.2 - 2,270,000	1900 (1) (420 - 111,000)	4000 (2) (420 - 111,000)
C	0	5	20	1	7	not addressed	5 (1) (0.7 - 12)	7 (2) (0.7 - 12)
Cm	calculated	4,000 780 – 22,970	18,000 7,666 – 44,260	6,000 ND	6,000 0	93 – 51,900	calculated	calculated
Cs	460	280 0.2 – 10,000	4,600 560 – 61,287	1,900 37 – 31,500	270 0.4 – 145,000	10 – 66,700	280 (1) (48 - 4800)	480 (2) (48 - 4800)
I	calculated	1 0.04 - 81	5 0.1 - 43	1 0.2 - 29	25 1.4 - 368	0.05 – 10,200	1 (1) (0.4 - 3.4)	2 (3) (0.4 - 3.4)
Np	calculated	5 0.5-390	25 1.3-79	55 0.4-2,575	1200 857-1,900	0.36 – 50,000	2.3 (4) (0.5 - 5.2)	3 (2) (0.5 - 5.2)
Pu	2,000	550 27-36,000	1200 100-5,933	5100 316-190,000	1900 60-62,000	5 – 2,550	2600 (4) (5 - 27,900)	3000 (2) (5 - 27,900)
Sr	30	15 0.05-190	20 0.01-300	110 3.6-32,000	150 8-4800	1 -1,700	5 (5) (1 - 32)	15 (2) (1 - 32)
Tc	0	0.1 0.01-16	0.1 0.01-0.4	1 1.16-1.32	1 0.02-340	0.01 – 340	0.1 (1) (0.01 - 4.1)	4.1 (3) (1 - 10)
U	50	35 0.03-2,200	15 0.2-4,500	1600 46-395,100	410 33-7,350	0.4 – 1,000,000	35 (1) (15 - 350)	10 (3) (1 - 100)

NOTES: (1) From Sheppard and Thibault 1990, for sand.
(2) Site specific value for the unweathered Lavery till (see Section 3.7.8, Table 3-20).
(3) Site specific value for the Lavery till (see Section 3.7.8, Table 3-20).
(4) Site specific value for the sand and gravel unit (see Section 3.7.8, Table 3-20).
(5) Dames and Moore (1995a, 1995b).

Table E-5. Lognormal Distribution Parameters for K_d Values from Literature

Element	Sand Soil[1]				Clay Soil[2]				RESRAD Default[3]			
	No. of Obs.	μ[4]	σ[5]	exp(μ)[6]	No. of Obs.	μ[4]	σ[5]	exp(μ)[6]	No. of Obs.	μ[4]	σ[5]	exp(μ)[6]
Am	29	7.6	2.6	1,998	11	9.0	2.6	8,100	219	7.28	3.15	1,451
C	3	1.1	0.8	3	0[7]	0.8		2.2	NA	2.40	3.22[8]	11
Cm	2	8.4	2.4	4,447	0[7]	8.7		6,000	23	8.82	1.82	6,761
Cs	81	5.6	2.5	270	28	7.5	1.6	1,810	564	6.10	2.33	446
I	22	0.04	2.2	1.0	8	0.5	1.5	1.7	109	1.52	2.19	4.6
Np	16	1.4	1.7	4.1	4	4.0	3.8	55	77	2.84	2.25	17
Pu	39	6.3	1.7	545	18	8.5	2.1	4,920	205	6.86	1.89	953
Sr	81	2.6	1.6	13.5	24	4.7	2.0	110	539	3.45	2.12	32
Tc	19	-2.0	1.8	0.1	4	0.2	0.06	1.2	59	-0.67	3.16	0.51
U	24	3.5	3.2	33	7	7.3	2.9	1,480	60	4.84	3.13	126

NOTES: (1) From Sheppard and Thibault 1990, Table A-1.
(2) From Sheppard and Thibault 1990, Table A-3.
(3) From Yu, et al. 2000, Table 3.9-1.
(4) The mean of the underlying normal distribution after taking natural logarithm of the K_d values.
(5) The standard deviation of the underlying normal distribution after taking natural logarithm of the K_d values.
(6) Exponential of the mean value [mL/g] or the geometric mean K_d.
(7) Default values for μ and exp(μ) have been predicted using soil-to-plant concentration ratios for nuclides with 0 observations.
(8) Standard deviation for data obtained from using the RESRAD default root uptake transfer factor and the correlation between K_d and the concentration ratio for loamy soil was set to 3.22 to consider a potential wide range of distribution.

LEGEND: NA = not available

Table E-6. Lognormal Distribution Parameters Used for K_d Uncertainty Analyses

Element	Surface Soil, Unsaturated Zone Saturated Zone					Subsurface Soil and Sediment in Contaminated Zone					Bounding Range
	Source(1)	μ(2)	σ(3)	exp(μ)(4)	DP K_d	Source(1)	μ(2)	σ(3)	exp(μ)(4)	DP K_d	
Am	S&T Sand	7.6	2.6	1,900	1,900	S&T Sand	7.6	2.6	1,900	4,000	0.5 - 390
C	S&T Sand	1.1	0.8	5	5	S&T Sand	1.1	0.8	5	7	0.7 - 12
Cm	RESRAD	8.82	1.82	6,761	6760	RESRAD	8.82	1.82	6,761	6760	780 - 22970
Cs	S&T Sand	5.6	2.5	280	280	RESRAD	6.10	2.33	446	480	10 - 10000
I	S&T Sand	0.04	2.2	1.0	1	S&T Clay	0.5	1.5	1	2	0.4 - 81
Np	S&T Sand	1.4	1.7	5	2.3	S&T Sand	1.4	1.7	5	3	0.5 - 390
Pu	RESRAD	6.86	1.89	953	2,600	S&T Clay	8.5	2.1	5,100	3,000	27 - 2550
Sr	S&T Sand	2.6	1.6	15	5	D&M	2.6	1.6	15	15	1 - 190
Tc	S&T Sand	-2.0	1.8	0.1	0.1	RESRAD	-0.67	3.16	0.51	4.1	0.01 - 16
U	S&T Sand	3.5	3.2	35	35	S&T Sand	3.5	3.2	35	10	0.4 - 2200

NOTES: (1) Sources: S&T Sand is Table A-1, Sheppard and Thibault 1990; S&T Clay is Table A-3, Sheppard and Thibault 1990; D&M from Dames and Moore, 1995a, 1995b, and RESRAD is Table 3.9-1, Attachment C, NUREG/CR-6697 (Yu, et al. 2000)

(2) The mean of the underlying normal distribution after taking natural logarithm of the K_d values.

(3) The standard deviation of the underlying normal distribution after taking natural logarithm of the K_d values.

(4) Exponential of the mean value [mL/g] or the geometric mean.

6.0 Parameter Correlation

The RESRAD code allows correlation of input parameters to limit the occurrence of unrealistic physical conditions (e.g., high outdoor and also high indoor time fractions). Parameters were correlated in pairs based on the user specified rank correlation coefficient as presented in Table E-7. The basis for the correlation coefficients for each conceptual model is discussed following the table.

Table E-7. Input Correlations for Probabilistic Evaluation[(1)]

Parameter 1	Parameter 2	Correlation Coefficient	Basis	Surface Soil Model	Subsurface Model	Sediment Model
Indoor time fraction	Outdoor time fraction	-0.95	Continuity of onsite time	•	•	
Contaminated zone hydraulic conductivity	Unsaturated zone hydraulic conductivity	0.95	Homogeneity in soil column	•		
Contaminated zone hydraulic conductivity	Saturated zone hydraulic conductivity	0.95	Homogeneity in soil column	•		
Unsaturated zone hydraulic conductivity	Saturated zone hydraulic conductivity	0.95	Homogeneity in soil column	•		
Precipitation rate	Rate of irrigation	-0.95	Less irrigation when rainy	•	•	
Precipitation rate	Well pumping rate	-0.95	Less pumping for irrigation when rainy	•	•	
Rate of irrigation	Well pumping rate	0.95	Pumping volume due mainly to irrigation	•	•	
Contaminated zone K_d	Unsaturated zone K_d	0.95	Homogeneity in soil column	•		
Unsaturated zone K_d	Saturated zone K_d	0.95	Homogeneity in soil column	•		
Contaminated zone K_d	Saturated zone K_d	0.95	Homogeneity in soil column	•		
Contaminated zone K_d	Plant transfer factor	-0.87	Baes, et. al. 1984	•	•	•
Contaminated zone K_d	Meat transfer factor	-0.87	Plant correlation used for meat	•	•	•
Contaminated zone K_d	Milk transfer factor	-0.87	Plant correlation used for milk	•	•	
Unsaturated zone K_d	Plant transfer factor	-0.87	Baes, et. al. 1984	•		
Unsaturated zone K_d	Meat transfer factor	-0.87	Plant correlation used for meat	•		
Unsaturated zone K_d	Milk transfer factor	-0.87	Plant correlation used for milk	•		
Saturated zone K_d	Plant transfer factor	-0.87	Baes, et. al. 1984	•		
Saturated zone K_d	Meat transfer factor	-0.87	Plant correlation used for meat	•		
Saturated zone K_d	Milk transfer factor	-0.87	Plant correlation used for milk	•		

NOTES: (1) Presented in the RESRAD probabilistic output files "LHS.REP" for each media.

6.1 Surface Soil Model

This section discusses the parameters correlated in the surface soil model, including distribution coefficients, plant transfer factors, hydraulic conductivities, as well as irrigation, precipitation, and well pumping rates.

The strongly negative correlation (R = -0.87) of K_d with plant transfer factors is based on regression results obtained from computer simulation for a range of elements (Baes, et. al. 1984). This Oak Ridge National Laboratory investigation included all areas of the country and therefore represents average results, which are used in lieu of site-specific correlations. Similarly, the meat and milk transfer coefficients were strongly correlated with the contaminated zone K_d for the principal radionuclides. Transfer factors for principal radionuclide daughter products were not correlated. As each additional parameter requires cross correlating with transfer factors for each soil layer, reducing the number of required correlations allows for reasonable code execution times.

The rate of irrigation and the well pumping rate were strongly correlated (R = 0.95) since the majority of water pumped by the well is used for irrigation. The precipitation rate was strongly negatively correlated (R = -0.95) with the irrigation and well pumping rate, assuming less groundwater will be needed to adequately water crops during wet years.

To ensure that the soils reflect relative homogeneity, the hydraulic conductivity in the three zones (contaminated, unsaturated and saturated) were correlated (R = 0.95).

6.2 Subsurface Soil Model

The subsurface soil model is based on a cistern excavation scenario, and is therefore based on a limited volume of source material brought to the surface. The potential configurations of contaminated zone area and thickness were evaluated in the deterministic sensitivity analysis presented in Section 5. Alternate parameters were selected for probabilistic evaluation.

6.3 Streambed Sediment Model

Parameters correlated in the streambed sediment model included:

- Contaminated zone and saturated zone hydraulic conductivity (0.95), and
- Contaminated zone K_d and plant/meat transfer factors (-0.87).

To ensure that intended correlations were reflected in the RESRAD model input vectors, values were viewed graphically to verify the parameter relationships for each media and radionuclide.

7.0 RESRAD Output

7.1 Basic Approach

The results of the probabilistic evaluation are output from RESRAD in numerous summary data files and graphic displays. As suggested in NUREG/CR-6676 (Kamboj, et al. 2000), the input values generated by the specified distributions and correlations were graphically viewed to verify parameter associations. RESRAD output was tabulated and probabilistic-based DCGLs were calculated as described below.

Additionally, the tabulated output parameter correlation ranks were used to identify the parameters most significantly associated with the modeled dose, as described in subsequent sections. Plots of the modeled dose over time are included in Attachment 1 for each radionuclide and media model. DCGLs were calculated from the RESRAD DSRs in the same manner as described in Appendix C to this plan.

7.2 Surface Soil

Key results of the surface soil evaluation are presented in Table E-8. Table E-9 compares the resulting probabilistic DCGLs with the DCGLs developed using the deterministic method.

As can be seen in Table E-9, key dose drivers Cs-137, Sr-90, I-129 and U-232 had probabilistic peak-of-the-mean DCGLs below the deterministic values, as did all radionuclides except Np-237. Radionuclides were identified as key dose drivers based on preliminary characterization data in WMA1 and WMA2 (See Attachment 1, Tables Att-1 and Att-2). Cs-137, Sr-90, I-129 and U-232 are discussed below (See also Table E-14).

- The Cs-137 dose is due primarily to external exposure in the initial years of exposure. However the depth of source thickness and exposure time fractions were the probabilistic parameters that are directly related to the external pathway, and were not highly correlated with resulting dose.
- The Sr-90 dose is due primarily to plant uptake in the initial years of exposure. Plant uptake factors and depth of roots were highly correlated with the resulting dose.
- I-129 dose is primarily due to ingestion of water and milk in the initial decades of exposure. Length parallel to groundwater flow and contaminated zone thickness were the most highly correlated parameters with the resulting dose.
- U-232 dose is primarily due to external exposure during the initial years of the simulation. The gamma shielding factor, and indoor/outdoor time fractions were most highly correlated with the resulting dose.

Attachment 1 presents plots of the probabilistic (peak-of-the-mean and 95th percentile) and deterministic dose-source ratios (DSRs) for comparison, for the radionuclides listed above. Also presented are plots of deterministic results compared with the cumulative probability derived from the probabilistic modeling. For all radionuclides (with the exception of Np-237) the peak-of-the-mean DCGLs were smaller than the deterministic DCGLs.

Table E-8. Key Output Dose Statistics (DSRs) – Surface Soil Model (mrem/y per pCi/g)(1)

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Am-241	2.01E+02	4.04E-02	3.49E+01	8.68E-01	1.32E+00
C-14	0.00E+00	2.12E-01	2.83E+00	1.53E+00	2.56E+00
Cm-243	0.00E+00	2.70E-01	4.69E+00	7.21E-01	1.60E+00
Cm-244	0.00E+00	4.94E-02	7.38E+00	3.85E-01	1.04E+00
Cs-137	0.0E+00	1.8E+00	2.2E+01	3.3E+00	6.3E+00
I-129	3.43E+00	3.31E-01	1.86E+03	7.68E+01	4.68E+02
Np-237	1.18E+01	9.16E-01	1.02E+03	9.59E+01	5.17E+02
Pu-238	0.00E+00	8.51E-02	8.10E+00	6.26E-01	1.78E+00

Table E-8. Key Output Dose Statistics (DSRs) – Surface Soil Model (mrem/y per pCi/g)[1]

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Pu-239	8.84E+02	2.73E-02	1.48E+01	9.86E-01	5.83E+00
Pu-240	7.81E+02	5.28E-02	1.32E+01	9.48E-01	5.84E+00
Pu-241	5.18E+01	3.34E-03	2.47E-01	2.15E-02	6.00E-02
Sr-90	0.00E+00	2.12E-01	2.11E+02	1.22E+01	4.17E+01
Tc-99	0.00E+00	2.30E-02	1.39E+01	1.19E+00	3.64E+00
U-232	1.2E+01	1.5E+00	5.6E+02	1.7E+01	1.1E+02
U-233	1.51E+01	2.07E-02	8.61E+01	3.02E+00	2.96E+01
U-234	1.33E+01	1.41E-02	1.35E+02	2.96E+00	2.60E+01
U-235	6.63E+01	7.77E-01	2.20E+01	7.20E+00	1.60E+01
U-238	1.33E+01	3.34E-02	6.82E+01	2.54E+00	2.27E+01

NOTE: (1) From RESRAD probabilistic output file "MCSUMMARY.REP".

Table E-9. Surface Soil $DCGL_W$ Values for 25 mrem in Peak Year in pCi/g

Nuclide	Deterministic[1]	Probabilistic[2]		Percent Difference Deterministic and Peak of the Mean
		Peak-of-the-Mean	95th Percentile	
Am-241	4.31E+01	2.88E+01	1.89E+01	-33%
C-14	2.00E+01	1.63E+01	9.77E+00	-18%
Cm-243	4.06E+01	3.47E+01	1.56E+01	-15%
Cm-244	8.22E+01	6.49E+01	2.40E+01	-21%
Cs-137[3][4]	**2.43E+01**	**1.52E+01**	**7.95E+00**	-37%
I-129[4]	3.47E-01	3.26E-01	5.34E-02	-6%
Np-237	9.42E-02	2.61E-01	4.84E-02	177%
Pu-238	5.03E+01	3.99E+01	1.40E+01	-21%
Pu-239	4.53E+01	2.54E+01	4.29E+00	-44%
Pu-240	4.53E+01	2.64E+01	4.28E+00	-42%
Pu-241	1.42E+03	1.16E+03	4.17E+02	-18%
Sr-90[3][4]	**6.25E+00**	**4.10E+00**	**1.20E+00**	-34%
Tc-99	2.37E+01	2.10E+01	6.87E+00	-11%
U-232[4]	5.84E+00	1.51E+00	2.23E-01	-74%
U-233[4]	1.90E+01	8.28E+00	8.45E-01	-56%
U-234[4]	1.97E+01	8.45E+00	9.62E-01	-57%
U-235[4]	1.87E+01	3.47E+00	1.79E+00	-81%
U-238[4]	2.06E+01	9.84E+00	1.10E+00	-52%

NOTES: (1) From Table 5-8 of Section 5.
(2) From RESRAD probabilistic output file "MCSUMMARY.REP".
(3) DCGLs for these radionuclides are multiplied by a factor of two to account for decay during 30 year institutional control period.
(4) Dose driver radionuclide (see Section 5.2.4 of the plan).

7.3 Subsurface Soil

Key results of the subsurface soil evaluation are presented in Table E-10. Table E-11 compares the resulting probabilistic DCGLs with the DCGLs developed using the deterministic method. Note that the deterministic DCGLs used in this table for comparison purposes are the DCGLs from Table 5-8, which are based on the original base-case conceptual model. The DCGLs from the multi-source analysis that takes into account continuing releases from the bottom of the deep excavations are not directly comparable with the peak-of-the-mean DCGLs because the model used in development of the latter does not account for this secondary source. Table 5-11c in Section 5 of this plan compares all of the different subsurface soil DCGLs.

Note also that the DCGLs presented in Table E-11 reflect a 10 fold dilution of the source term (i.e. using 1/10th the DSRs presented in Table E-10) as described in Section 5 of the DPlan.

As can be seen in Table E-11, only Sr-90, Tc-99, and U-232 had probabilistic peak-of-the-mean DCGLs at least 10 percent below the deterministic values. These radionuclides are discussed below (See also Table E-15).

- The Sr-90 dose is due primarily to plant uptake in the initial years of exposure. Depth of roots and plant uptake factors were highly correlated with the resulting dose.
- The Tc-99 dose is due primarily to plant uptake in the initial years of exposure. Depth of roots and plant uptake factors were highly correlated with the resulting dose.
- The U-232 dose is due primarily to external exposure in the initial years of the simulation. The contaminated zone K_d and gamma shielding factors were most highly correlated with the resulting dose.

Attachment 1 presents the plots of the probabilistic (peak-of-the-mean and 95th percentile) and deterministic DSRs for comparison, for the key dose drivers Sr-90, Cs-137, and U-232. Also presented are plots of deterministic results compared with the cumulative probability derived from the probabilistic modeling. For seven other radionuclides, the peak-of-the-mean DCGLs were greater than or equal to the deterministic.

Table E-10. Key Output Dose Statistics (DSRs) – Subsurface Soil Model (mrem/y per pCi/g)(1)

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Am-241	0.0E+00	2.4E-02	2.4E-01	3.7E-02	5.8E-02
C-14	0.0E+00	1.4E-04	1.2E-03	3.5E-04	6.9E-04
Cm-243	0.0E+00	1.6E-01	3.8E-01	2.2E-01	2.7E-01
Cm-244	0.0E+00	6.0E-03	7.3E-02	1.1E-02	2.3E-02
Cs-137	0.0E+00	1.4E+00	2.4E+00	1.7E+00	1.8E+00
I-129	1.2E+01	2.1E-03	1.7E+00	3.7E-01	9.6E-01

Table E-10. Key Output Dose Statistics (DSRs) – Subsurface Soil Model (mrem/y per pCi/g)[(1)]

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Np-237	2.5E+01	6.5E-08	2.3E+01	2.7E+00	8.5E+00
Pu-238	0.0E+00	9.7E-03	1.6E-01	1.8E-02	3.7E-02
Pu-239	0.0E+00	1.1E-02	1.9E-01	2.0E-02	4.1E-02
Pu-240	0.0E+00	1.1E-02	4.7E-01	2.1E-02	3.9E-02
Pu-241	5.2E+01	2.0E-04	7.7E-03	1.0E-03	1.6E-03
Sr-90	0.0E+00	1.3E-02	5.0E+00	1.5E-01	4.8E-01
Tc-99	0.0E+00	5.5E-04	5.2E-01	1.7E-02	5.7E-02
U-232	6.4E+00	5.4E-03	5.1E+00	3.4E+00	4.6E+00
U-233	3.7E+02	2.3E-14	6.3E-01	2.5E-02	7.4E-02
U-234	3.7E+02	4.5E-07	1.3E+00	2.0E-02	6.7E-02
U-235	0.0E+00	1.5E-01	3.6E-01	2.7E-01	3.3E-01
U-238	0.0E+00	3.3E-02	1.1E-01	5.4E-02	6.6E-02

NOTE: (1) From RESRAD probabilistic output file "MCSUMMARY.REP".

Table E-11. Subsurface Soil $DCGL_W$ Values for 25 mrem in Peak Year in pCi/g

Nuclide	Deterministic[(1)]	Probabilistic[(2)]		Percent Difference Deterministic and Peak-of-the-Mean
		Peak-of-the-Mean	95th Percentile	
Am-241	7.16E+03	6.81E+03	4.30E+03	-5%
C-14	5.59E+05	7.18E+05	3.64E+05	28%
Cm-243	1.15E+03	1.12E+03	9.33E+02	-3%
Cm-244	2.37E+04	2.21E+04	1.08E+04	-7%
Cs-137[(3)(4)]	**4.36E+02**	**3.01E+02**	**2.72E+02**	-31%
I-129[(4)]	6.46E+02	6.70E+02	2.60E+02	4%
Np-237	5.77E+01	9.33E+01	2.95E+01	62%
Pu-238	1.47E+04	1.37E+04	6.83E+03	-7%
Pu-239	1.33E+04	1.23E+04	6.11E+03	-7%
Pu-240	1.33E+04	1.21E+04	6.44E+03	-9%
Pu-241	2.41E+05	2.50E+05	1.59E+05	4%
Sr-90[(3)(4)]	**4.36E+03**	**3.42E+03**	**1.03E+03**	-21%
Tc-99	1.59E+04	1.44E+04	4.36E+03	-10%
U-232[(4)]	1.06E+02	7.40E+01	5.43E+01	-30%
U-233[(4)]	2.72E+03	9.92E+03	3.39E+03	264%

Table E-11. Subsurface Soil $DCGL_W$ Values for 25 mrem in Peak Year in pCi/g

Nuclide	Deterministic[1]	Probabilistic[2]		Percent Difference Deterministic and Peak-of-the-Mean
		Peak-of-the-Mean	95th Percentile	
U-234[4]	2.81E+03	1.26E+04	3.75E+03	349%
U-235[4]	9.41E+02	9.33E+02	7.60E+02	-1%
U-238[4]	2.94E+03	4.60E+03	3.79E+03	57%

NOTES: (1) From Table 5-8 of Section 5. More limiting deterministic values for the resident gardener are available as an alternative comparison for some radionuclides. Refer to Section 5.2.8 for a comparison between the probabilistic DCGLs and all other sets of subsurface soil DCGLs.

(2) From RESRAD probabilistic output file "MCSUMMARY.REP" for the resident farmer with a contamination zone of 100 m^2.

(3) DCGLs for these radionuclides are multiplied by a factor of two to account for decay during 30 year institutional control period.

(4) Dose driver radionuclide (see Section 5.2.4 of the plan).

7.3 Streambed Sediment

Key results of the streambed sediment evaluation are presented in Table E-12. Table E-13 compares the resulting probabilistic DCGLs with the DCGLs developed using the deterministic method.

As can be seen in Table E-13, all radionuclides had probabilistic peak-of-the-mean DCGLs at least 10 percent below the deterministic values. Key dose drivers for sediment are Sr-90 and Cs-137. These radionuclides are discussed below (See also Table E-16).

- Sr-90 dose is due primarily to ingestion of venison in the initial years of exposure. The resulting dose is highly correlated to the contaminated zone K_d value; however, the plant and fish biotransfer factors were more closely correlated than the meat biotransfer factors.
- Cs-137 dose is primarily due to external exposure in the initial years of exposure. As expected, the outdoor time fraction was highly correlated with dose.

Attachment 1 presents the plots of the probabilistic (peak-of-the-mean and 95th percentile) and deterministic DSRs for comparison. Also presented are plots of deterministic results compared with the cumulative probability derived from the probabilistic modeling.

Table E-12. Key Output Dose Statistics (DSRs) – Streambed Sediment Model (mrem/y per pCi/g)[1]

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Am-241	1.0E+00	9.1E-04	5.7E-02	2.5E-03	4.8E-03
C-14	0.0E+00	5.8E-03	4.5E-01	1.4E-02	3.4E-02
Cm-243	0.0E+00	3.7E-03	1.4E-02	8.2E-03	1.2E-02
Cm-244	0.0E+00	2.6E-04	2.4E-03	6.5E-04	9.9E-04
Cs-137	0.0E+00	2.3E-02	8.8E-02	4.8E-02	6.9E-02
I-129	0.0E+00	6.1E-03	6.6E-01	3.2E-02	7.2E-02

Table E-12. Key Output Dose Statistics (DSRs) – Streambed Sediment Model (mrem/y per pCi/g)(1)

Radionuclide	Year of Peak Dose	Minimum	Maximum	Mean	95th Percentile
Np-237	0.0E+00	1.0E-02	2.2E+00	7.7E-02	2.3E-01
Pu-238	1.0E+00	6.9E-04	1.4E-01	2.0E-03	3.6E-03
Pu-239	1.0E+00	8.8E-04	2.3E-02	2.1E-03	4.1E-03
Pu-240	1.0E+00	9.0E-04	1.6E-02	2.1E-03	4.2E-03
Pu-241	5.2E+01	2.8E-05	1.9E-03	7.3E-05	1.3E-04
Sr-90	0.0E+00	1.4E-03	1.5E-01	1.1E-02	3.0E-02
Tc-99	0.0E+00	3.4E-06	1.1E-03	3.8E-05	1.1E-04
U-232	7.2E+00	4.6E-02	9.3E-01	1.1E-01	1.7E-01
U-233	0.0E+00	1.1E-04	5.2E-02	1.2E-03	3.9E-03
U-234	0.0E+00	1.2E-04	2.9E-02	1.2E-03	4.2E-03
U-235	0.0E+00	4.9E-03	4.0E-02	1.1E-02	1.6E-02
U-238	0.0E+00	1.1E-03	9.0E-02	3.1E-03	5.5E-03

NOTE: (1) From RESRAD probabilistic output file "MCSUMMARY.REP".

Table E-13. Streambed Sediment $DCGL_W$ Values for 25 mrem in Peak Year in pCi/g

Nuclide	Deterministic(1)	Probabilistic(2)		Percent Difference Deterministic and Peak-of-the-Mean
		Peak-of-the-Mean	95th Percentile	
Am-241	1.55E+04	1.02E+04	5.19E+03	-34%
C-14	3.44E+03	1.84E+03	7.42E+02	-46%
Cm-243	3.59E+03	3.06E+03	2.08E+03	-15%
Cm-244	4.84E+04	3.83E+04	2.52E+04	-21%
Cs-137(3)(4)	**1.29E+03**	**1.04E+03**	**7.24E+02**	-19%
I-129	3.69E+03	7.91E+02	3.49E+02	-79%
Np-237	5.19E+02	3.25E+02	1.11E+02	-37%
Pu-238	1.99E+04	1.24E+04	7.02E+03	-38%
Pu-239	1.79E+04	1.19E+04	6.08E+03	-33%
Pu-240	1.79E+04	1.20E+04	5.98E+03	-33%
Pu-241	5.11E+05	3.44E+05	1.92E+05	-33%
Sr-90(3)(4)	**9.49E+03**	**4.72E+03**	**1.67E+03**	-50%
Tc-99	2.17E+06	6.61E+05	2.38E+05	-70%
U-232	2.61E+02	2.23E+02	1.49E+02	-15%
U-233	5.75E+04	2.16E+04	6.38E+03	-62%
U-234	6.04E+04	2.16E+04	5.94E+03	-64%

Table E-13. Streambed Sediment $DCGL_W$ Values for 25 mrem in Peak Year in pCi/g

Nuclide	Deterministic(1)	Probabilistic(2)		Percent Difference Deterministic and Peak-of-the-Mean
		Peak-of-the-Mean	95th Percentile	
U-235	2.89E+03	2.34E+03	1.58E+03	-19%
U-238	1.25E+04	8.17E+03	4.55E+03	-34%

NOTES: (1) From Table 5-8 of Section 5.
(2) From RESRAD probabilistic output file "MCSUMMARY.REP".
(3) DCGLs for these radionuclides are multiplied by a factor of two to account for decay during 30 year institutional control period.
(4) Dose driver radionuclide (see Section 5.2.4 of the plan).

7.4 Preliminary Dose Assessment for Remediated WMA 1 Excavation

As indicated in Section 5.4.4 of this plan, the preliminary dose assessment for the remediated WMA 1 excavated area estimated by using information from the multi-source deterministic analysis was a maximum of approximately 8 mrem per year. Using the probabilistic modeling results, the estimates are as follows:

- A peak-of-the-mean estimate of 1.9 mrem per year
- A 95th percentile value of 2.8 mrem per year

Table Att-1 of Attachment 1 shows the calculations of these values. The probabilistic results were not used because they were lower than the 8 mrem per year estimate produced using information from the multi-source deterministic analysis.

7.5 Preliminary Dose Assessment for Remediated WMA 2 Excavation

As indicated in Section 5.4.4 of this plan, the preliminary dose assessment for the remediated WMA 2 excavated area estimated by using information from the multi-source deterministic analysis was a maximum of approximately 0.2 mrem per year. Using the probabilistic modeling results, the estimates are as follows:

- A peak-of-the-mean estimate of 0.11 mrem per year
- A 95th percentile value of 0.13 mrem per year

Table Att-2 of Attachment 1 shows the calculations of these values. The probabilistic results were not used because they were lower than the 0.2 mrem per year estimate produced using information from the multi-source deterministic analysis.

8.0 Parameter Output Rank Correlations

The RESRAD results include several correlations of input parameters with the output modeled dose. Several correlations are available based on actual numerical calculated values and relative rankings.

Guidance for RESRAD probabilistic modeling in NUREG/CR-6676 (Kamboj, et al. 2000) indicates that correlation coefficients based on relative rankings are preferable where nonlinear relationships, widely disparate scales, or long tails are present in the input and outputs. Therefore, determinations of parameter significance presented in this section are based on the partial rank correlation coefficient (PRCC). Where strong correlations between an input parameter and the dose were indicated in the output ranking, scatter plots were inspected to confirm the conclusion.

RESRAD also calculates the overall coefficients of determination (R^2) for each model, which provides an indication of the variability in the overall radionuclide dose accounted for by the selected input parameters.

As described previously, numerous parameters were selected for probabilistic evaluation for each radionuclide. The tables presented and discussed below focus on the three highest ranked parameter correlations for all included parameters for each radionuclide in each media.

To ensure sufficient model iterations were being used to allow for convergence of the results, three sets of 1,000 iterations were selected. This was considered to be appropriate as the peak-of-the-mean doses for the three datasets were within approximately +/-10 percent. The run with the largest peak-of-the-mean dose was selected as the basis for the information in the summary tables.

8.1 Surface Soil Model

Table E-14 presents a summary of the parameters which correlate most closely with the overall dose for each radionuclide. In general, K_d, plant transfer factors, and root zone depth were most strongly correlated with dose. The plant transfer factors have the higher correlations (mostly >0.7) when compared with K_d (<0.7).

The R^2 values ranged from 0.71 (U-232) to 0.99 (I-129). Where the overall correlation is low, identification of additional probabilistic parameters for these radionuclides may better describe the variability in the model output.

Table E-14. Summary of Parameter Rankings – Surface Soil Model[1]

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
Am-241	Plant transfer factor for Am (0.78)	Contaminated zone Thickness (0.54)	Depth of roots (-0.49)	3 (0.93)
C-14	Contaminated zone thickness (0.98)	Depth of roots (-0.79)	Plant transfer factor for C (0.08)	3 (0.96)
Cm-243	Plant transfer factor for Cm (0.86)	Contaminated zone Thickness (0.65)	Depth of roots (-0.64)	2 (0.96)
Cm-244	Plant transfer factor for Cm (0.87)	Contaminated zone Thickness (0.68)	Depth of roots (-0.67)	3 (0.96)
Cs-137	Plant transfer factor for Cs (0.71)	Depth of roots (-0.56)	Contaminated zone Thickness (0.52)	3 (0.95)
I-129	Length parallel to groundwater flow (0.64)	Contaminated zone Thickness (0.62)	Irrigation rate (0.34)	2 (0.99)
Np-237	Length parallel to groundwater flow (0.73)	Contaminated zone Thickness (0.60)	Saturated zone hydraulic conductivity (-0.45)	2 (0.99)

Table E-14. Summary of Parameter Rankings – Surface Soil Model(1)

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
Pu-238	Plant transfer factor for Pu (0.86)	Depth of roots (-0.67)	Contaminated zone Thickness (0.66)	3 (0.96)
Pu-239	Plant transfer factor for Pu (0.72)	Depth of roots (-0.44)	Contaminated zone Thickness (0.43)	1 (0.91)
Pu-240	Plant transfer factor for Pu (0.74)	Depth of roots (-0.44)	Contaminated zone Thickness (0.43)	1 (0.91)
Pu-241	Plant transfer factor for Am (0.81)	Contaminated zone Thickness (0.39)	Depth of roots (-0.37)	1 (0.75)
Sr-90	Plant transfer factor for Sr (0.84)	Depth of roots (-0.62)	Contaminated zone thickness (0.60)	3 (0.96)
Tc-99	Contaminated zone Thickness (0.67)	Plant transfer factor for Tc (0.55)	Depth of roots (-0.33)	3 (0.92)
U-232	Gamma shileding factor (0.38)	Outdoor time fraction (0.34)	Indoor time fraction (0.21)	1 (0.67)
U-233	Contaminated zone Thickness (0.23)	Meat transfer factor for U (-0.19)	Plant transfer factor for Th (0.18)	3 (0.92)
U-234	Contaminated zone Thickness (0.32)	Meat transfer factor for U (-0.15)	Depth of roots (-0.13)	3 (0.95)
U-235	Length parallel to groundwater flow (0.78)	Contaminated zone Thickness (0.77)	Saturated zone Kd (-0.46)	3 (0.93)
U-238	Contaminated zone Thickness (0.23)	Length parallel to groundwater flow (0.16)	Depth of roots (-0.16)	1 (0.96)

NOTE: (1) From RESRAD probabilistic output file "MCSUMMARY.REP". Simulation (out of three) with largest peak-of-the-mean dose was used to determine the parameter ranking, based on the PRCCs with statistic (either R or R2) in parentheses.

8.2 Subsurface Soil Model

As shown in Table E-15, the most highly correlated parameters for the subsurface model, like with the surface soil model, are the K_d, plant transfer coefficients, and root depth. The highest correlations (-0.99) were calculated for the depth of roots; however the K_d correlations were generally lower than those for the plant transfer factors. The R^2 values ranged from 0.17 (U-233) to 1.00 (Np-237).

Table E-15. Summary of Parameter Rankings - Subsurface Soil Model(1)

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
Am-241	Depth of roots (-0.82)	Plant transfer factor for Am (0.76)	Outdoor time fraction (0.58)	1 (0.93)
C-14	Depth of roots (-0.99)	Meat transfer factor for C (0.18)	Plant transfer factor for C (0.17)	2 (0.98)
Cm-243	Outdoor time fraction (0.91)	Indoor time fraction (0.53)	Plant transfer factor for Cm (-0.44)	1 (0.96)

Table E-15. Summary of Parameter Rankings - Subsurface Soil Model[(1)]

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
Cm-244	Depth of roots (-0.93)	Plant transfer factor for Cm (0.89)	Indoor time fraction (0.40)	1 (0.97)
Cs-137	Outdoor time fraction (0.93)	Gamma shielding factor (0.92)	Indoor time fraction (0.81)	3 (0.96)
I-129	Contaminated zone K_d for I (-0.94)	Well pumping rate (-0.56)	Irrigation rate (0.27)	1 (0.99)
Np-237	Contaminated zone K_d for Np (-0.95)	Well pumping rate (-0.55)	Irrigation rate (0.29)	3 (1.00)
Pu-238	Depth of roots (-0.93)	Plant transfer factors for Pu (0.32)	Outdoor time fraction (0.32)	1 (0.97)
Pu-239	Depth of roots (-0.93)	Plant transfer factor for Pu (0.89)	Outdoor time fraction (0.29)	2 (0.97)
Pu-240	Depth of roots (-0.93)	Plant transfer factor for Pu (0.90)	Indoor time fraction (0.33)	1 (0.97)
Pu-241	Plant transfer factor for Am (0.81)	Depth of roots (-0.62)	Contaminated zone K_d for Am (0.52)	1 (0.77)
Sr-90	Depth of roots (-0.94)	Plant transfer factor for Sr (0.91)	Contaminated zone K_d for Cs (-0.10)	1 (0.98)
Tc-99	Depth of roots (-0.93)	Plant transfer factor for Tc (0.90)	Well pumping rate (-0.10)	1 (0.97)
U-232	Contaminated zone K_d for U (0.49)	Gamma shielding factor (0.48)	Outdoor time fraction (0.41)	3 (0.87)
U-233	Contaminated zone K_d for U (-0.34)	Milk transfer factor for U (-0.31)	Plant transfer factor for U (-0.29)	3 (0.17)
U-234	Contaminated zone K_d for U (-0.31)	Milk transfer factor for U (-0.24)	Meat transfer factor for U (-0.22)	3 (0.25)
U-235	Outdoor time fraction (0.71)	Indoor time fraction (0.28)	Meat transfer factor for U (-0.15)	2 (0.85)
U-238	Outdoor time fraction (0.48)	Milk transfer factor for U (-0.22)	Meat transfer factor for U (-0.21)	1 (0.62)

NOTE: (1) From RESRAD probabilistic output file "MCSUMMARY.REP". Simulation (out of three) with largest peak-of-the-mean dose was used to determine the parameter ranking, based on the Partial Rank Correlation Coefficients (PRCC) with statistic (either R or R2) in parentheses.

8.3 Streambed Sediment Model

Table E-16 shows the correlation coefficients and highest ranked sediment parameters for streambed sediment. Fourteen radionuclides have a correlation coefficient greater than or equal to 0.85 and one radionuclide has a coefficient below 0.5. The R^2 values ranged from 0.23 (U-233) to 0.99 (Cm-243). The outdoor time fraction accounted for the majority of the highest correlations.

Table E-16. Summary of Parameter Rankings – Streambed Sediment Model[1]

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
Am-241	Outdoor time fraction (0.86)	Fish transfer factor for Am (0.43)	Meat transfer factor for Am (0.13)	1 (0.81)
C-14	Fish transfer factor for C (0.98)	Contaminated zone K_d for C (-0.43)	Meat transfer factor for C (0..07)	1 (0.97)
Cm-243	Outdoor time fraction (1.00)	Contaminated zone K_d for Cm (-0.14)	Fish transfer factor for Cm (0.11)	1 (0.99)
Cm-244	Outdoor time fraction (0.92)	Fish transfer factor for Cm (0.29)	Meat transfer factor for Cm (0.26)	1 (0.89)
Cs-137	Outdoor time fraction (0.99)	Meat transfer factor for Cs (0.33)	Plant transfer factor for Cs (0.18)	1 (0.98)
I-129	Fish transfer factor for I (0.81)	Contaminated zone K_d for I (-0.48)	Meat transfer factor for I (0.44)	1 (0.95)
Np-237	Fish transfer factor for Np (0.89)	Outdoor time fraction (0.52)	Contaminated zone K_d for Np (-0.47)	1 (0.93)
Pu-238	Outdoor time fraction (0.82)	Fish transfer factor for Pu (0.74)	Contaminated zone K_d for Pu (-0.23)	1 (0.87)
Pu-239	Outdoor time fraction (0.81)	Fish transfer factor for Pu (0.74)	Contaminated zone K_d for Pu (-0.27)	1 (0.86)
Pu-240	Outdoor time fraction (0.81)	Fish transfer factor for Pu (0.74)	Contaminated zone K_d for Pu (-0.30)	1 (0.96)
Pu-241[2]	Outdoor time fraction (0.79)	Contaminated zone K_d for Am (-0.58)	Fish transfer factor for Am (0.38)	1 (0.72)
Sr-90	Contaminated zone K_d for Sr (-0.73)	Fish transfer factor for Sr (0.59)	Plant transfer factor for Sr (0.30)	1 (0.97)
Tc-99	Fish transfer factor for Tc (0.91)	Plant transfer factor for Tc (0.17)	Meat transfer factor for Tc (0.13)	1 (0.86)
U-232	Outdoor time fraction (0.96)	Fish transfer factor for U (0.27)	Plant transfer factor for U (-0.14)	1 (0.93)
U-233	Contaminated zone K_d for Th (-0.21)	Outdoor time fraction (0.26)	Meat transfer factor for Tc (0.20)	1 (0.23)
U-234	Fish transfer factor for U (0.45)	Outdoor time fraction (0.28)	Contaminated zone K_d for U (-0.26)	3 (0.78)
U-235	Outdoor time fraction (0.94)	Fish transfer factor for U (0.35)	Meat transfer factor for U (0.20)	1 (0.90)
U-238	Outdoor time fraction (0.85)	Fish transfer factor for U (0.41)	Contaminated zone K_d for U (-0.23)	1 (0.85)

NOTES: (1) From RESRAD probabilistic output file "MCSUMMARY.REP". Simulation (out of three) with largest peak-of-the-mean dose was used to determine the parameter ranking, based on the Partial Rank Correlation Coefficients (PRCC) with statistic (either R or R2) in parentheses.

(2) This analog was assumed give the decay of Pu-241 to Am-241.

9.0 Conclusions from the Uncertainty Analyses and Related Actions

9.1 Conclusions

The following conclusions can be drawn from the results of the probabilistic modeling described above.

Surface Soil DCGLs

Table E-9 shows that deterministic DCGLs for 17 of the 18 radionuclides of interest are not bounding because they are greater than the peak-of-the mean probabilistic DCGLs. Parameters highly correlated with the output are plant transfer factors, depth of roots, and length parallel to aquifer flow.

The length parallel to aquifer flow is a parameter selected to vary the dilution factor in groundwater.

These input parameters therefore lack sufficient conservatism insofar as the 17 radionuclides are concerned. This group of radionuclides includes three that have been identified as dose drivers: Sr-90, Cs-137, and U-235.

The lack of conservatism in these surface soil criteria can be quantified in another manner by considering the average soil concentrations at the deterministic DCGLs. If the average residual concentration of Sr-90, for example, were to be 6.25 pCi/g (the deterministic DCGL for surface soil), then the probabilistic modeling would indicate that the probability that the resulting dose would not exceed 25 mrem in the peak year would be approximately 55 percent (see Figure Att-2 in Attachment 1).

The primary conclusion for the surface soil model is that some input parameters used in the deterministic modeling are not sufficiently conservative and, consequently, the deterministic DCGLs for 17 radionuclides are not bounding.

Subsurface Soil DCGLs

Table E-11 shows that 10 of the deterministic DCGLs are not bounding because they exceed the peak-of-the mean probabilistic DCGLs, however only three radionuclides were below the deterministic DCGL by more than 10 percent. The comparisons above are based on the deterministic values for the resident farmer scenario, however more limiting values are available for the resident gardener scenario for comparison. The most limiting of all deterministic and probabilistic scenarios will be used to establish the cleanup levels (See Section 5). Parameters highly correlated with the output are depth of roots, contaminated zone K_d, and outdoor time fraction. The outdoor time fraction is based on assumptions of anticipated activity and may be refined with additional site-specific considerations. Refer to Section 5.2.8 for comparisons between the probabilistic DCGLs and other sets of subsurface soil DCGLs.

Streambed Sediment DCGLs

Table E-13 indicates that none of the deterministic DCGLs are bounding because they all exceed the peak-of-the-means DCGLs. For the key sediment dose drivers Sr-90 and Cs-137, the probabilistic values less than the deterministic by 50 percent and 19 percent respectively. The outdoor time fraction is most highly correlated with the dose for Cs-137, and Sr-90 was most highly correlated with the contaminated zone K_d. The outdoor time fraction is based on assumptions of anticipated activity and may be refined with additional site-specific considerations.

Preliminary Dose Assessments

The probabilistic dose estimates for the WMA 1 excavation area show that doses are likely to be less than 1.9 mrem/y, due primarily to Sr-90. The probabilistic dose estimates for the WMA 2 excavation area show that the doses are likely to be less than 0.11 mrem/y, due primarily to Cs-137.

Based on these results, it is anticipated that a small number of radionuclides will account for the majority of the dose.

Input Parameters and Dose Variability

The determination of which input parameters account for the majority of variability in the output was accomplished by inspection of the output correlation coefficients, which indicated the following:

- For surface soil, output dose results were well described by the input parameters, as only two radionuclides (Pu-241 and U-232) had coefficients of determination <+/-0.9. The highest parameter correlations (>+/-0.7) were for plant transfer factors and contaminated zone thickness.
- For subsurface soil, the variability in the calculated dose was moderately well described by the input parameters (six radionuclides with R^2 <+/-0.9). The highest correlations for individual parameters (>+/-0.9) were the depth of roots, contaminated zone K_d, and outdoor time fraction
- Sediment dose variability was well described by the input parameters (nine radionuclides with R^2 <+/-0.9), with the highest correlations (>+/-0.9) observed for the outdoor time fraction and fish transfer factor.

The probabilistic evaluation has identified parameters that are well correlated with the calculated dose. Based on these results, the input parameters that account for the majority of variability in the output are plant transfer factors, contaminated zone thickness, depth of roots, contaminated zone K_d, outdoor time fraction, and fish transfer factors.

9.2 Actions

The conclusions on the probabilistic uncertainty analysis results just described led to the decision to make use of the probabilistic peak-of-the-mean DCGLs in place of the deterministic DCGLs provided in Revision 0 to this plan for surface soil and streambed sediment. The probabilistic peak-of-the-mean DCGLs were used for subsurface soil for three radionuclides as discussed in Section 5.2.8. Changes in Section 5 made as part of Revision 2, including changes to the cleanup goals, reflect these decisions.

10.0 References

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11.0 ATTACHMENTS

(1) Plots of Probabilistic and Deterministic Results

(2) Electronic Files Described in Section 1.3 (provided separately)

ATTACHMENT 1

Plots of Probabilistic and Deterministic Results

Note that the deterministic results used in this attachment are the deterministic results based on the original base-case conceptual model. The multi-source analysis results were not used because they are not directly comparable with the probabilistic results.

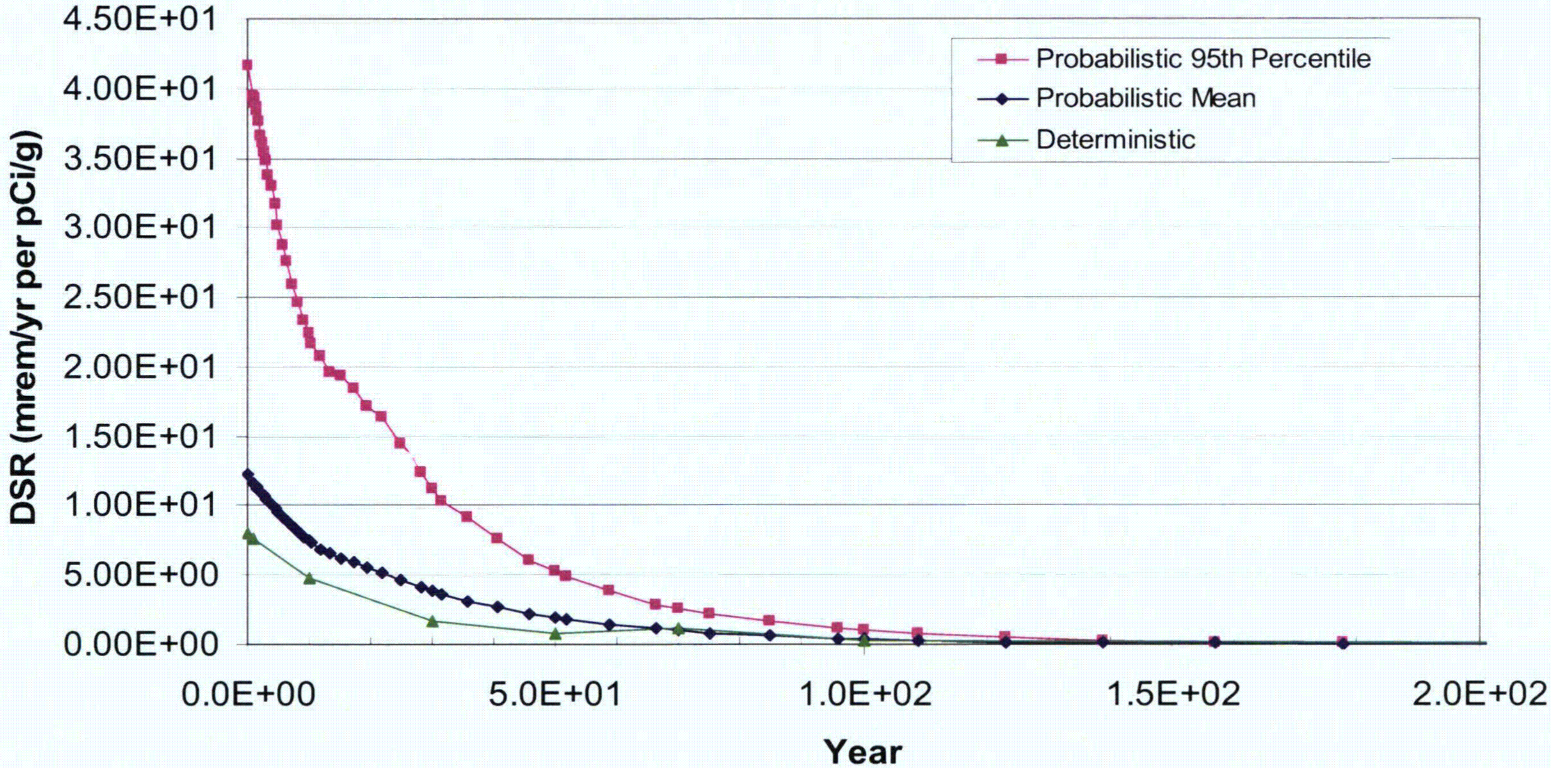


Figure Att-1. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Sr-90 – Surface Soil

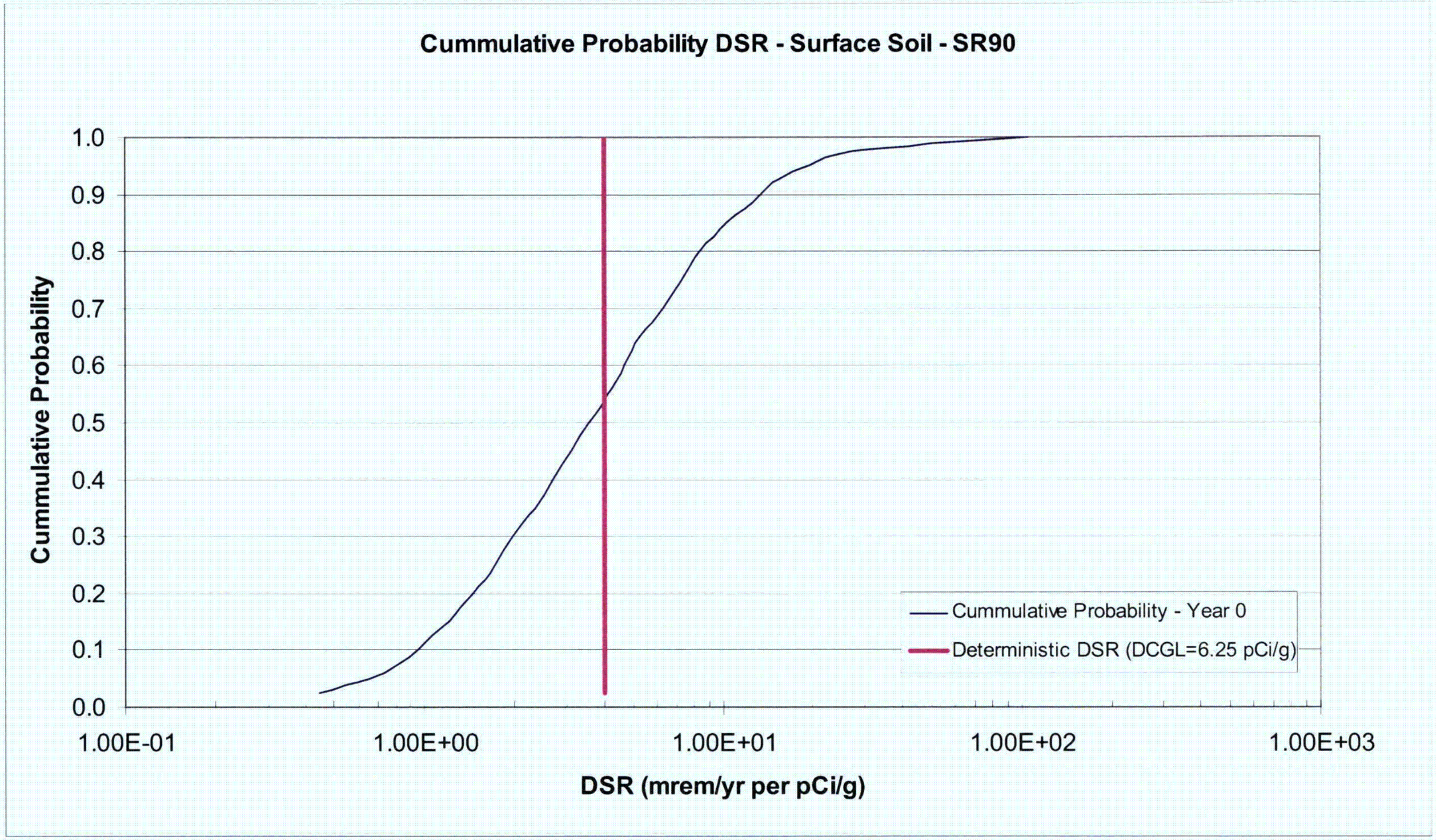


Figure Att-2. Cumulative Probability Dose-Source Ratio, Sr-90 – Surface Soil

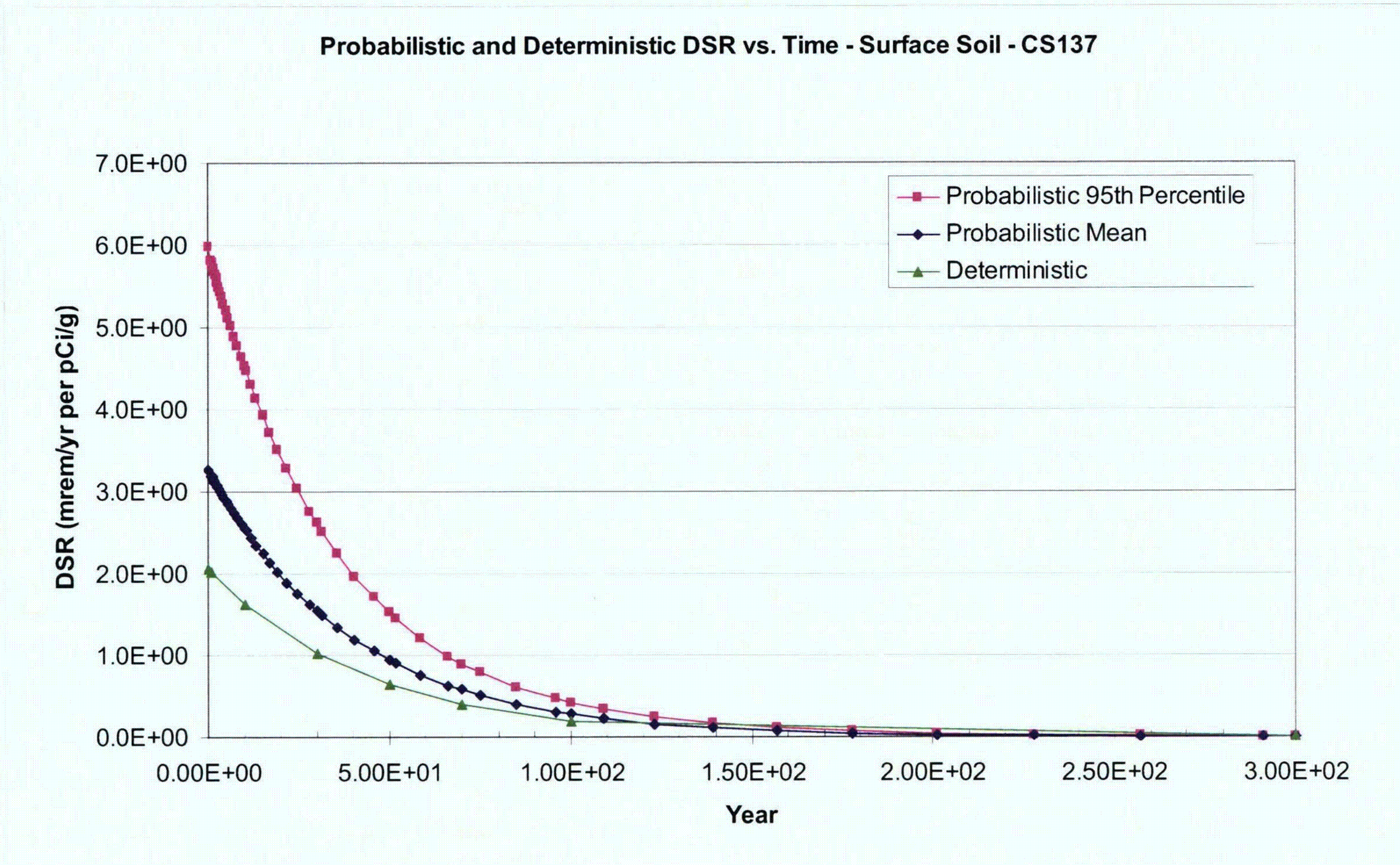


Figure Att-3. Probabilistic and Deterministic Dose-Source Ratio, Cs-137 – Surface Soil

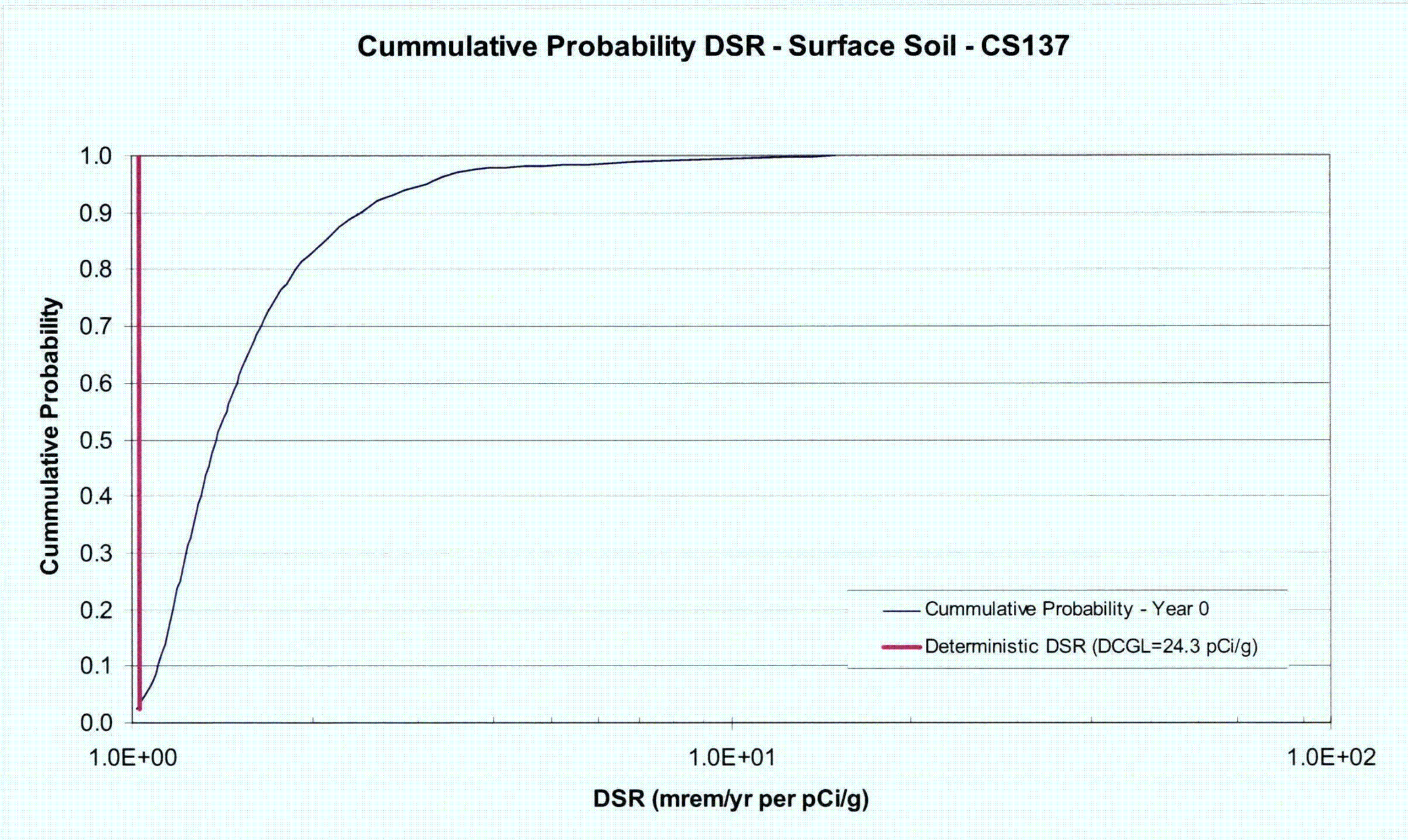


Figure Att-4. Cumulative Probability Dose-Source Ratio, Cs-137 – Surface Soil

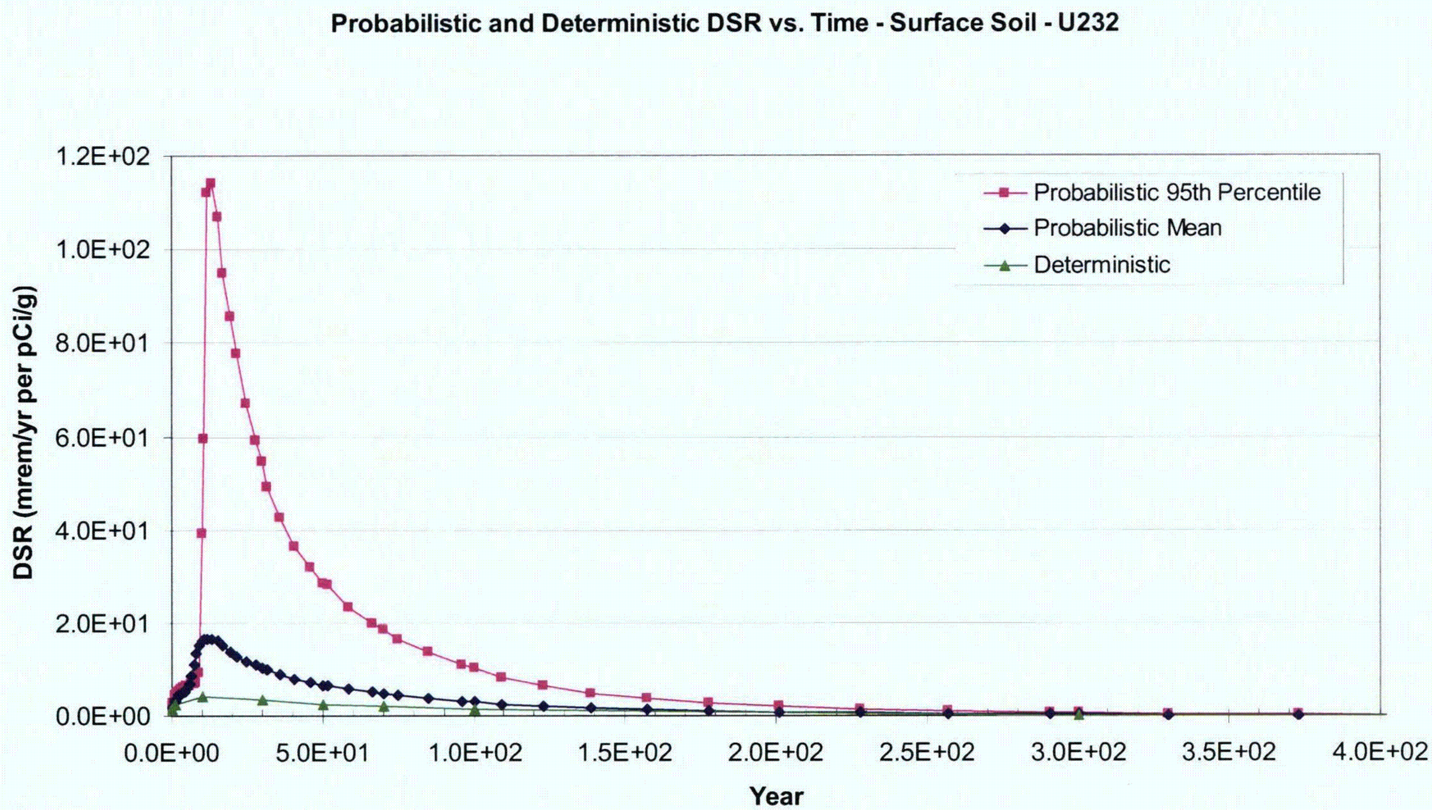


Figure Att-5. Probabilistic and Deterministic Dose-Source Ratio vs. Time, U-232 – Surface Soil

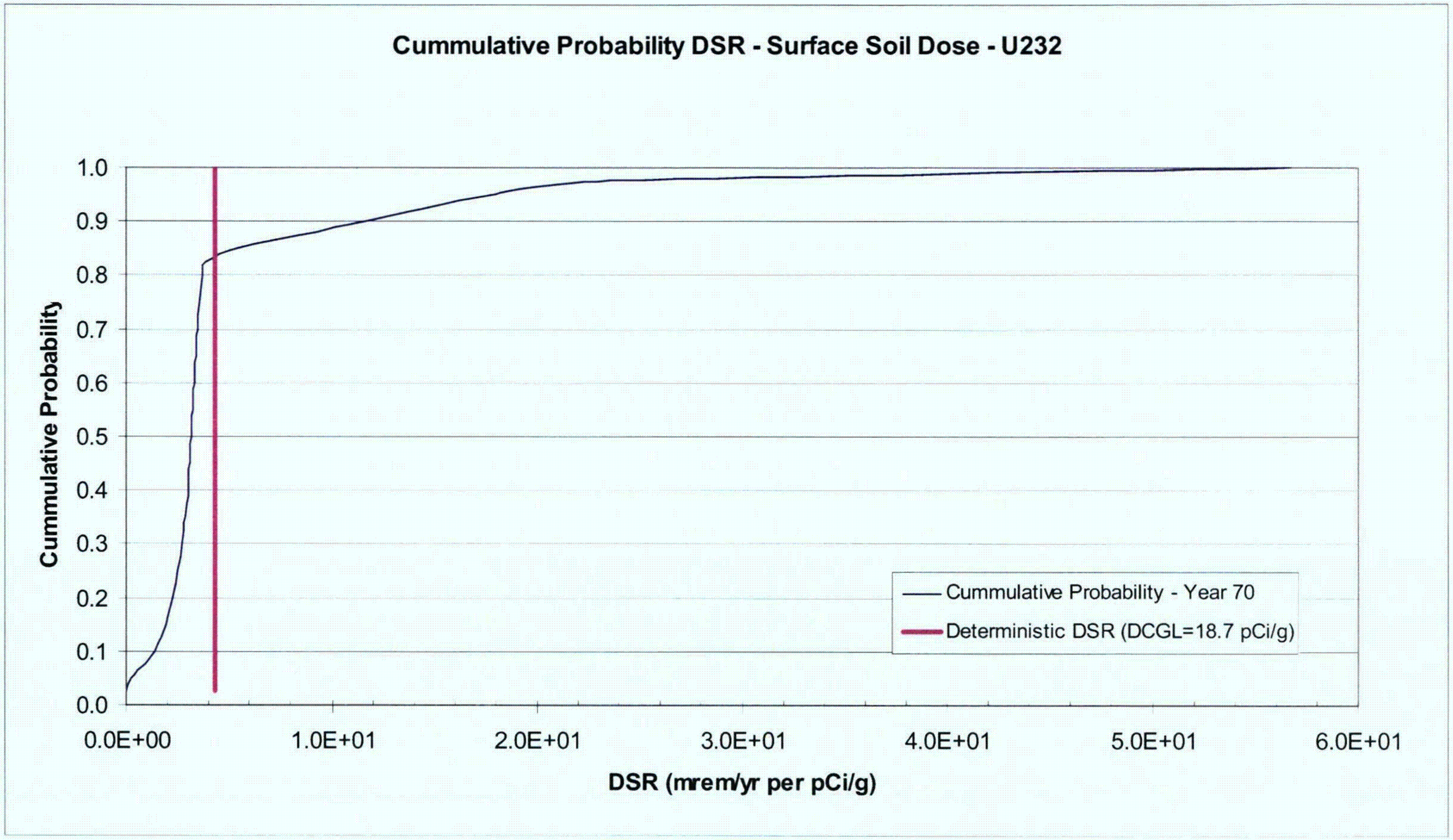


Figure Att-6. Cumulative Probability Dose-Source Ratio, U-232 – Surface Soil

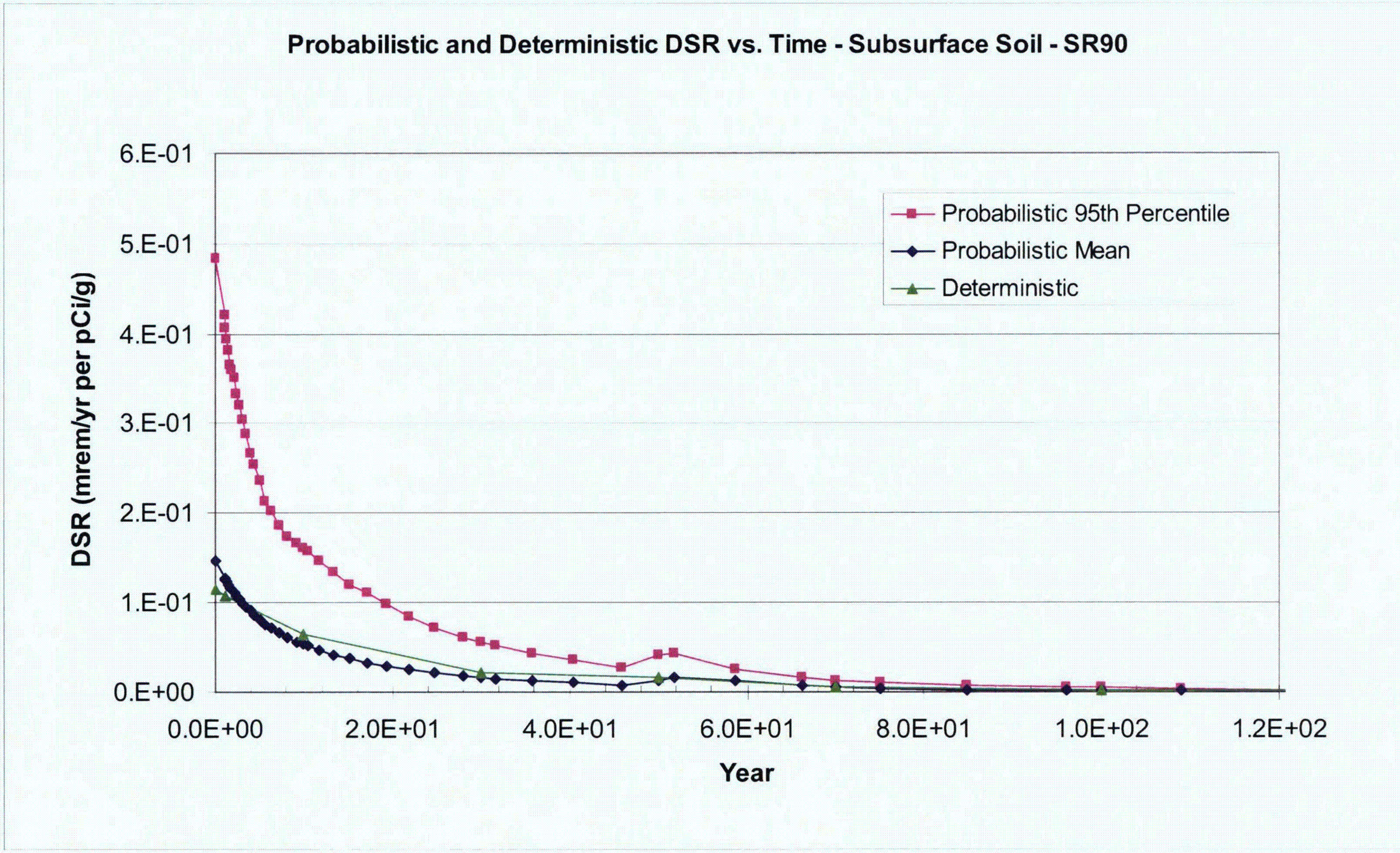


Figure Att-7. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Sr-90 – Subsurface Soil

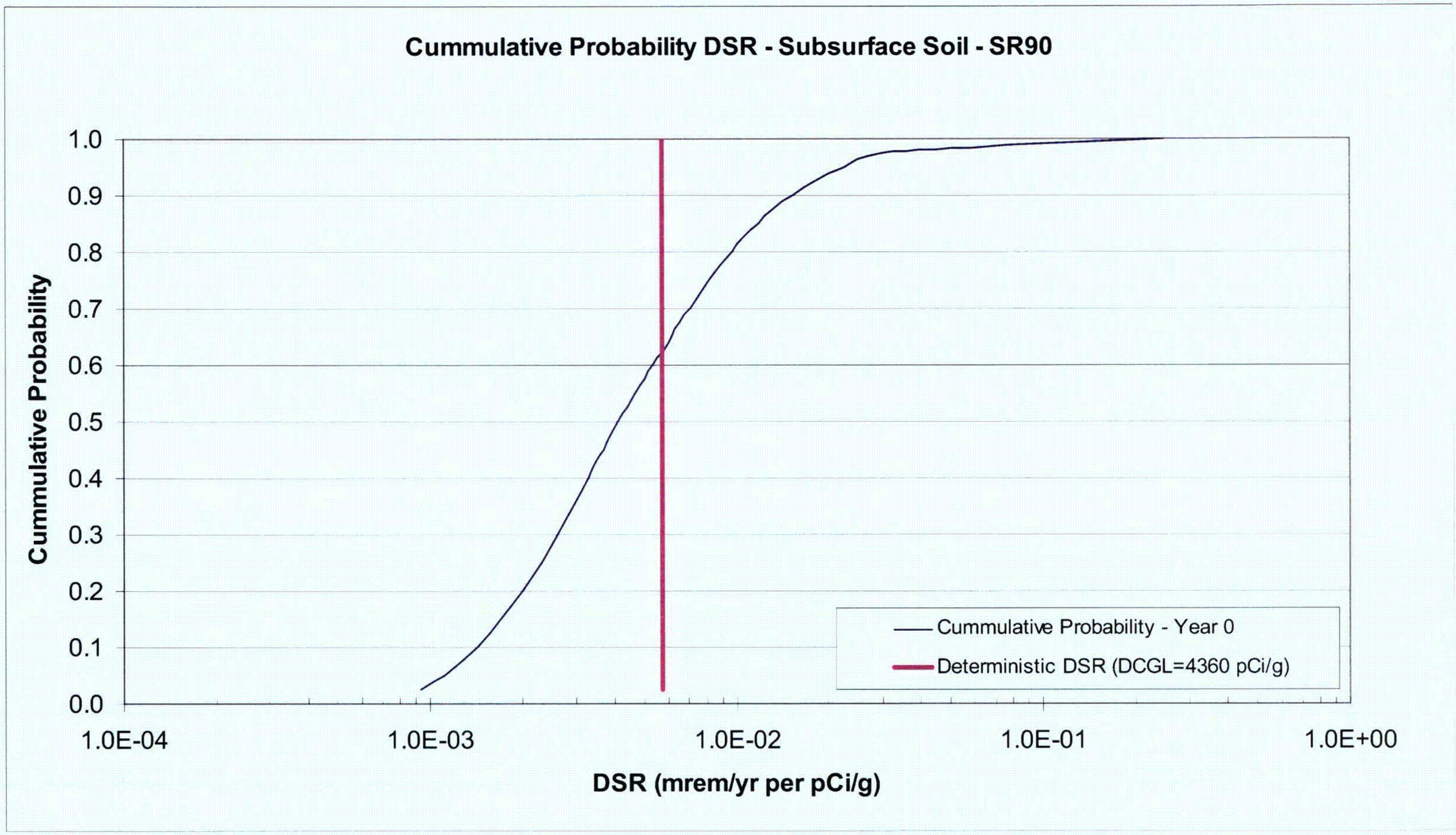


Figure Att-8. Cumulative Probability Dose-Source Ratio, Sr-90 – Subsurface Soil

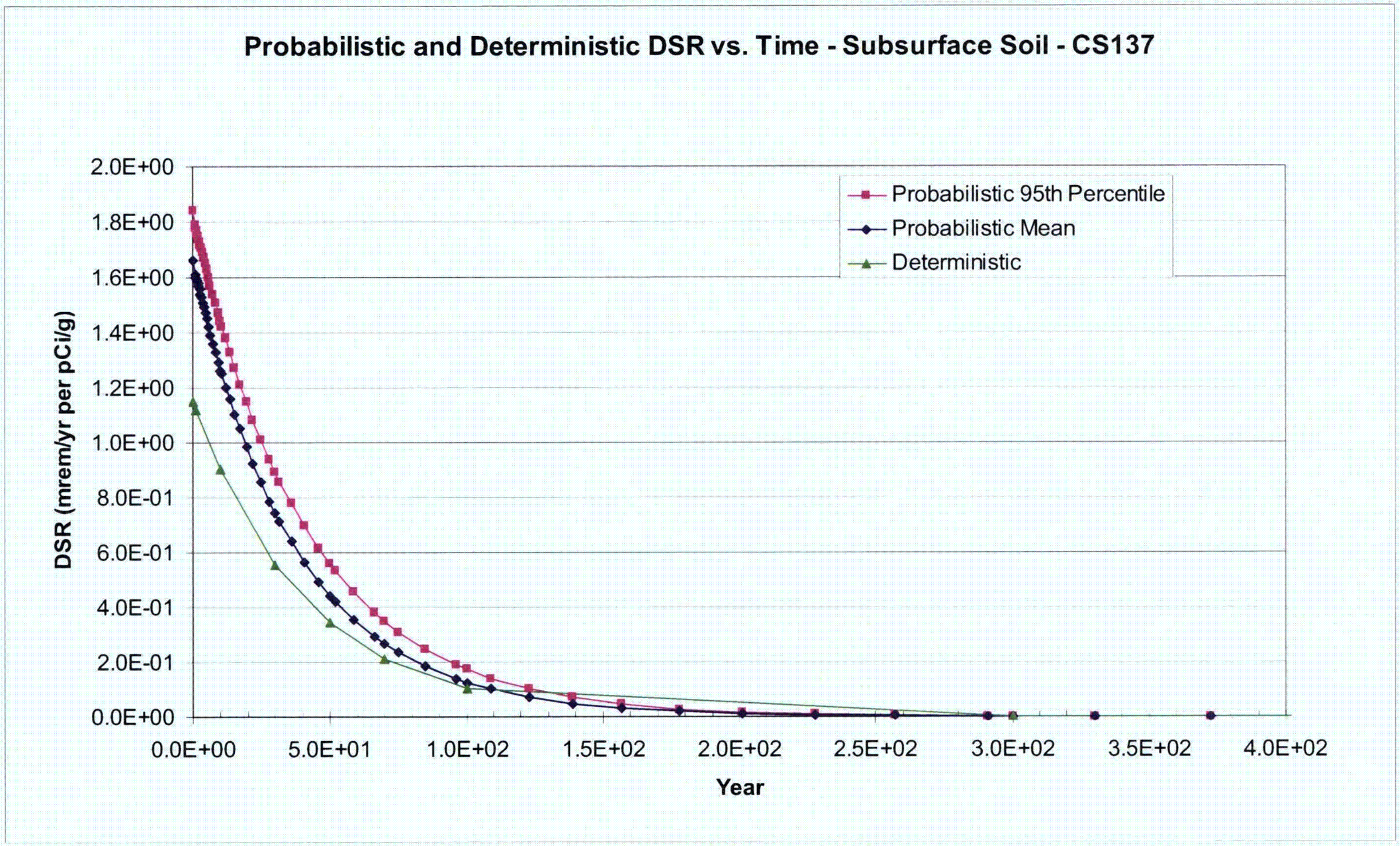


Figure Att-9. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Cs-137 – Subsurface Soil

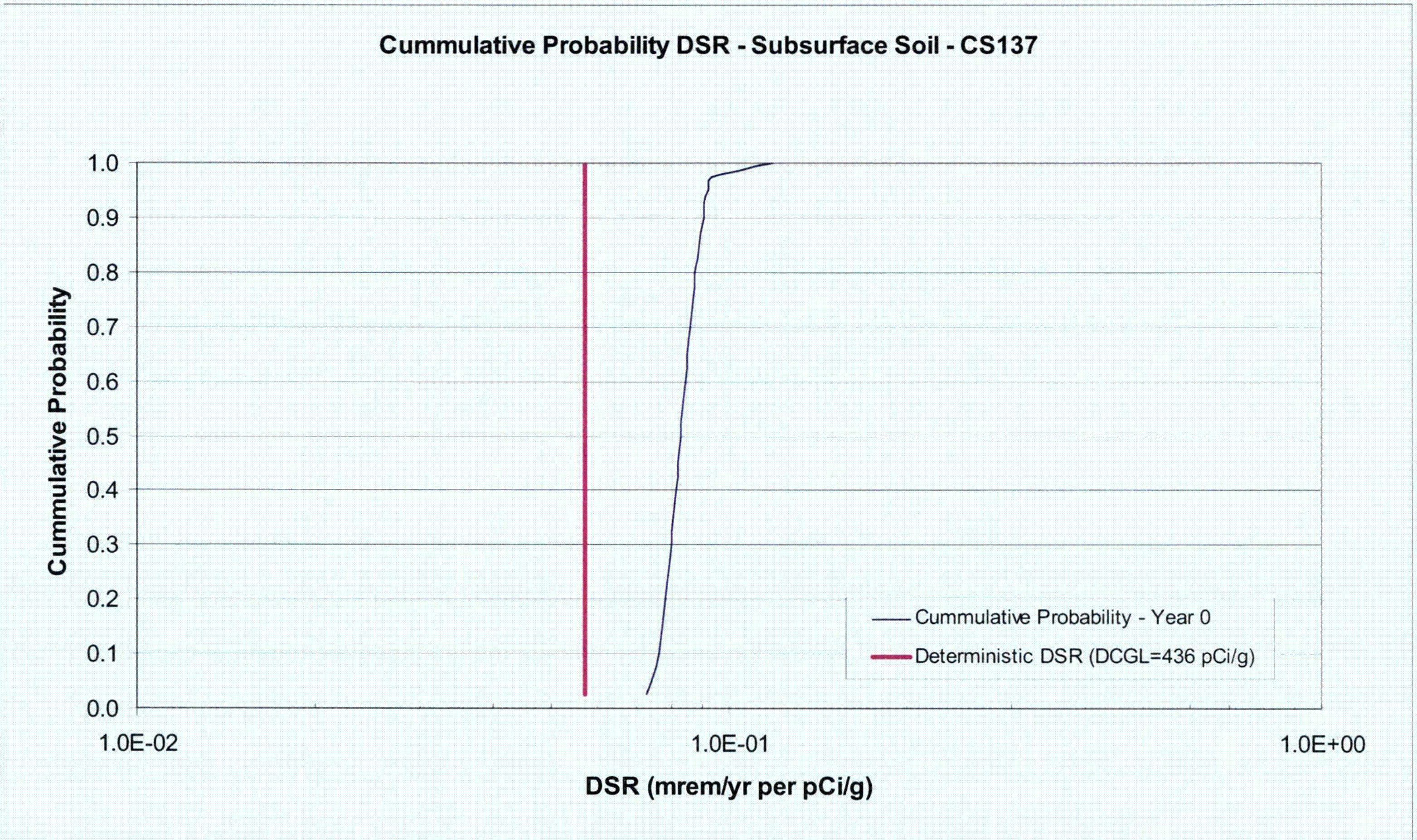


Figure Att-10. Cumulative Probability Dose-Source Ratio, Cs-137 – Subsurface Soil

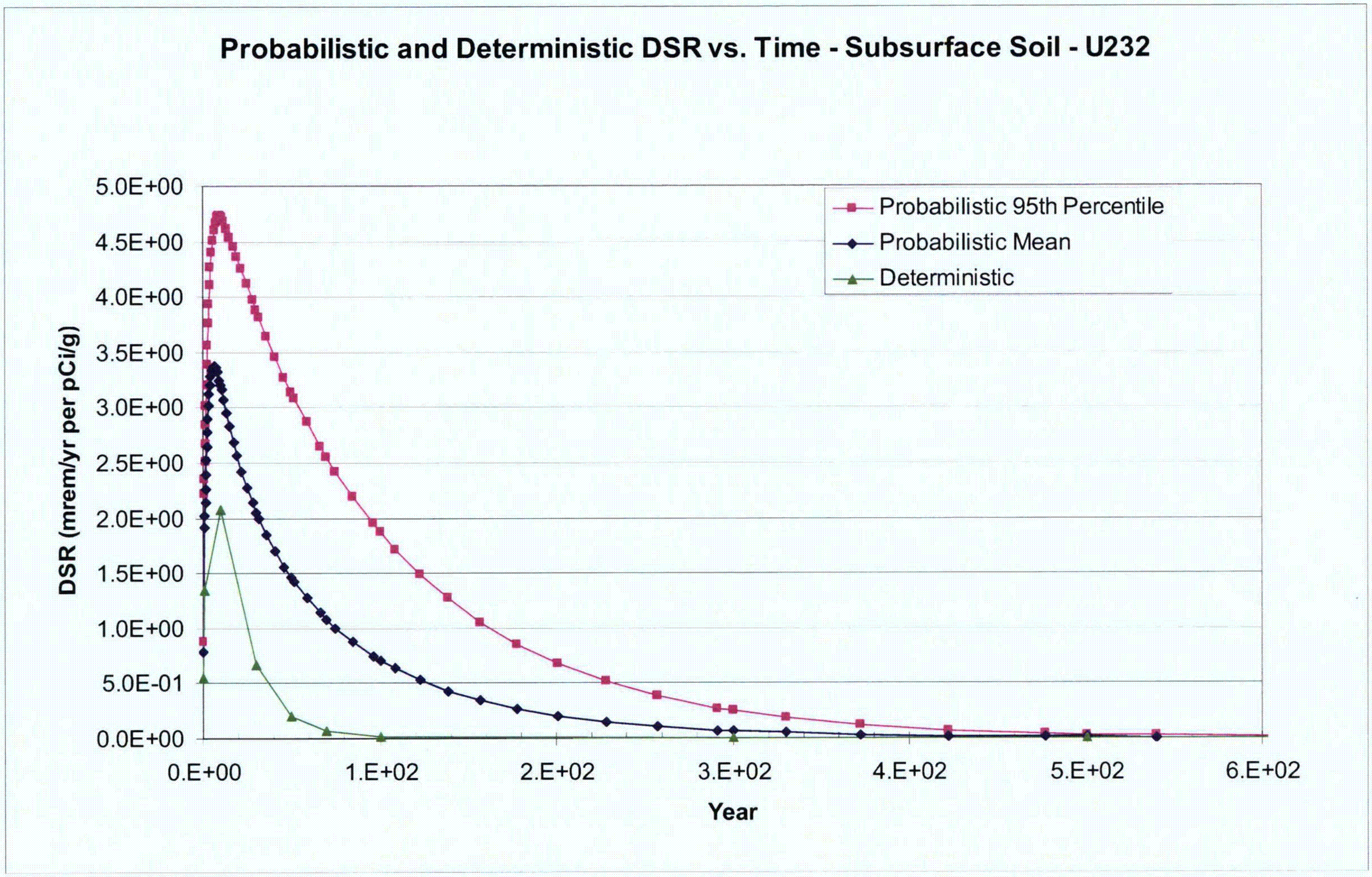


Figure Att-11. Probabilistic and Deterministic Dose-Source Ratio vs. Time, U-232 – Subsurface Soil

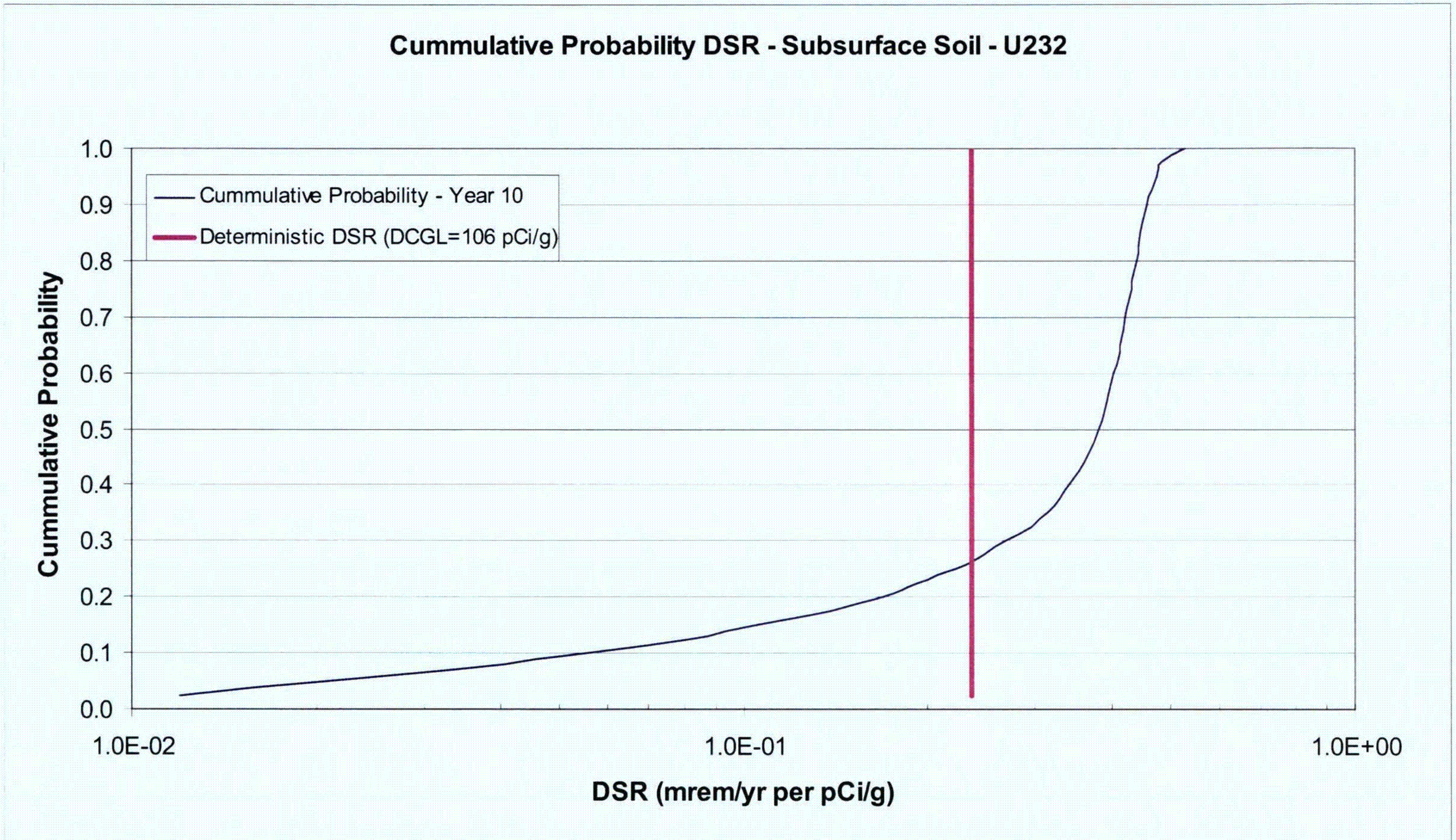


Figure Att-12. Cumulative Probability Dose-Source Ratio, U-232, Subsurface Soil

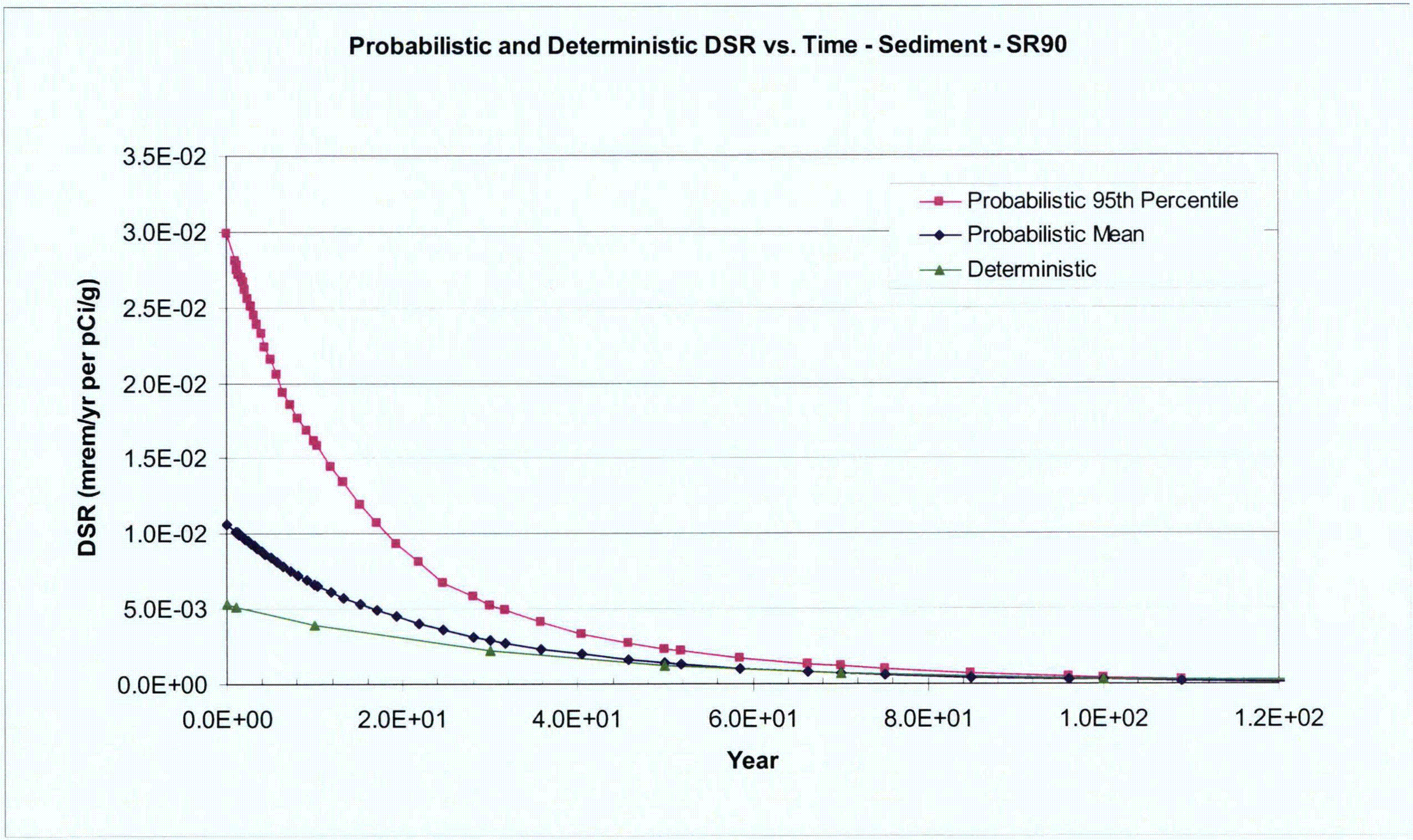


Figure Att-13. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Sr-90 – Streambed Sediment

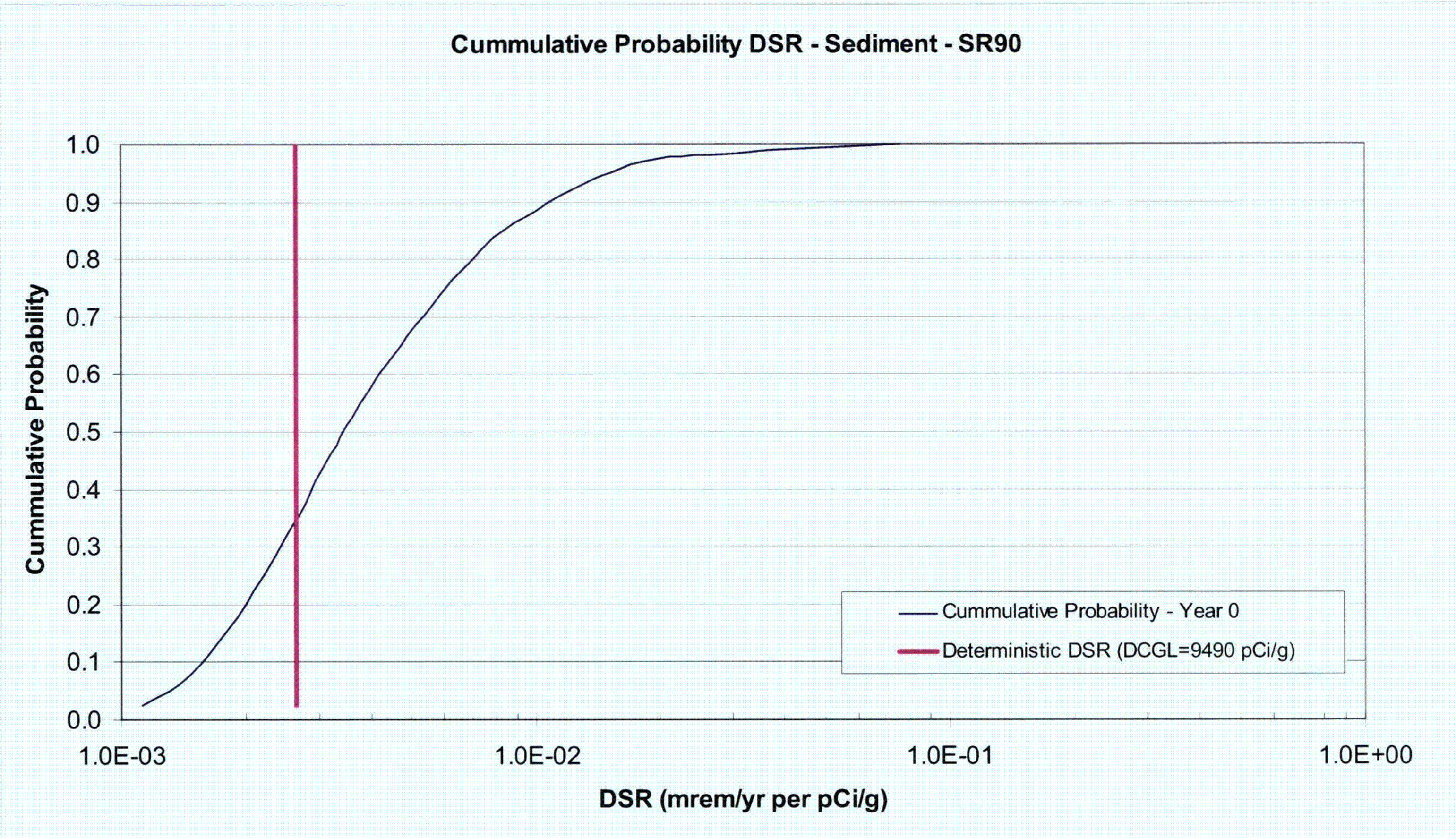


Figure Att-14. Cumulative Probability Dose-Source Ratio, Sr-90 – Streambed Sediment

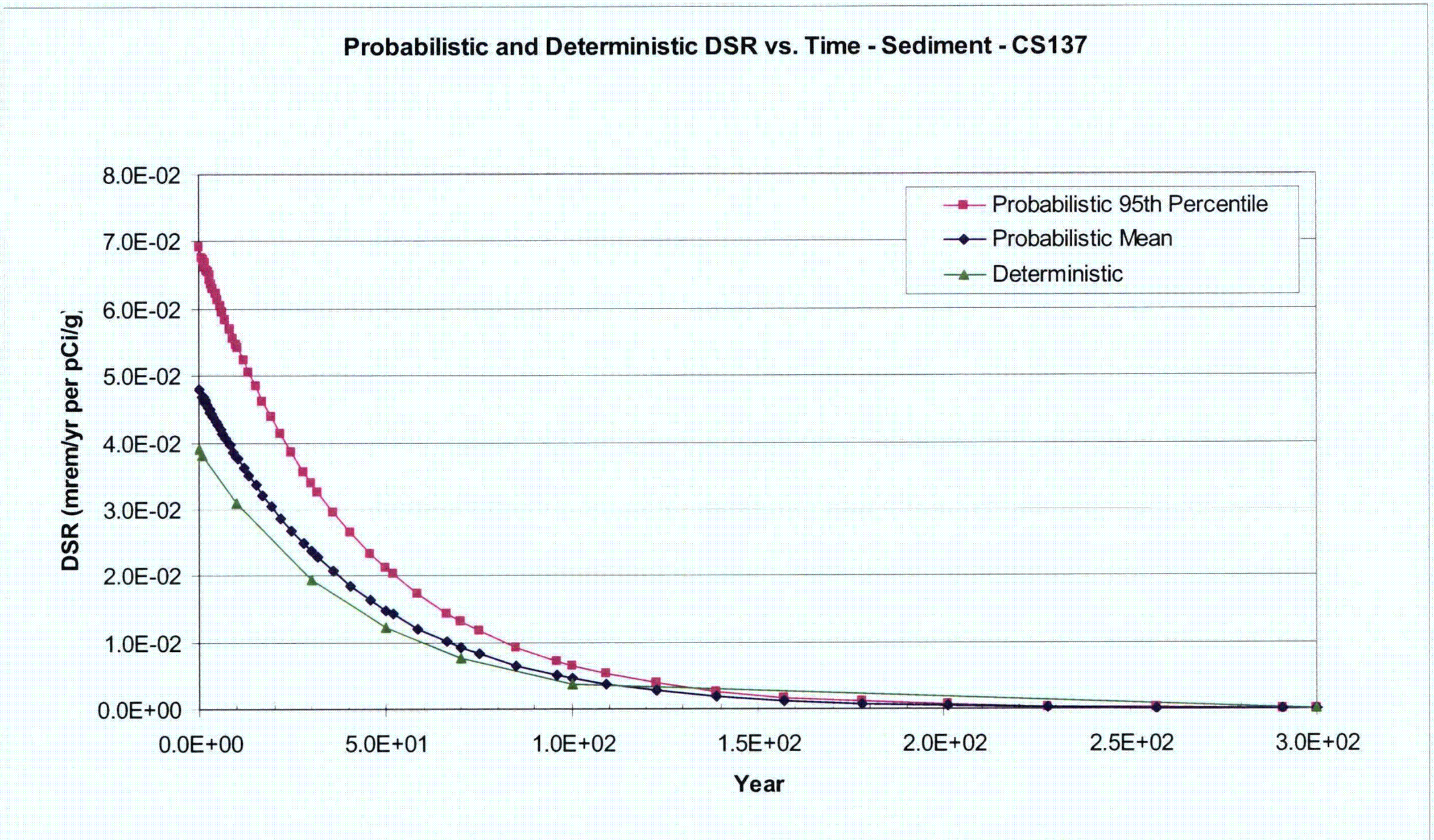


Figure Att-15. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Cs-137 – Streambed Sediment

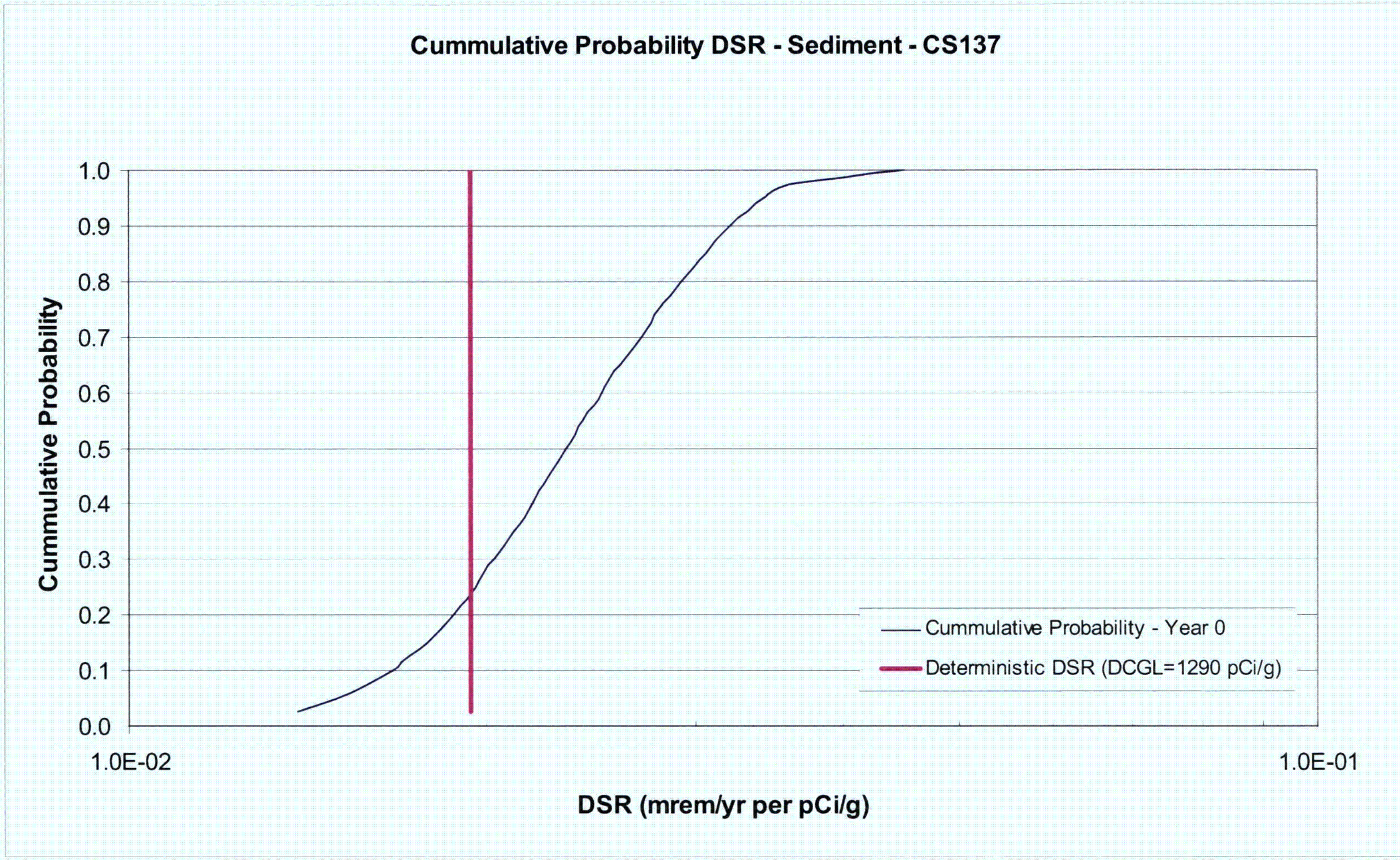


Figure Att-16. Cumulative Probability Dose-Source Ratio, Cs-137 – Streambed Sediment

Table Att-1. Estimated WMA 1 Doses from Observed Maximum Radionuclide Concentrations in the Lavery Till

Radionuclide	Maximum Detection (pCi/g)(1)	Depth (ft)	Peak-of-the-Mean Subsurface Soil $DCGL_w$ (pCi/g)(2)	95th Percentile Subsurface Soil $DCGL_w$ (pCi/g)	Peak-of-the-Mean Estimated Dose (mrem/y)(3)	95th Percentile Estimated Dose (mrem/y)(3)
Am-241	1.3E-01	38-40	6.8E+03	4.3E+03	4.8E-04	7.6E-04
C-14	1.1E-01	38-40	3.7E+05	3.6E+05	7.3E-06	7.5E-06
Cs-137	3.9E+00	38-40	3.0E+02	2.7E+02	3.6E-01	3.6E-01
Cm-243	2.3E-02	38-40	1.1E+03	9.3E+02	6.2E-04	6.2E-04
Cm-244	2.3E-02	38-40	2.2E+04	1.1E+04	5.3E-05	5.3E-05
I-129	2.9E-01	38-40	5.2E+01	5.2E+01	1.4E-01	1.4E-01
Np-237	2.1E-02	37-39	4.3E+00	4.3E+00	1.2E-01	1.2E-01
Pu-238	2.3E-02	38-40	1.4E+04	6.8E+03	4.2E-05	8.4E-05
Pu-239	6.4E-02	38-40	1.2E+04	6.1E+03	1.3E-04	2.6E-04
Pu-240	6.4E-02	38-40	1.2E+04	6.4E+03	1.3E-04	2.5E-04
Pu-241	5.7E-01	38-40	2.4E+05	1.6E+05	5.9E-05	8.9E-05
Sr-90	5.9E+01	38.5-39	3.2E+03	1.0E+03	4.6E-01	1.4E+00
Tc-99	5.5E-01	37-39	1.1E+04	4.4E+03	1.2E-03	3.2E-03
U-232	4.1E-02	24-26	7.4E+01	5.4E+01	1.4E-02	1.9E-02
U-233	2.3E+00	38-40	1.9E+02	1.9E+02	3.0E-01	3.0E-01
U-234	2.3E+00	38-40	2.0E+02	2.0E+02	2.9E-01	2.9E-01
U-235	1.4E-01	24-26	2.1E+02	2.1E+02	1.7E-02	1.7E-02
U-238	1.4E+00	41-43	2.1E+02	2.1E+02	1.7E-01	1.7E-01
				Total Estimated Dose	1.9E+00	2.8E+00

NOTES: (1) Maximum detections from Table 5-1. Radionuclides with maximum detections below the detection limit were evaluated at the detection limit.

(2) Subsurface DCGLs are presented in Appendix E and account for 10 to 1 dilution of contaminated till with clean overlying soil during excavation. Subsurface DCGL are the lower of the deterministic values for the resident gardener and farmer or the probabilistic value for the farmer.

(3) Estimated dose (mrem/y) = 25 (mrem/y) x (maximum detection / $DCGL_W$)

Table Att-2. Estimated WMA 2 Doses from Observed Maximum Radionuclide Concentrations in the Lavery Till

Radionuclide	Maximum Detection (pCi/g)(1)	Depth (ft)	Peak-of-the-Mean Subsurface Soil $DCGL_w$ (pCi/g)(2)	95th Percentile Subsurface Soil $DCGL_w$ (pCi/g)	Peak-of-the-Mean Estimated Dose (mrem/y)(3)	95th Percentile Estimated Dose (mrem/y)(3)
Am-241	3.0E-02	12-14	6.8E+03	4.3E+03	1.1E-04	1.7E-04
C-14	None	None	3.7E+05	3.6E+05	NA	NA
Cm-243	None	None	1.1E+03	9.3E+02	NA	NA
Cm-244	None	None	2.2E+04	1.1E+04	NA	NA
Cs-137	4.5E-01	12-14	3.0E+02	2.7E+02	4.1E-02	4.1E-02
Np-237	None	None	4.3E+00	4.3E+00	NA	NA
I-129	None	None	5.2E+01	5.2E+01	NA	NA
Pu-238	1.0E-02	12-14	1.4E+04	6.8E+03	1.8E-05	3.7E-05
Pu-239	5.9E-03	12-14	1.2E+04	6.1E+03	1.2E-05	2.4E-05
PU-240	5.9E-03	12-14	1.2E+04	6.4E+03	1.2E-05	2.3E-05
Pu-241	1.3E+00	12-14	2.4E+05	1.6E+05	1.4E-04	2.0E-04
Sr-90	8.5E-01	12-14	3.2E+03	1.0E+03	6.7E-03	2.1E-02
Tc-99	None	None	1.1E+04	4.4E+03	NA	NA
U-232	1.2E-02	12-14	7.4E+01	5.4E+01	4.1E-03	5.5E-03
U-233	1.8E-01	12-14	1.9E+02	1.9E+02	2.3E-02	2.3E-02
U-234	1.8E-01	12-14	2.0E+02	2.0E+02	2.3E-02	2.3E-02
U-235	5.9E-03	12-14	2.1E+02	2.1E+02	7.1E-04	7.1E-04
U-238	1.1E-01	12-14	2.1E+02	2.1E+02	1.3E-02	1.3E-02
				Total Estimated Dose	**1.1E-01**	**1.3E-01**

NOTES: (1) Maximum detections from Table 5.1. Radionuclides with maximum detections below the detection limit were evaluated at the detection limit.

(2) Subsurface DCGLs are presented in Appendix E and account for 10 to 1 dilution of contaminated till with clean overlying soil during excavation. Subsurface DCGL are the lower of the deterministic values for the resident gardener and farmer or the probabilistic value for the farmer.

(3) Estimated dose (mrem/y) = 25 (mrem/y) x (maximum detection / $DCGL_W$)

LEGEND: NA = not available

APPENDIX F
ESTIMATED RADIOACTIVITY IN SUBSURFACE PIPING

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to provide conservative estimates of residual radioactivity in underground piping to supplement information on the radiological status of facilties discussed in Section 4.1.

INFORMATION IN THIS APPENDIX

Information in this appendix was drawn from a radioisotope inventory report completed in July 2004. Included are a list of all buried pipelines and estimates for residual activity in pipelines in three areas: (1) beneath the Process Building, (2) west of the Process Building, and (3) east of the Process Building. An estimate is also included for residual radioactivity in the Leachate Transfer Line that runs from the NRC-Licensed Disposal Area (NDA) to Lagoon 2.

RELATIONSHIP TO OTHER PARTS OF THE PLAN

The information in this appendix supplements the information provided in Section 4 and supports the decommissioning activities described in Section 7.

1.0 Introduction

Various underground lines in WMA 1 and WMA 2 carried radioactive liquid during NFS and WVDP operations. All were evaluated and conservative estimates of residual radioactivity were made as described in the radioisotope inventory report (Luckett, et al. 2004). During this evaluation, the sources were divided into categories, including:

- Lines beneath the footprint of the Process Building,
- High-activity lines primarily west of the Process Building,
- Low-activity lines primarily east of the Process Building, and
- The leachate transfer line from the NDA to Lagoon 2.

The evaluation process included the following steps:

- Collection and review of available information and data on pipe design and location;
- Consideration of process history to determine which lines had actually carried radioactive liquid;
- Review of radiological data and inventories generated by the Facility Characterization Project;
- Preparation of activity estimates for indicator radionuclides based on (1) data on fluids carried by the pipes and an empirical relationship between the activity of the HLW fluid

and the resulting residual contamination on the pipe interior or (2) the results of surveys of rooms and systems where the pipe contents originated;

- Application of conservative radionuclide distribution scaling factors from the point of origin of the contamination to produce a conservative estimate of the activity in each line; and
- Combining individual line estimates into conservative curie estimates, that were corrected for decay and ingrowth to 2011, for groups of related lines appropriate to dose modeling.

A listing of the underground lines identified in the evaluation is provided in Table F-1. The column "Radionuclide Distribution Surrogate" refers to the distribution of radionuclide ratios assigned to each line, based on process history, the origin and terminus of the line, and the geographic location category. Note that acronyms used in the table are defined in the legend at the end of the table. Residual activity estimated to remain inside the lines is summarized below in Section 2 through 4 of this appendix. Details of the calculations, a discussion of the basis for the assignment of the surrogate radionuclide distribution, and the surface contamination ($\mu Ci/m^2$) for each radionuclide in each of the distributions are provided in Luckett, et al. 2004.

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet)			Radionuclide Distribution Surrogate
				Below Process Bldg	West of Process Bldg	East of Process Bldg	
1P64-1	1	FRS	MSM Valve Pit	25	0	400	CD Pit
7P19-1	1	Miniature Cell	Tank 7D-14	70.6	0	0	Not Used
7P331a-3	0.25	Tank 7D-13	capped	0	30	0	Tank 7D-13
7P331b-3	0.25	Tank 7D-13	7D-13 Sample station southwest stairwell	0	30	0	Tank 7D-13
7P331c-2	0.50	Tank 7D-13	7D-13 Sample station southwest stairwell	0	30	0	Tank 7D-13
7P63-1	1	Tank 7D-8	Miniature Cell	76.6	0	0	Not Used
7P71-3	3	CPC Floor	59 ft Outside Bldg Capped	70	59	0	Not Used
7P74-3	3	CPC Floor	59 ft Outside Bldg Capped	70	59	0	Not Used
7P90-3	3	CPC Floor	59 ft Outside Bldg Capped	70	59	0	Not Used
7P112-3	3	CPC Floor	Tank 8D-1	65.8	462	0	Not Used
7P113-3	3	Tank 7D-10/ CPC Floor	Tank 8D-2	64.3	462	0	7P113
7P114-3	3	CPC Floor	59 ft Outside Bldg Capped	67.5	59	0	Not Used
7P115-3	3	CPC Floor	59 ft Outside Bldg Capped	67.6	59	0	Not Used
7P116-3	3	CPC Floor	59 ft Outside Bldg Capped	67.7	59	0	Not Used
7P120-3	3	Tank 7D-4/ CPC Floor	THOREX to 8D-4	58.7	462	0	7P120
7P151-3	3	Tank 7D-10	Future HLW Storage Capped 59 ft Outside Bldg	68.2	59	0	Not Used

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet)			Radionuclide Distribution Surrogate
				Below Process Bldg	West of Process Bldg	East of Process Bldg	
7P156-2	2	Tank 7D-13 Vent	OGC	35.6	20	0	Tank 7D-13
7P159-2	2	Tank 7D-13 Jet	GP Catch Tank 7C-5	0	60	0	Tank 7D-13
7P170-2	2	7C-5 Jet	Tank 8D-1	0	482	0	Tank 8D-1
7P177-12	1.5	7 E-13 GP Evap.	7D-13	0	60	0	Tank 7D-13
7P180-12	1.5	7 E-13 via 7P177	15WW568	0	10	0	WW
7P271-2	2	7D-6 Weak Acid Catch Tank Pump 7G-1	Interceptor	0	10	0	WW
8P11-2	2	Tank 8D-1 8G-4	Lagoon	0	0	825	Vault Drip Pan
8P12-3	3	Waste Tank Off Gas Knockout Drum 8D-6	Tank 8D-1	0	41	0	Tank 8D-1
8P27-3	3	Waste Tank Off Gas Knockout Drum 8D-6	Tank 8D-2	0	52	0	Tank 8D-2
8P29-16	16	Tanks 8D-1 via 8P13; and 8D-2 via 8P28; and PVS	Waste Tank Off Gas Condensers and Relief Knock Out Drum 8D-7	0	52	0	8P29-16
8P34-2	2	Waste Tank O/H Condensate Pump 8G-1	7C-5	0	425	0	Tank 8D-2
8P35-2	2	Waste Tank Cond. Pump 8G-1 via 8P34	8D-2 via 7P170	0	5	0	Tank 8D-2
8P38-2	2	Waste Tank Blowers 8K-1/ 8K-1A VIA 8P-46	Tank 8D-2 via 8P-27	0	5	0	Tank 8D-2
8P46-6 (old)	6	Waste Tank Blowers 8K-1/8K-1A	Stack 15F-1	0	435	0	8P46-6
8P46-6 (new)	6	Waste Tank Blowers 8K-1/8K-1A	To line 6P95-8	0	415	0	8P46-6
8P68-2	2	Equipment shelter Manifold	Lagoon	0	52	0	Vault Drip Pan
8P95-3	3	Con Ed Tank 8C-1 Caustic Scrubber	Tank 8D-6 Off-Gas Knockout Drum	0	52	0	Tank 8D-4
8P120-3	3		Tank 8D-1	0	52	0	Tank 8D-1
4P92-12	1.5	Tank 4D-2 Jet 4H-60	59 ft Outside Bldg Capped	61.8	59	0	Not Used
15CH739-3	3	PMC Floor Drain	GPC Sump via 15CH760-3	13.2	0	0	PMCR
15CH750-3	3	CCR Drain	Tank 35104 via 12CH240-6	40.2	0	0	CCR
15CH752-3	3	Equipment Decon Room	Tank 35104 via 12CH240-6	65.8	0	0	EDR

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet)			Radionuclide Distribution Surrogate
				Below Process Bldg	West of Process Bldg	East of Process Bldg	
15CH753-2	2	GPC Sump Jet and Tank 35104 Eductor	1st U Cycle Tank 4D-10	66.8	0	0	GCR
15CH754-12	1.5	From GCR Sump Jet	Tank 7D-2	77	0	0	GCR
15CH758-3	3	Mechanical Crane Room	Tank 35104 via 12CH240-6	65.5	0	0	PMCR
15CH760-3	3	PMC Floor Drain	GPC Sump	47.6	0	0	PMCR
15CH763-3	3	Scrap Removal	Tank 35104 via 12CH240-6	57.9	0	0	SRR
15CH773-3	3	Tank 35104 Eductor 15H-1	Tank 7D-2	98.2	0	0	Tank 35104
15CH774-3	3	CPC/EDR Door Slot Drain	Tank 35104 via 12CH240-6	6.6	0	0	CPC
1WW48-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	20	0	0	CD Pit
1WW49-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	20	0	0	CD Pit
1WW50-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW51-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW52-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW53-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW54-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW55-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
1WW56-4	4	FRS Cask Decon Drain	Interceptor via 15WW571-6	6.5	0	0	CD Pit
02WW359-3	3	Lagoon 1	Lagoon 2	0	0	540	WW
02WW360-6	6	LLWTF underslab piping drains	LLWTF Sump	0	0	80	WW
02WW362-6	6	LLWTF underslab piping drains	LLWTF Sump	0	0	40	WW
02WW363-8	8	Sump Manhole, LLWTF	Lagoon 1	0	0	167	WW
02WW364-3	3	LLWTF underslab piping drains	Lagoon 2	0	0	150	WW
15WW533-6	6	Neutralization Pit	Interceptor	0	0	10	WW
15WW534-6	6	Neutralization Pit	New Interceptor thru West Valve Pit	0	0	120	WW
15WW536-2	2	West Valve Pit	New Interceptor A	0	0	30	WW
15WW538-4	4	Interceptor B thru E Valve Pit	Lagoon 2 thru new 15WW549-4	0	0	35	WW
15WW539-4	4	New Interceptor A	E Valve Pit	0	0	10	WW
15WW549-4	4	East of Interceptor	Lagoon 1	0	0	200	WW

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet)			Radionuclide Distribution Surrogate
				Below Process Bldg	West of Process Bldg	East of Process Bldg	
15WW567-2	2	Tank 7D-13	Interceptor thru 15WW568-2	80	0	0	WW
15WW568-2	2	Tank 7D-13	Interceptor thru 15WW569-6	50	0	0	WW
15WW569-6	6	Trunk Line S side Process Bldg	Interceptor thru 15WW533-6	100	0	110	WW
15WW570-4	4	N side Process Bldg / FRS	Interceptor thru 15WW571-6	0	0	200	WW
15WW571-6	6	FRS Cask Decon Drains	Interceptor thru 15WW843-6	60	0	13	CD Pit
15WW841-4	4	N Side of MSM Repair	Interceptor thru 15WW852-3	12	0	25	WW
15WW842-3	3	E Side of MSM Repair	Interceptor thru 15WW570-4	19	0	15	WW
15WW843-6	6	Trunk Line East of Process Bldg	Interceptor thru 15WW569-6	72	0	120	WW
15WW846-3	3	Under Lower Warm Aisle	Interceptor thru 15WW569-6	5	0	0	WW
15WW847-3	3	Under Lower Warm Aisle	Interceptor thru 15WW569-6	5	0	0	WW
15WW848-3	3	Trunk line, upper floors South side Process Bldg	Interceptor thru 15WW569-6	5	0	0	WW
15WW850-4	4	Under Floor RAM Equipment Room	Interceptor thru 15WW843-6	16	0	0	WW
15WW851-3	3	Under Floor CPC	Interceptor thru 15WW895-4	80	0	0	WW
15WW852-3	3	Equipment Decon Room	Interceptor thru 15WW570-4	13.3	0	55	WW
15WW857-3	3	Under Floor PMC	Interceptor thru 15WW851-3	45	0	0	WW
15WW858-3	3	Under Floor RAM Equipment Room	Interceptor thru 15WW895-4	6	0	0	WW
15WW859-3	3	Under Floor RAM Equipment Room	Interceptor thru 15WW895-4	20	0	0	WW
15WW860-3	3	Under Floor Cell Access Aisle	Interceptor thru 15WW851-3	16	0	0	WW
15WW861-3	3	Under Floor W Main Op Aisle	Interceptor thru 15WW895-4	25	0	0	WW
15WW863-3	3	Under Floor W Main Op Aisle	Interceptor thru 15WW895-4	6	0	0	WW
15WW885-2	2	Sink Drains	Tank 7D-13	120	0	0	WW
15WW887-2	2	Sink Drains	Tank 7D-13 via 15WW885-2	25	0	0	WW
15WW892-3	3	Scrap Removal Room	Interceptor thru 15WW852-3	10	0	10	WW

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet) Below Process Bldg	West of Process Bldg	East of Process Bldg	Radionuclide Distribution Surrogate
15WW895-4	4	Under Floor RAM Equipment Room	Interceptor thru 15WW843-6	25	0	0	WW
15WW896-3	3	GOA Sump ejector	Interceptor thru 15WW841-4	3	0	0	WW
15WW899-3	3	Floor PPS	Interceptor thru 15WW843-6	3	0	0	WW
15WW900-3	3	Floor UPC	Interceptor thru 15WW843-6	15	0	0	WW
15WW916-6	6	FRS Resin Wash Pit	Interceptor thru 15WW843-6	5	0	20	WW
15WW917-4	4	Tank 14D-1 and Tank 14D-2	Interceptor thru 15WW920-4	0	0	15	WW
15WW918-4	4	Tank 14D-1 and Tank 14D-2	Interceptor thru 15WW920-4	0	0	15	WW
15WW919-4	4	Tank 14D-1 and Tank 14D-2	Interceptor thru 15WW920-4	0	0	15	WW
15WW920-4	4	Tank 14D-1 and Tank 14D-2	Interceptor thru 15WW569-6	0	0	125	WW
15WW923-6	6	Utility Room Floor Drain	Interceptor thru 15WW569-6	30	0	0	WW
15WW924-4	4	Utility Room Floor Drain	Interceptor thru 15WW569-6	30	0	0	WW
15WW925-6	6	Utility Room Floor Drain	Interceptor thru 15WW569-6	30	0	0	WW
15WW926-2	2	Utility Room Floor Drain	Interceptor thru 15WW569-6	30	0	0	WW
15WW927-4	4	Utility Room Floor Drain	Interceptor thru 15WW569-6	30	0	0	WW
15WW929-3	3	Tank 15D-6	New Interceptor East Valve Pit	0	0	660	WW
15WW1231-3	3	Floor Drain PPS	Interceptor via 15WW569-6	15	0	0	WW
15WW1232-3	3	Floor Drain Acid Rec Pump Room	Interceptor via 15WW569-6	15	0	0	WW
15WW1744-2	3	Laundry Sump	New Interceptor A	0	0	175	WW
6-71-6-001	6	6-50-2-015, 6-71-2-019, 6-71-2-675, 6-50-2-015	Tank 35104	0	0	15	WW
6-71-2-003	2	12CH241	Tank 35104 Pump Suction	0	0	15	WW
6-71-1-006	1	Tank 35104 Pump Discharge	LWTS Evaporator	0	0	40	WW
6-71-3-016	3	Floor Drain in 35104 pump niche	General crane Room extension	0	0	30	WW
6-71-2-019	2	Truck Fill	Tank 35104 via 6-71-6-001	0	0	4	WW
6-71-2-020	2	Tank 7D-13 Eductor 7H-19 via 7P159	PPC manifold via 01/14 & Pipe Chase	0	0	45	WW

Table F-1. List of Buried Pipelines

Line Number	Pipe Dia. (in)	From	To	Length (feet)			Radionuclide Distribution Surrogate
				Below Process Bldg	West of Process Bldg	East of Process Bldg	
6-71-2-021	2	Tank 7D-13 Eductor 7H-19 via 7P159	Interceptor via 15WW848	0	0	25	WW
6-71-4-022	4	CSS Drain Header	Tank 7D-13	0	0	70	WW
6-71-2-023	2	Tank 35104 Pump Discharge	6-50-2-153, return to STS	0	0	10	WW
6-71-2-031	2	Drain from 7D-13 valve pit	Tank 7D-13 via 6-71-4-022	0	0	15	WW
6-71-2-032	0.5	Tank 35104 Pump Discharge	35104 Sample Station GPC-CR Lower Air lock	0	0	50	WW
6-71-2-675	0.5	35104 Sample Station GPC-CR Lower Air lock	35104 Waste Catch tank via 6-71-6-001	0	0	50	WW
12CH240-6	6	Drains	Tank 35104	0	0	30	WW
12CH241-3	3	Tank 35104 Eductor	Tank 7D-2 LWC or Tank 35104 Pump Suction	0	0	20	WW
12CH365-1/8	0.125	35104 Pit	Cut and Capped 18"below grade	0	0	10	WW
12CH366-2	0.5	35104 Pit	Cut and Capped 18"below grade	0	0	10	WW
12CH367-1	1	35104 Pit	Cut and Capped 18"below grade	0	0	10	WW
undesignated	2	Tank 15D-6	MSM Valve Pit	0	0	150	Tank 5D-6
undesignated	2	MSM Shop 2 Floor Drains	Tank 15D-6	50	0	50	Tank 15D-6
Leachate Line	2	NDA Hardstand	LLWTF Lagoon 2	0	0	2,000	n/a

LEGEND: Tanks referred to are located within the Process Building, except 15D-6 that is an underground tank located northeast of the Process Building. CCR is the Chemical Process Cell Crane Room. CD Pit is the Cask Decon Pit. CPC is the Chemical Process Cell. CSS is the Cement Solidification System. EDR is the Equipment Decontamination Room. FRS is Fuel Receiving and Storage. GOA is General Purpose Cell Operating Aisle. GP is General Purpose. GPC is General Purpose Cell. GPC-CR is the General Purpose Cell Crane Room. LWC is the Liquid Waste Cell. LWTS is the Liquid Waste Treatment System. MSM is Master-Slave Manipulator. OGC is the Off-Gas Cell. PMCR is the Process Mechanical Cell Crane Room. PPC is the Product Purification Cell. SRR is the Scrap Removal Room. STS is the Supernatant Treatment System. WW is wastewater.

2.0 Lines Beneath the Process Building

Review of drawings and process history established that 57 pipelines or portions of pipelines located beneath the Process Building, Utility Room, or Utility Room Expansion carried radioactive liquid. These include:

- Eleven process drains,
- Two waste transfer lines,

- Eleven Fuel Receiving and Storage Area cask decon lines,
- Thirty-three wastewater drains.

There were 11 lines under the Process Building that were designed to carry radioactive fluids, but were spares that were never used as designed. Their inventory is considered negligible (zero).

Figure F-1 shows the lines that were estimated to contribute more than 98 percent of the total activity in the lines beneath the Process Building. The lines in each category and the estimated source terms are described below.

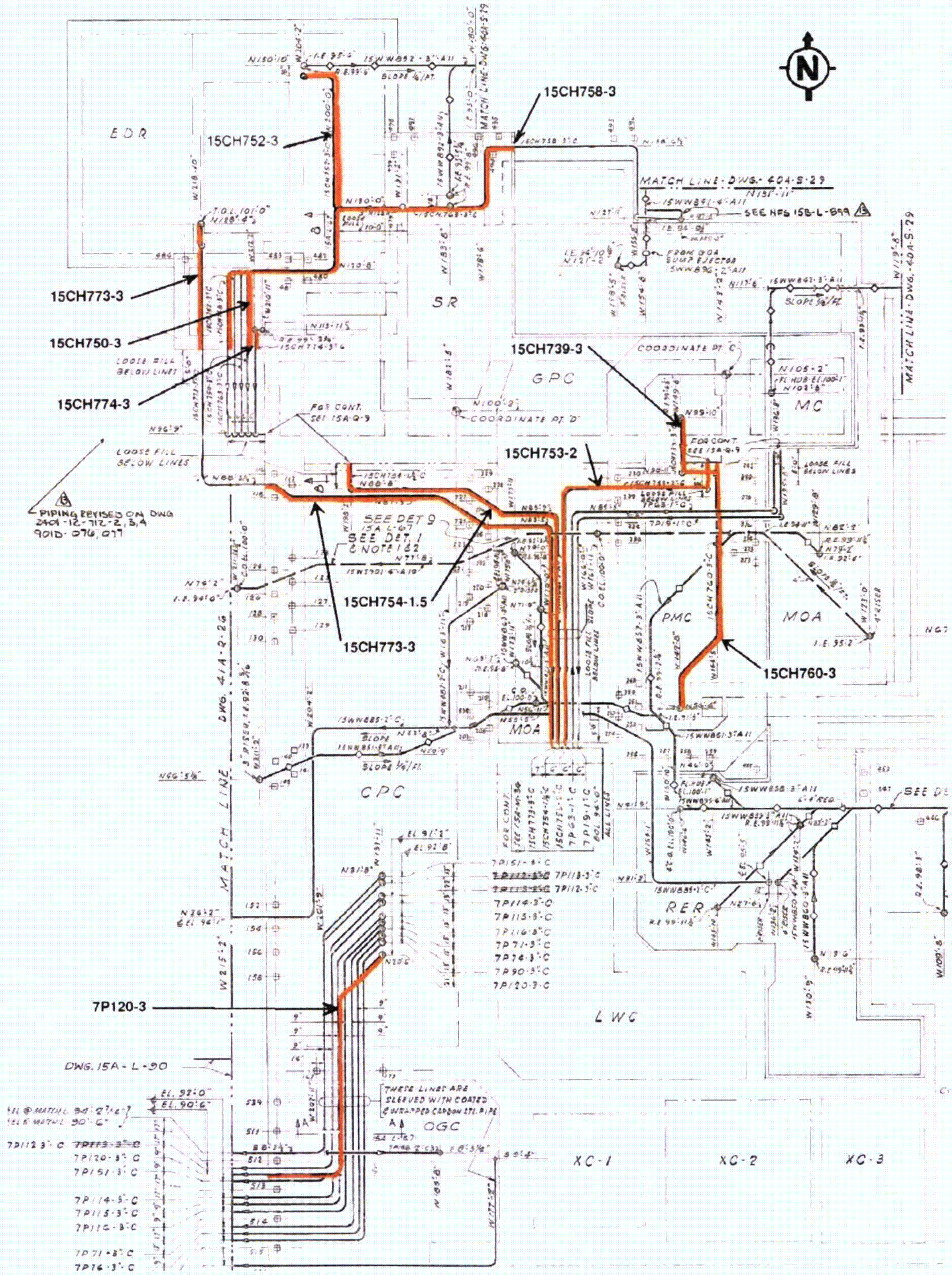


Figure F-1. Location of Pipelines Beneath the Process Building. (Marked lines are estimated to contain more than 98 percent of the activity in piping under the building.)

2.1 Process Drain Lines

All 11 lines are stainless steel pipe designated for chemical service. Eight are three-inch, two are two-inch, and the other is 1.5-inch in diameter. Each line is encased in an outer carbon steel pipe providing double containment. They are located in side-by-side runs within earth fill beneath the Process Building's reinforced concrete floor slabs.

The lines run typically about 10 feet below grade (reference elevation approximately 90 feet) and are sloped downward in the direction of flow, typically about 0.25 inch per foot. Table F-2 shows conservative estimates of the total activity within all 11 lines.

Table F-2. Estimated Process Drain Line Activity in Curies (as of 2011)

Nuclide	Activity	Nuclide	Activity	Nuclide	Activity
Am-241	7.5E-02	Np-237	3.7E-05	Tc-99	3.9E-04
C-14	1.3E-04	Pu-238	1.8E-02	U-232	4.4E-05
Cm-243	7.8E-05	Pu-239	1.7E-02	U-233	4.2E-05
Cm-244	1.8E-03	Pu-240	1.1E-02	U-234	1.6E-05
Cs-137	8.0E-01	Pu-241	2.6E-01	U-235	6.8E-05
I-129	2.0E-06	Sr-90	4.6E-01	U-238	2.0E-05

2.2 Waste Transfer Lines

Both lines are three-inch stainless steel pipe; each is encased within an outer six-inch carbon steel pipe. These lines run approximately 10 feet below grade within a concrete pipe trench. The lines are sloped downward in the direction of flow, about 0.25 inch per foot. Estimated activity in the lines is shown in Table D-3 below.

Line 7P120-3 contains much more radioactivity than the other line, 7P113-3. Line 7P120-3, which runs from the Chemical Process Cell to HLW Tank 8D-4, was used by NFS to transfer THOREX process waste during one fuel reprocessing campaign. Line 7P113-3 was used by NFS to transfer PUREX process wastes to Tank 8D-2; this line was flushed with decontamination solutions and with lower level waste solutions after reprocessing operations ended. Table F-3 shows conservative estimates of the total activity within both lines.

Table F-3. Estimated Waste Transfer Line Activity in Curies (as of 2011)

Nuclide/Line	7P113-3	7P120-3	Nuclide/Line	7P113-3	7P120-3
Am-241	1.1E-05	1.0E-02	Pu-240	1.3E-06	3.3E-04
C-14	1.9E-07	5.4E-06	Pu-241	1.7E-05	1.1E-02
Cm-243	3.8E-08	5.3E-06	Sr-90	2.9E-04	1.0E+01
Cm-244	8.9E-07	2.2E-04	Tc-99	2.2E-07	4.3E-03
Cs-137	3.6E-03	1.1E+01	U-232	3.6E-08	8.9E-05

Table F-3. Estimated Waste Transfer Line Activity in Curies (as of 2011)

Nuclide/Line	7P113-3	7P120-3	Nuclide/Line	7P113-3	7P120-3
I-129	1.6E-07	7.4E-06	U-233	1.6E-08	8.7E-05
Np-237	9.9E-09	1.3E-05	U-234	7.9E-09	9.1E-05
Pu-238	2.4E-06	1.6E-02	U-235	6.3E-11	2.1E-07
Pu-239	1.7E-06	6.4E-04	U-238	8.0E-10	2.9E-09

2.3 Cask Decon Lines

Nine lines are four inches in diameter and are associated with floor drains for the Fuel Receiving and Storage Building; these lines connect to the six-inch trunk line (15WW571-6). Line 1P64-1, a one-inch discharge line running toward the Low-Level Waste Treatment Facility (LLWTF) Interceptor, is also grouped with the cask decon lines.

The estimated activity in these lines, based on the assumption that their average interior surface contamination is similar to that remaining on the floor of the Cask Decon Pit, is shown in Table F-4.

Table F-4. Estimated Cask Decon Line Activity in Curies (as of 2011)

Nuclide	Activity	Nuclide	Activity	Nuclide	Activity
Am-241	1.9E-02	Np-237	2.3E-06	Tc-99	5.2E-05
C-14	2.5E-05	Pu-238	2.8E-03	U-232	2.9E-06
Cm-243	7.4E-06	Pu-239	5.4E-03	U-233	6.9E-06
Cm-244	1.5E-04	Pu-240	2.8E-03	U-234	5.9E-07
Cs-137	1.3E-01	Pu-241	7.6E-02	U-235	8.4E-07
I-129	1.2E-07	Sr-90	1.2E-01	U-238	7.1E-06

2.4 Wastewater Drain Lines

These lines deliver low-level or uncontaminated wash water and spills from various drains in the Process Building to the LLWTF Interceptor. This piping is made of Duriron, a high silicone cast iron, in diameters ranging from two-inch to six-inch. Beneath the Process Building, the runs are encased within concrete of 12-inch-square cross section. They are located eight to 12 feet below grade, sloping about 0.25 inch per foot.

The estimated activity in these lines was based on an empirical relationship between the residual contamination and the radioactivity in the fluid carried by the lines observed in HLW lines. (This relationship is based on WVDP experience with residual contamination measured in other piping where the activity of the liquid that passed through the piping was known.) The LLWTF Interceptor operating limit (0.005 μCi/mL) was used in the calculations for conservatism; many discharges though the lines likely had radioactivity concentrations well below this value. The use of the bounding spent nuclear fuel distribution as the surrogate for the waste water also provides a level of conservatism by assigning the maximum radionuclide ratio observed in any spent fuel batch to the residual in the waste water pipes. The total estimated activity in all the lines is shown in Table F-5.

Table F-5. Estimated Wastewater Drain Line Activity in Curies (as of 2011)

Nuclide	Activity	Nuclide	Activity	Nuclide	Activity
Am-241	2.1E-06	Np-237	1.3E-09	Tc-99	5.6E-09
C-14	3.2E-11	Pu-238	2.3E-07	U-232	5.8E-10
Cm-243	1.2E-08	Pu-239	7.2E-08	U-233	2.4E-10
Cm-244	2.6E-07	Pu-240	5.2E-08	U-234	9.7E-11
Cs-137	1.4E-04	Pu-241	1.1E-06	U-235	2.5E-12
I-129	2.6E-14	Sr-90	1.3E-04	U-238	2.3E-11

2.5 Total Estimated Inventory in Lines Beneath the Process Building Footprint

As shown in Table F-6 the total estimated residual inventory for all the combined lines beneath the Process Building footprint is approximately 23 Ci, predominantly Sr-90 and Cs-137 activity. The table indicates that Line 7P120-3 and the process drain lines have over 95 percent of the Cs-137 and Sr-90 activity under the Process Building, as well as 71-98 percent of the Pu and U isotopes.

Table F-6. Estimated Total Residual Inventory in Lines Under the Process Building (as of 2011)

Nuclide	Residual Inventory (Ci)			Contribution to Total	
	Total All Lines	Process Drains	Line 7P120-3	Line 7P120-3	Line 7P120-3 and Process Drains
Am-241	1.0E-01	7.5E-02	1.0E-02	10.0%	85.0%
C-14	1.6E-04	1.3E-04	5.4E-06	3.4%	84.6%
Cm-243	9.1E-05	7.8E-05	5.3E-06	5.8%	91.5%
Cm-244	2.2E-03	1.8E-03	2.2E-04	10.0%	91.8%
Cs-137	1.2E+01	8.0E-01	1.1E+01	91.7%	98.3%
I-129	9.7E-06	2.0E-06	7.4E-06	76.3%	96.9%
Np-237	5.2E-05	3.7E-05	1.3E-05	25.0%	96.2%
Pu-238	3.7E-02	1.8E-02	1.6E-02	43.2%	91.9%
Pu-239	2.3E-02	1.7E-02	6.4E-04	2.8%	76.7%
Pu-240	1.4E-02	1.1E-02	3.3E-04	2.4%	80.9%

Table F-6. Estimated Total Residual Inventory in Lines Under the Process Building (as of 2011)

Nuclide	Residual Inventory (Ci)			Contribution to Total	
	Total All Lines	Process Drains	Line 7P120-3	Line 7P120-3	Line 7P120-3 and Process Drains
Pu-241	3.5E-01	2.6E-01	1.1E-02	3.1%	77.4%
Sr-90	1.1E+01	4.6E-01	1.0E+01	90.9%	95.1%
Tc-99	4.7E-03	3.9E-04	4.3E-03	91.5%	99.8%
U-232	1.4E-04	4.4E-05	8.9E-05	63.6%	95.0%
U-233	1.4E-04	4.2E-05	8.7E-05	62.1%	92.1%
U-234	1.1E-04	1.6E-05	9.1E-05	82.7%	97.3%
U-235	6.9E-05	6.8E-05	2.1E-07	0.3%	98.9%
U-238	2.8E-05	2.0E-05	2.9E-09	0.0%	71.4%

3.0 Lines West of the Process Building

The lines west of the Process Building identified in Table F-1 include:

- Four ventilation lines;
- Three waste transfer lines, two of which were used; and
- Twenty-four other lines that carried wastewater or ventilation condensate.

3.1 Lines of Interest

Ventilation Lines

The ventilation lines are:

- 8P29-16, a 16-inch header line that runs from the Permanent Ventilation System to the Equipment Shelter
- 8P34-2, an abandoned and capped two-inch ventilation condensate line from Tank 8D-2,
- 7P170-2, an abandoned and capped two-inch ventilation condensate line from Tank 8D-1, and
- 8P46-6 (old and new), two six-inch lines that connect the Equipment Shelter to the Main Plant Stack.

Waste Transfer Lines

The two waste transfer lines of interest are the downstream ends of those discussed in Section 2.2, 7P120-3 and 7P113-3.

Other Lines West of the Process Building

The other 24 lines of interest shown in Table F-1 carried process drain fluids, wastewater, and ventilation condensate.

3.2 Estimated Inventory in Lines West of the Process Building

The estimated total inventory of the 31 underground lines west of the Process Building is shown in Table F-7. The total length of all of these lines together is approximately 4,176 feet. The total interior surface area is approximately 3.47E+06 cm^2.

Table F-7. Estimated Total Residual Inventory of Lines West of the Process Building in Curies (as of 2011)

Nuclide	Activity	Nuclide	Activity	Nuclide	Activity
Am-241	8.3E-02	Np-237	1.0E-04	Tc-99	3.4E-02
C-14	4.6E-05	Pu-238	1.3E-01	U-232	7.1E-04
Cm-243	4.4E-05	Pu-239	5.2E-03	U-233	6.9E-04
Cm-244	1.8E-03	Pu-240	2.7E-03	U-234	7.2E-04
Cs-137	8.5E+01	Pu-241	8.6E-02	U-235	1.8E-06
I-129	6.0E-05	Sr-90	8.1E+01	U-238	1.0E-06

4.0 Lines East of the Process Building

4.1 Lines of Interest

Table F-1 identifies 47 lines east of the Process Building. Most deliver low-level radioactive or uncontaminated wastewater, wash water, or liquid from spills from various drains throughout the Process Building to the Interceptor in WMA 2. From the Interceptor, the water can be sampled, diverted to storage tanks, sent to the LLWTF for treatment, or released to the lagoon system through other lines identified in the table. Other lines in WMA 2 connect various tanks with the LLWTF and the LLWTF to the lagoons. From the lagoons, waters can be discharged to surface streams on the Center.

Various underground lines were realigned from Lagoon 1 to Lagoon 2 and from Lagoon 2 to Lagoon 3 in 1984 when Lagoon 1 was removed from service. At that time, Lagoon 2 became the initial receiving lagoon for the LLWTF. Originally, water treatment was performed in the O2 Building, but it was replaced by the LLWTF. The New Interceptors (A and B) were installed in 1967 to replace the single Old Interceptor.

4.2 Estimated Inventory in Lines East of the Process Building

The estimated total inventory of the 47 underground lines east of the Process Building is shown in Table F-8. The total length of all of these lines together is approximately 4,559 feet. The total interior surface area is approximately 3.40 E+06 cm^2.

Table F-8. Estimated Total Residual Inventory of Lines East of the Process Building in Curies (as of 2011)

Nuclide	Activity	Nuclide	Activity	Nuclide	Activity
Am-241	1.3E-02	Np-237	1.5E-06	Tc-99	3.4E-05
C-14	1.6E-05	Pu-238	1.9E-03	U-232	1.9E-06
Cm-243	4.9E-06	Pu-239	3.6E-03	U-233	4.6E-06
Cm-244	9.9E-05	Pu-240	1.9E-03	U-234	3.9E-07
Cs-137	8.5E-02	Pu-241	5.0E-02	U-235	5.6E-07
I-129	7.9E-08	Sr-90	7.9E-02	U-238	4.7E-06

5.0 Leachate Transfer Line

5.1 Description

The Leachate Transfer Line is a buried two-inch polyvinylchloride pipe that originates on the south plateau at the NDA and continues northward across WMA 6 to Lagoon 2 in WMA 2. The line was laid within a five-inch sand layer at the base of a 36-inch wide trench located five feet below the surface.

The line was originally used to transfer fluids originating from the SDA Lagoons to Lagoon 1 in the LLWTF via a pumphouse adjacent to the NDA hardstand. More recently, it has been used to transfer groundwater from the NDA interceptor trench to Lagoon 2. The total length of the line is approximately 2,000 feet. The location of the Leachate Transfer Line is shown on Drawing 40C-S-1057, on which Figure F-2 is based.

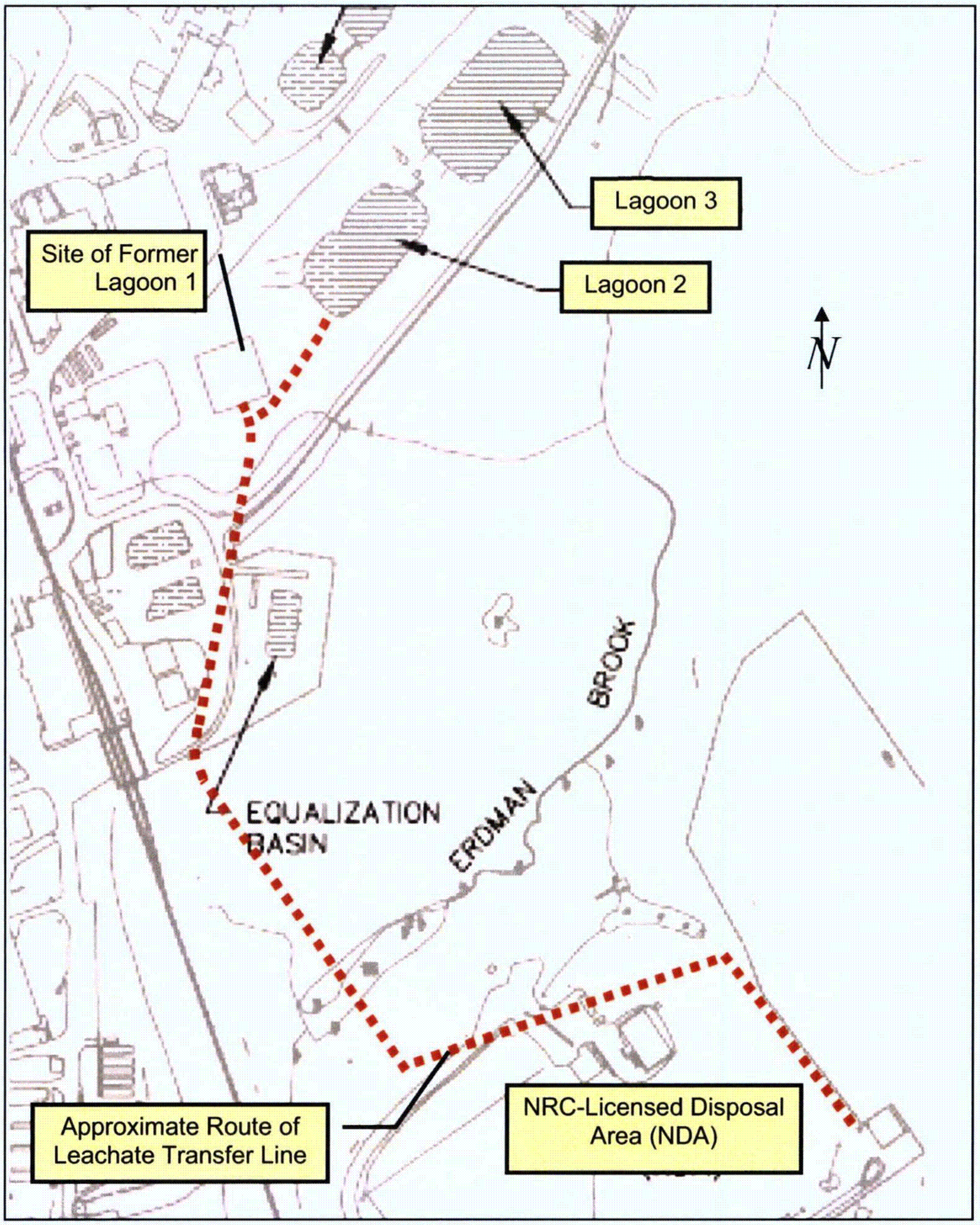


Figure F-2. Leachate Transfer Line Routing From NDA to Lagoon 1 (based on drawing 40C-S-1057)

5.2 Fluids Conveyed by the Line

The use of the Leachate Transfer Line to convey burial trench leachate is described in the RCRA Facility Investigation Report for the NYSERDA-maintained portions of the Center (NYSERDA 1994).

In March 1975 leachate levels in Trenches 4 and 5 of the SDA[1] reached the ground surface and seeped through the earthen covers. NFS began a permitted operation to pump, treat and dispose of leachate[2] from the burial trenches. From 1975 through 1981 NFS pumped over 2,850,000 gals of fluid through the Leachate Transfer Line to Lagoon 1 in WMA 2 for treatment in the LLWTF and eventual discharge to Erdman Brook. Typically, concentrations of radionuclides were in the range of 1 E-03 to 1 E-06 µCi/mL, although in the case of tritium (H-3), concentrations up to ~4 µCi/mL were observed. Before transfer to Lagoon 1 the leachate was chlorinated to destroy biological matter and then treated to reduce water hardness and to precipitate some of the radionuclides. A list of SDA trench-pumping events and volumes is provided in Luckett, et al. 2004. Activity concentrations of radionuclides detected in the leachate are also provided in Luckett, et al. 2004.

The NDA interceptor trench was installed in 1991 on the northeast and northwest boundaries of the NDA to intercept and collect potentially contaminated groundwater migrating from the NDA. The base of the trench extends to a minimum of one foot below the interface of the weathered till with the unweathered till. The trench is drained by a drainpipe that directs accumulated water to a collection sump.

Liquid that collects in the sump is routinely sampled, analyzed, and transferred through the Leachate Transfer Line to Lagoon 2 in WMA 2 for treatment and release. Since its installation, over 3,000,000 gallons of intercepted groundwater have been pumped through the Leachate Transfer Line. Details of fluid volumes pumped through the Leachate Transfer Line from the interceptor trench during the period 1991-2003 are provided in Luckett, et al. 2004.

The NDA interceptor trench is sampled as part of the WVDP environmental monitoring program. Radionuclides detected in samples of the fluid are typically in the range of 1 E-07 to 1 E-10 µCi/mL with two exceptions: Tritium (H-3) is observed in the range of 1 E-05 µCi/mL and uranium, attributed to naturally occurring materials, is observed in the range of 3E-03 µg/mL. A summary of radionuclides detected and their concentrations in the samples of the fluid during the period 1993-2003 are provided in Luckett, et al. 2004

5.3 Estimate of Activity Inventory in Leachate Transfer Line

Based on the design, operating history, and radioactivity analyses of fluids conveyed by the line, residual activity remaining in the line is insignificant to the performance assessment. Among the factors which led to this conclusion:

- The line is made of plastic designed to be non-reactive with water-based fluids.

[1] The term "leachate" is used here as a general term for water that has accumulated in a disposal trench and leached constituents from the materials disposed of in the trench. The use of the term does not imply that the water and the associated leached constituents constitute a regulated "leachate" as defined under RCRA or other regulatory regimes.

- The leachates were dilute fluids, which had been treated with a precipitant; there would have been little material in solution to plate out or deposit in the pipe.
- The leachate had been chlorinated; there would have been little opportunity for flora or scum to grow in the pipe and filter or trap radioactive materials conveyed in the fluids.
- The major activity in the leachate was tritium which passed through the pipe with the fluid.
- Since the leachate was conveyed in the pipe, the pipe has been flushed with over 2,600,000 gallons of groundwater that is essentially free of radionuclides.
- Measured radionuclide concentrations are detectable only with the most sensitive analysis and are well below the regulatory limits for the LLWTF inflow waters of 5.0E-03 μCi/ml.
- The total uranium observed is typical of uranium occurring naturally in groundwater, and is well below the EPA drinking water standard of 30 μg/L (or 3.0 E-02 μg/mL) for uranium, as specified in Title 10 CFR 40, Part 141.55.

6.0 References

Luckett, et al. 2004, *Radioisotope Inventory Report for Underground Lines and Low Level Waste Tanks at the West Valley Demonstration Project*, WSMS-WVNS-04-0001, Revision 0. Luckett, L., J. Fazio, and S. Marschke, Washington Safety Management Solutions, Aiken, South Carolina, July 6, 2004.

NYSERDA 1994, *RCRA Facility Investigation for NYSERDA-Maintained Portions of the Western New York Nuclear Services Center*, NYSERDA, West Valley, New York, December 1994.

APPENDIX G

PHASE 1 FINAL STATUS SURVEY CONCEPTUAL FRAMEWORK

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to describe the conceptual basis for the Phase 1 Final Status Survey Plan.

INFORMATION IN THIS APPENDIX

This appendix describes the design basis for the Phase 1 Final Status Survey Plan, including the key assumptions, and then outlines the final status survey approach. It closes with a discussion of documentation requirements. Logic diagrams are provided to illustrate the processes involved.

RELATIONSHIP TO OTHER PARTS OF THE PLAN

The information in this appendix supplements the requirements for the Phase 1 Final Status Survey Plan described in Section 9.

1.0 Introduction

The purpose of this conceptual framework is to describe the design basis and general approach for the WVDP Phase 1 Final Status Survey Plan, thus augmenting the requirements outlined in Section 9 of this plan.

Section 7.2.2 of this plan provides for Phase 1 final status surveys in three types of areas:

(1) The major areas to be made inaccessible during Phase 1 decommissioning activities, that is, the bottom and sides of excavations for removal of key WVDP facilities and contaminated subsurface soil (i.e., the WMA 1 and WMA 2 large excavations);

(2) Excavated soil laydown areas after the soil and ground covering are removed; and

(3) Potentially impacted areas with no subsurface soil contamination that meet the unrestricted release criteria during Phase 1 of the decommissioning.

The primary objective of these surveys is to confirm that cleanup goals specified in Section 5 of this plan have been achieved. However, if an excavated soil laydown area is known to have subsurface contamination, then the objective of the survey of that area will be to determine the radiological status of the surface soil.

Note that the Characterization Sample and Analysis Plan, rather than the Phase 1 Final Status Survey Plan, will provide for radiological status surveys of:

(1) Soil in the footprints of structures, concrete slabs, asphalt pavement, and gravel pads outside of the WMA 1 and WMA 2 large excavations to be removed during Phase 1 decommissioning activities; and

(2) The interior of the HLW transfer trench following removal of piping and equipment in the trench and the associated pump pits and diversion pit.

If DOE chooses to demonstrate that soil in the footprints of selected structures, concrete slabs, asphalt pavement, or gravel pads outside of the WMA 1 and WMA 2 large excavations removed during Phase 1 decommissioning activities meets the unrestricted release criteria, then Phase 1 final status surveys will also be performed in those areas if the characterization data are not sufficient for final status survey purposes.

2.0 Final Status Survey Design Basis

As required by Section 9 of this plan, the Phase 1 Final Status Survey Plan will be consistent, to the extent possible, with the MARSSIM (NRC 2000). There are aspects of the WVDP project premises (e.g., buried subsurface soil contamination, etc.) that are beyond MARSSIM's scope. In those instances, the protocols will be consistent with the intent of MARSSIM.

2.1 Project Premises and Phase I Activities

As explained in Section 3 of this plan, the project premises comprise 156.4 acres. The major features of the project premises include existing facilities and associated above-ground and buried infrastructure, disposal areas, wastewater lagoons, roads, hardstands, paved parking lots, a railway spur, streams that drain the parcel, and open land. The project premises were used for spent fuel reprocessing in the 1960s and early 1970s. Reprocessing activities resulted in environmental releases of radionuclides to surrounding soils, surface water, and groundwater as discussed in Section 2 of this plan.

To address known historical releases whose residual environmental contamination pose significant dose concerns, Phase 1 activities include the following planned environmental remediation activities:

(1) A deep (30 – 45 feet), extensive (approximately three acre) excavation of contaminated soils adjacent to and beneath the Main Plant Process Building (WMA 1);

(2) A deep (up to 14 feet), extensive (approximately four acre) excavation of contaminated soils adjacent to and beneath facilities and lagoons associated with the Low-Level Waste Treatment Facility (WMA 2); and

(3) Excavation of contaminated and uncontaminated near-surface soils (approximately two feet below grade) associated with selected building and infrastructure removal in WMA 1, WMA 3, WMA 5, WMA 6, WMA 7, WMA 9, and WMA 10.

In addition to these planned excavations, DOE may also choose to remove additional contaminated soils and/or sediments as part of Phase 1 decommissioning work. Any residual contamination within the project premises that still poses a dose concern will be addressed by Phase 2 decommissioning activities.

2.2 Cleanup Criteria

As indicated in Section 5 of this plan, there are 18 radionuclides of interest for the project premises. The DCGL values for each radionuclide are based on a 25 mrem/y dose requirement (incremental to background) assuming a goal of unrestricted release.

The DCGL requirements include a $DCGL_W$ value to be applied as an area-averaged goal to final status survey units and a $DCGL_{EMC}$ value applicable to 1-square meter (m^2) areas. Different DCGL values are provided for surface soils (defined as soils to a depth of 1 m), for subsurface soils (defined as soils at significant depth that will be temporarily exposed by Phase 1 excavation activities in WMA 1 and WMA 2), and for streambed sediments. These DCGL values were further refined to reflect cumulative dose concerns, resulting in a final set of cleanup goals reflected in Table 5-14 of this plan[1].

2.3 Key Assumptions

This conceptual framework includes several key assumptions:

- ***Decommissioning Plan Changes.*** This conceptual framework is based on DCGLs in Revision 2 to the plan. Any changes in DCGL values or definitions may require changes to this framework.
- ***DCGL Definitions.*** The surface soil DCGLs apply to a vertical interval (contamination zone thickness) of one meter. The planned characterization work

[1] Section 5 of this plan explains the difference between the DCGLs developed to correspond to 25 mrem per year for individual areas and the cleanup goals to be used in remediation activities. As in Section 9 of this plan, the term *DCGL* as used in this appendix from this point on is understood to mean *cleanup goal*.

may identify project premises characteristics that are inconsistent with the conceptual site model used for DCGL derivation (e.g., surface contamination restricted to the top few inches of soil surface, subsurface contamination covered by a few inches of clean soil, or contaminated soils extending to a depth greater than one meter). To address this potential issue:

(1) Surface soil DCGL standards will only be applied when contamination impacts are less than one meter in depth;

(2) Surface soil DCGL standards will be applied separately to the top 15 cm (six inches) of soil and to the top one meter soil interval as part of the final status survey process; and

(3) The presence of thin, highly elevated zones overlain by clean surface soils will be evaluated by Characterization Sampling and Analysis Plan data collection. If near surface contaminated layers are encountered during this data collection effort that result in potential dose concerns but that would not have been identified by the Phase 1 Final Status Survey Plan data collection approach, the Final Status Survey Plan process will be modified to meet the specific needs of those areas.

- ***LBGR.*** MARSSIM's Lower Bound on the Grey Region (LBGR) corresponds to the average residual activity concentration that will be present when final status survey data collection activities begin. For areas that do not require remediation, the LBGR is the existing average level of contamination present. For areas requiring remediation, the LBGR is the cleanup level targeted by the remediation program. In combination with the Type II error rate and expected sample variability, the LBGR is an important determinant of the number of systematic samples required to demonstrate compliance with the $DCGL_W$ values.

- ***Data Gaps.*** There are key data gaps that will be addressed as part of the pre-design characterization work discussed in Section 9 of this plan. One example of these is the presence and spatial prevalence of the 18 radionuclides of interest. A second example is the presence and importance of radionuclides other than the 18 identified in this plan. While unlikely, the Final Status Survey Plan framework may need to be revisited if Phase 1 conditions encountered during characterization work are determined to be significantly different from the assumptions and conceptual site model in this plan.

- ***Chemical Contamination.*** Chemical contamination may exist for portions of the facility. Chemical contamination concerns will be addressed in compliance with RCRA requirements, and are not directly within the scope of the Final Status Survey Plan. Samples collected as part of the Final Status Survey Plan process may also be analyzed for chemical constituents as necessary for waste stream characterization needs, and/or to fulfill RCRA requirements.

- ***Scope of Phase 1 Final Status Survey Plan Data Collection.*** As part of Phase 1 decommissioning activities, data will be collected to demonstrate that the floors and the sides (at depths greater than three feet) of the WMA 1 and 2 excavations meet the appropriate DCGL requirements. In addition, DOE may also choose to collect data to demonstrate that surface soils for other portions of the WVDP project premises also meet the Phase 1 cleanup goals for those situations where contamination is not present at depths greater than one meter. Examples of these areas include: (1) soils exposed by hardstand, pad, or foundation removal that are believed to be below DCGL requirements; (2) soils with surface contamination above DCGL goals that DOE chooses to remediate; and/or (3) other soils where there is no evidence of contamination above DCGL requirements. The Final Status Survey Plan framework as described applies to soils and does not apply to sediments, surface water or groundwater.

- ***Sign Test Applicability.*** Because all 18 radionuclides identified in the decommissioning plan are either not naturally occurring or have $DCGL_W$ requirements an order of magnitude or more above background levels, the Sign test is considered appropriate for demonstrating compliance with wide-area DCGL ($DCGL_W$) requirements. In the event that DCGL values are lowered it may be necessary to establish a background reference area and use the Wilcoxon Rank Sum (WRS) test instead to demonstrate compliance with the $DCGL_W$ requirements.
- ***$DCGL_{EMC}$ Applicability.*** The $DCGL_{EMC}$ is radionuclide-specific and applies to 1-m^2 areas. Gross gamma surveys will be used for demonstrating compliance with the $DCGL_{EMC}$ criteria where appropriate. In addition, appropriate $DCGL_{EMC}$ values will be calculated that correspond to the area represented by systematic samples collected to demonstrate $DCGL_W$ compliance using area factors provided in Tables 9-1 and 9-2 of Section 9 of this plan. The latter approach is intended to address the radionuclides of interest that are not detectable by gamma scans and that may exist in isolation for specific portions of the project premises (e.g., the floor of the WMA 1 dig where Sr-90 may be the principal radionuclide of interest).
- ***Radionuclides of Interest List.*** Because processes and contaminant release scenarios vary from location to location across the project premises, not all 18 radionuclides of interest may be pertinent to specific areas. The assumption is that Characterization Sample and Analysis Plan data collection may be used to determine which of the 18 radionuclides of interest are pertinent to specific areas and that final status survey sampling for those areas may be limited to the smaller set of the pertinent radionuclides of interest.
- ***Use of Sum-of-Ratios Calculations***. Because of the many radionuclides of interest, all final status survey determinations will be based on sample sum-of-ratios calculations. The sum-of-ratios calculation for any particular sample will be based on the radionuclides pertinent to the final status survey unit that was the source of the sample.
- ***Subsurface Soil Contamination.*** The Phase 1 Final Status Survey Plan is not applicable to areas outside the WMA 1 and 2 excavations where subsurface contamination exists at depths greater than one meter.
- ***Null Hypothesis and Acceptable Error Rates.*** For the Sign test, the null hypothesis will be that final status survey units are contaminated above $DCGL_W$ levels based on sample sum-of-ratios values. In this context, the acceptable Type I

error rate (i.e., rejecting the null hypothesis when it should have been accepted) will be 0.05. The Type II error rate (i.e., accepting the null hypothesis when it should have been rejected) will be set based on an engineering cost analysis that weighs the potential for false contaminated conclusions with the costs of final status survey data collection. The Type I error rate establishes the minimum number of systematic samples required for Sign test implementation. In the case of an error rate of 0.05, the minimum number is five samples per survey unit; final status survey units, however, will likely require more systematic samples than this minimum number to meet Type II error rate needs.

- ***Role of Composite Sampling.*** While not discussed in MARSSIM, the use of composite samples is one means for attaining desired Type II error rates while controlling analytical costs when performing $DCGL_W$ evaluations. Composite sampling can also significantly increase the likelihood that $DCGL_{EMC}$ exceedances are identified for radionuclides that are not detectable by gross activity scans. Composite sampling combines soil increments systematically distributed across a portion of a final status survey unit into homogenized composite samples before analysis. The minimum number of composites per survey unit is determined by the desired Type I error rate. The minimum number of soil increments contributing to each composite sample is a function of the desired Type II error rate, the degree of heterogeneity expected within survey units, and the expected average residual activity concentration. Composite sampling will be used when appropriate during the final status survey process to improve overall decision-making performance. Sufficient composite samples are collected from each survey unit to satisfy Sign or WRS test requirements. The type of compositing proposed, and its advantages are well documented, have been used effectively within the RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup programs, and have regulatory support (see EPA 1995, EPA 2002a and EPA 2002b).

> NOTE
>
> There currently is insufficient soil characterization information available within the project premises to determine whether the use of composite soil sampling for FSS purposes is appropriate. A decision on whether the use of composite soil sampling for final status survey purposes is appropriate will be made once the soil sampling data collection and interpretation associated with the Characterization Sample and Analysis Plan is completed.

- ***Analytical Methods.*** Some of the radionuclides of interest have relatively low $DCGL_W$ values. The 18 radionuclides span a range of required analytical techniques, including gamma spectroscopy, alpha spectroscopy, liquid scintillation, and gas proportional counting. The Final Status Survey Plan will specify the analytical performance requirements expected for each radionuclide (Table 9-5 of this plan identifies target detection limits). In some cases (e.g., gamma spectroscopy and liquid scintillation), a field-based laboratory may prove advantageous, particularly for those radionuclides that will likely be the primary decision drivers (e.g., Cs-137 and Sr-90). Whether data from field deployable techniques can be used for final status survey compliance demonstration purposes will depend on whether data quality standards can be achieved and documented. There may be cases where a particular field-deployable technique may not have sufficient data quality for final status survey purposes, but where the technique still serves an important and useful role as a screening tool for elevated area concerns, or as part of pre-final status survey/remedial support data collection to determine that an area is ready for final status survey data collection.

- ***Use of Pre-Design Investigation Data for Final Status Survey Purposes.*** The final status survey logic and Final Status Survey Plan were developed in tandem with the Characterization Sample and Analysis Plan for pre-design data collection. The intent is that pre-design data, if collected consistent with Final Status Survey Plan protocols and data quality standards, can potentially be used for final status survey purposes if contamination levels requiring remediation are not identified.

2.4 Role of Pre-Design Data Collection

The Characterization Sample and Analysis Plan will address key data gaps pertinent to decommissioning work. Some of those data gaps are also important from the perspective of designing and implementing the final status survey process for the project premises. These include:

- ***Determining whether the list of the 18 radionuclides of interest as identified by the DP is complete***. An additional 12 radionuclides have been identified as possibly (but unlikely to be) present at the site. In addition, the presence of progeny not in equilibrium with the 18 radionuclides of interest has also been identified as a possible concern. Both issues have the potential for requiring changes to the radionuclides of interest list. The Characterization Sample and Analysis Plan will determine whether this is necessary.
- ***Addressing the prevalence, spatial distribution, and potential collocation of the 18 radionuclides of interest***. There are several potential outcomes from this data collection. If particular radionuclides of interest are either not present to any significant degree or are always dominated from a sum-of-ratios perspective by other radionuclides, the analytical list for systematic samples may be reduced to those that are pertinent. The list of "pertinent" radionuclides of interest might vary with location. Alternatively, if a few readily measurable radionuclides of interest (e.g., Cs-137) are ubiquitous and at relatively stable ratios to other radionuclides of interest, a surrogate approach might be adopted for DCGL analysis.
- ***Determining the presence/absence and prevalence of near-surface subsurface soils (e.g., soils that are at depths just below one meter) that exceed DCGL standards***. The Phase 1 surface soil DCGL requirements are only applicable to areas where contamination is not present below a depth of one meter. The Characterization Sample and Analysis Plan will delineate where near-surface subsurface soil contamination is a concern.

- ***Identifying whether thin layers of buried contamination exist within the top one meter of soils that might pose dose concerns if exposed but would be missed by the Final Status Survey Plan sampling logic.*** The Characterization Sample and Analysis Plan will determine if this is the case, and if so, identify the areas where this will be a concern. If such areas exist, then the Final Status Survey Plan logic will be adjusted to address those concerns.
- ***Supporting layout of final status survey unit areas for the site.*** The MARSSIM defines three different classifications of final status survey units that may potentially be applied to one or more areas of a site. The selection of the appropriate final status survey unit classification for a particular area depends on its expected contamination status relative to the DCGLs. The Characterization Sample and Analysis Plan will provide the data necessary for the correct classification and delineation of MARSSIM final status survey units.
- ***Estimating likely residual radionuclide activity concentrations to be encountered after Phase 1 activities are complete.*** Expected average residual activity concentrations, in conjunction with expected heterogeneity and Type II error requirements, will affect final status survey sample numbers.

3.0 Final Status Survey Approach

Final status survey data collection will take place for soils within the project premises. In the case of soils, if the final status survey data collection conclusions are that DCGL standards have not been attained, DOE may remediate the area and collect additional final status survey data to demonstrate compliance with DCGL requirements.

For the deep excavated surfaces within WMA 1 and WMA 2, additional remediation will take place if subsurface DCGL requirements are not met. For areas outside the WMA 1 and WMA 2 deep excavations, if a final status unit fails the final status survey process, DOE may choose to remediate the affected area until DCGL requirements are met or to postpone remediation until Phase 2.

If DOE chooses to remediate soils exceeding DCGL standards and the original unit was a Class 1 unit, final status survey data collection will be repeated after additional remediation is complete. If the original unit was an unexcavated Class 2 or Class 3 unit, the affected area will be remediated, reclassified as one or more Class 1 units, and final status survey data collection repeated. DOE may defer remediating areas that are not currently identified as requiring excavation by the DP until Phase 2.

3.1 Surface Soils

A complete logged gamma walkover survey of accessible areas within the project premises using an appropriate detector (e.g., Field Instrument for Detecting Low Energy Radiation (FIDLER)) will be performed as part of Characterization Sample and Analysis Plan data collection activities. This walkover survey, in conjunction with biased surface soil sampling and intrusive GeoProbe® data collection, will be used to identify areas likely requiring remediation or impacted at levels approaching soil DCGL levels but not planned for remediation (Class 1 areas), areas impacted but with no evidence of soil DCGL exceedances (Class 2 areas), and areas within the WVDP project premises' boundary that either show no evidence of impacts, or are minimally impacted at very low levels compared to soil DCGL standards (Class 3 areas). Based on data available to date, it is expected that the majority of the project premises will be classified as either Class 1 or Class 2 final status survey units.

As part of Characterization Sample and Analysis Plan data collection, a background reference area will be identified that can be used to assess the background response of the detector used and that can serve as a source of background samples if a WRS test is required to demonstrate $DCGL_W$ compliance. One outcome of reference area gross gamma data collection will be the identification of appropriate field investigation levels to be applied to gross gamma data during routine use of detectors for pre-design characterization, remediation support, and final status survey data collection.

An example of a field investigation level will be a detector response that is not statistically consistent with background readings (e.g., above the 95 percent upper tolerance limit for background data sets). Biased sampling, in conjunction with gamma walkover survey data and associated field investigation levels, will be used during pre-design data collection work in contaminated areas to develop additional field investigation levels that could potentially be used to reliably identify gross activity responses that might be indicative of soil DCGL exceedance concerns.

For areas that are excavated, the final exposed dig face (walls and floors) will be scanned using one or more logged detectors to evaluate the potential presence of either general contamination above soil $DCGL_W$ standards, or very localized contamination potentially associated with soil $DCGL_{EMC}$ concerns. Biased sampling will be used to further evaluate evidence of contamination potentially above soil DCGL standards if encountered by the detector. Detector data will be collected with the goal of complete spatial coverage at a density of one logged measurement per square meter, on average.

Prior to the initiation of final status survey sample collection, the layout of final status survey units will be finalized for surface soils that are considered ready for final status survey data collection. Areas that are candidates for Phase 1 final status survey data collection are areas where there is no evidence or concern about contamination deeper than one meter, and where Characterization Sample and Analysis Plan data indicate that residual contamination levels likely meet surface soil DCGL requirements. Soil Class 1 survey units will not exceed 2,000 m^2 in size. Soil Class 2 survey units will not exceed 10,000 m^2 in size. There is no size constraint for Class 3 survey units.

For each survey unit the pertinent radionuclides of interest subset will be defined based on historical information, Characterization Sample and Analysis Plan sampling results for that area, and remedial support data in the case of excavated area Class 1 units.

In all cases of sample collection and analysis (systematic and biased), the sum-of-ratios values calculated for samples will be used to test compliance with DCGL standards. Sum-of-ratios values will be calculated based on soil $DCGL_{EMC}$ requirements and based on soil $DCGL_W$ requirements. As part of the sum-of-ratios calculation, background will not be subtracted for those radionuclides that occur naturally. The radionuclides of interest subset used for sum-of-ratios calculation purposes may vary from survey unit to survey unit, depending on which radionuclides of interest have been determined to be pertinent to the area of interest.

The primary determinant of soil $DCGL_{EMC}$ compliance for each survey unit will be scanning results combined with associated biased sampling for radionuclides of interest that lend themselves to scanning, and systematic soil samples for radionuclides of interest that are not detectable via scans. All survey units (Class 1, Class 2, and Class 3) will have complete scanning coverage. Scanning data sets will be logged to allow for post-data collection mapping, analysis, presentation, and data preservation. Biased samples collected in response to scan results, or for any other reason, will be compared to 1-m^2 soil $DCGL_{EMC}$ requirements.

If biased soil samples are collected, two samples will be collected and analyzed for each biased sampling location: one that is representative of the top 15 cm of exposed soils, and one that is representative of a 1 m soil depth. Sample results (biased or systematic) that exceed soil $DCGL_{EMC}$ requirements indicate soil conditions requiring further remediation. In addition, appropriate $DCGL_{EMC}$ values will be calculated based on the areas represented by systematic samples collected for $DCGL_W$ purposes using area factors provided by the DP; systematic sample results will also be compared to these additional $DCGL_{EMC}$ values.

The primary determinant of soil $DCGL_W$ compliance will be systematic sample results. Systematic samples will be collected on a random start triangular grid. Systematic samples will be composite samples formed from soil increments distributed across the immediate area the systematic sample represents. Two composite samples will be formed from each grid node, one representative of soils to a depth of 15 cm and one representative of soils to a depth of one meter. The minimum number of systematic soil sample grid locations per survey unit will be five (consistent with achieving a Type I error rate of 0.05). In the case of each composite, sufficient soil mass will be collected to allow analysis for all 18 radionuclides of interest, if necessary.

Figure G-1 contains a decision logic flow diagram for surface soil final status survey units. Sum-of-ratios values for systematic sample results will first be calculated based on soil $DCGL_{EMC}$ requirements. There are two applicable $DCGL_{EMC}$ values of interest. The first is the 1-m^2 $DCGL_{EMC}$ value explicitly defined in this plan. This standard will be applied to biased soil sample results. The second is a $DCGL_{EMC}$ value determined from the $DCGL_W$ using area factors (provided in Section 9 of the plan) that are appropriate for the area the systematic sample represents. This approach will be applied to systematic soil sample results.

If there are no soil $DCGL_{EMC}$ concerns, sum-of-ratios values corresponding to soil $DCGL_W$ requirements will be calculated. Samples results representing depths of 15 cm will be evaluated separately from sample results representing a depth of one meter. In each case, if the average of the results is less than unity, the Sign test will be applied assuming a Type I error rate of 0.05. If the null hypothesis is rejected for both depth intervals, the unit will be considered compliant with all relevant soil DCGL standards.

3.2 Subsurface Soils

In the case of the final exposed soil surface for the WMA 1 and 2 deep excavations, the general final status survey process will mirror what has already been described in Section 3.1 utilizing the appropriate subsurface DCGL standards. (One exception is that the sample interval for subsurface soil will be 0-1 m; no 0-15 cm samples are required for subsurface soil.)

The primary differences in the case of WMA 1 are the foundation pilings that will remain in place after excavation is complete. There are some 476 pilings and there are concerns that they may have provided vertical preferential flow pathways for contaminated groundwater into the Lavery Till, resulting in soil contamination at levels of potential concern within the till. This issue will be addressed both by remedial support data collection described in the Characterization Sample and Analysis Plan, and by data collection as part of the final status survey process for final status survey units that include foundation pilings.

If foundation piles did serve as preferential pathways for contamination entry into the Lavery Till, the following conditions would be expected:

- Contamination would have occurred between the piling and surrounding soil,
- Contamination that penetrated into the till would have left evidence at the till/sand and gravel unit interface (i.e., soil contamination at that interface), and
- The possibility for till contamination to occur would have been greatest where groundwater contamination was the greatest – beneath the original release point and immediately down gradient.

Based on these assumptions, the final status survey process for demonstrating that there is no significant till contamination concerns associated with pilings would have the following components:

- Excavation work will identify the exact locations of pilings and remedial action support surveys will determine where contaminated soil at levels of concern existed immediately above the Lavery Till.
- Pilings will be considered in two groups: pilings that fell within the greater-than-DCGL footprint of contaminated soils immediately above the Lavery till, and pilings that did not – final status survey data collection will target those pilings falling within the greater-than-DCGL footprint.
- In this set of pilings, sampling will be a combination of biased and systematic data collection:
  - Ten piling locations will be selected for biased sampling to look for $DCGL_{EMC}$ exceedances. This selection will target those pilings most likely to exhibit till contamination, if it existed. The selection will be based on a combination of factors, including proximity to the original release event, level of soil contamination as identified by remedial support sampling immediately above the till, visual evidence of "spaces" between the till and pilings that might have provided preferential flow pathways, etc.
  - A minimum of eight of the pilings in the footprint will be selected for each final status survey unit, at random, for $DCGL_W$ sampling. In the event that this random

selection process identifies a piling already selected for biased sampling, the sample collected from that piling will be used for both $DCGL_{EMC}$ and $DCGL_W$ compliance demonstration purposes.

For those pilings selected for sampling (either biased or systematic) sampling focus on obtaining a soil sample from immediately along the piling at a depth of one meter below the excavation surface.

If any individual soil sample identifies contamination above $DCGL_{EMC}$ requirements, additional excavation will occur to identify the extent of contamination and remove it. Additional samples will be collected from the final exposed dig face to demonstrate that no further $DCGL_{EMC}$ exceedances exist.

For each final status survey unit that includes pilings falling within the greater-than-DCGL overburden footprint, the systematic sample results from pilings will be evaluated using the Sign test. If the pilings satisfy the Sign test and there are no biased piling samples with $DCGL_{EMC}$ exceedances, till contamination associated with pilings will not be considered an issue. If fewer than five systematic piling samples are available, rather than the Sign test all systematic piling samples will be compared to the $DCGL_W$ requirement. If none are above the $DCGL_W$ values, then till contamination associated with pilings will not be considered an issue.

Figure G-2 shows the decision flow logic for final status survey data collection from the deep excavations in WMA 1 and WMA 2 floors.

3.2 Sediments

NOTE
The initial issue of the Phase 1 Final Status Survey Plan will not provide for Phase 1 final status surveys of Erdman Brook and Franks Creek. If it is later determined that such surveys will be performed during Phase 1 of the decommissioning, the Phase 1 Final Status Survey Plan will be revised to address these surveys following the protocols described below.

For the purposes of this conceptual framework, sediments are defined as soil or sediment-like materials associated with the bed and banks of Erdman Brook and Franks Creek within the project premises.

Historical data have demonstrated that stream sediments in Erdman Brook and Franks Creek contained within the WVDP fence line are impacted by Phase 1 radionuclides. The Characterization Sample and Analysis Plan pre-design data collection will include stream sediment and stream bank sampling to determine if remediation may be required for portions of the stream within the WVDP fence line. Currently there is no remediation planned for sediments as part of the Phase 1 decommissioning activities. Because of the integrating nature of project premises drainage features, final status survey data collection for stream features will likely be one of the final activities to avoid the possibility of re-contamination occurring post-final status survey data collection due to soil erosion and deposition within drainage features.

However, to support overall final status survey planning, the delineation of final status survey unit areas for stream and drainage features within the WVDP fence line will occur as part of Phase 1 activities. All stream features will be classified as Class 1 areas. Consistent with the sediment DCGL derivation contained in the decommissioning plan, the definition of a stream final status survey unit includes sediments within the streambed itself and three m of bank on either side of the streambed. Each unit will be at most 333 m long, comprising an area of at most 2,000 m^2. Subsurface contamination deeper than the 1-m definition of sediments is not considered a plausible scenario for a stream setting; consequently final status survey data collection will focus on surface sediments and adjacent bank soils. This assumption will be tested by Characterization Sample and Analysis Plan data collection.

The decision logic for sediment survey units is identical to surface soils (Figure G-1). As with surface soils across the site, a complete gamma walkover of exposed sediments and associated banks will be performed using an appropriate detector. Biased samples will be collected to clarify scan results that might be indicative of DCGL excedances. For locations where biased samples are collected, two samples will be collected, one representative of a depth of 15 cm, and one representative of a depth of 1 m.

Biased samples collected in response to scan results or for any other reason from within sediment final status survey units will be compared to sediment 1-m^2 $DCGL_{EMC}$ requirements. In addition, appropriate $DCGL_{EMC}$ values will be calculated based on the areas represented by systematic samples collected for $DCGL_W$ purposes using area factors provided in Section 9 of this plan; systematic sample results will also be compared to these additional $DCGL_{EMC}$ values. Sample results (biased or systematic) that exceed sediment $DCGL_{EMC}$ requirements indicate conditions requiring remediation.

Sediment $DCGL_W$ compliance will be demonstrated through the use of systematic sediment samples. A minimum of five systematic composite samples will be collected and submitted for laboratory analysis. For each location where a composite sample is obtained, two samples will be formed, one representative of a depth of 15 cm and one representative of a depth of 1 m. The radionuclides of interest subset for the analyses will be determined based on historical data and Characterization Sample and Analysis Plan data collection results.

The systematic sediment sample locations will conform to a linear grid down the length of the survey unit with a fixed grid node separation distance but random start. At each grid node, the sample collected will be formed from three increments, one from the stream centerline, and two collected from randomly selected distances up the bank from the bank's edge. In the case of each composite, sufficient soil/sediment mass will be collected to allow analysis for all 18 radionuclides of interest, if necessary.

Systematic sediment samples will be submitted for analysis based on the radionuclides of interest subset pertinent to that final status survey unit. Sum-of-ratios values for systematic sample results will first be calculated based on sediment $DCGL_W$ requirements corrected by appropriate area factors contained in Section 9 of this plan and evaluated for $DCGL_{EMC}$ exceedances. If there are no sediment $DCGL_{EMC}$ exceedances, sum-of-ratios values corresponding to sediment $DCGL_W$ requirements will be calculated. If the average of these is less than unity, the Sign test will be applied assuming a Type I error rate of 0.05.

This will be done for both depth intervals. If the null hypothesis is rejected in both cases, the unit will be considered compliant with all relevant soil DCGL standards.

In the event that the radionuclides of interest subset does not include all 18 radionuclides, one composite sample per survey unit will be formed by sub-sampling all individual systematic composite samples (after homogenization) representative of a depth of one meter from a survey unit and submitted for a complete analysis of all 18 radionuclides. If the resulting sediment $DCGL_W$ sum-of-ratios value exceeds unity, then the unit will require additional remediation. If the sum-of-ratios value is significantly influenced by radionuclides that were originally not considered pertinent to that final status survey unit, the remaining composite soil mass for each radionuclide will be analyzed for the balance of the 18 radionuclides not already analyzed, $DCGL_W$ sum-of-ratios values recalculated, and compliance with $DCGL_W$ standards re-evaluated.

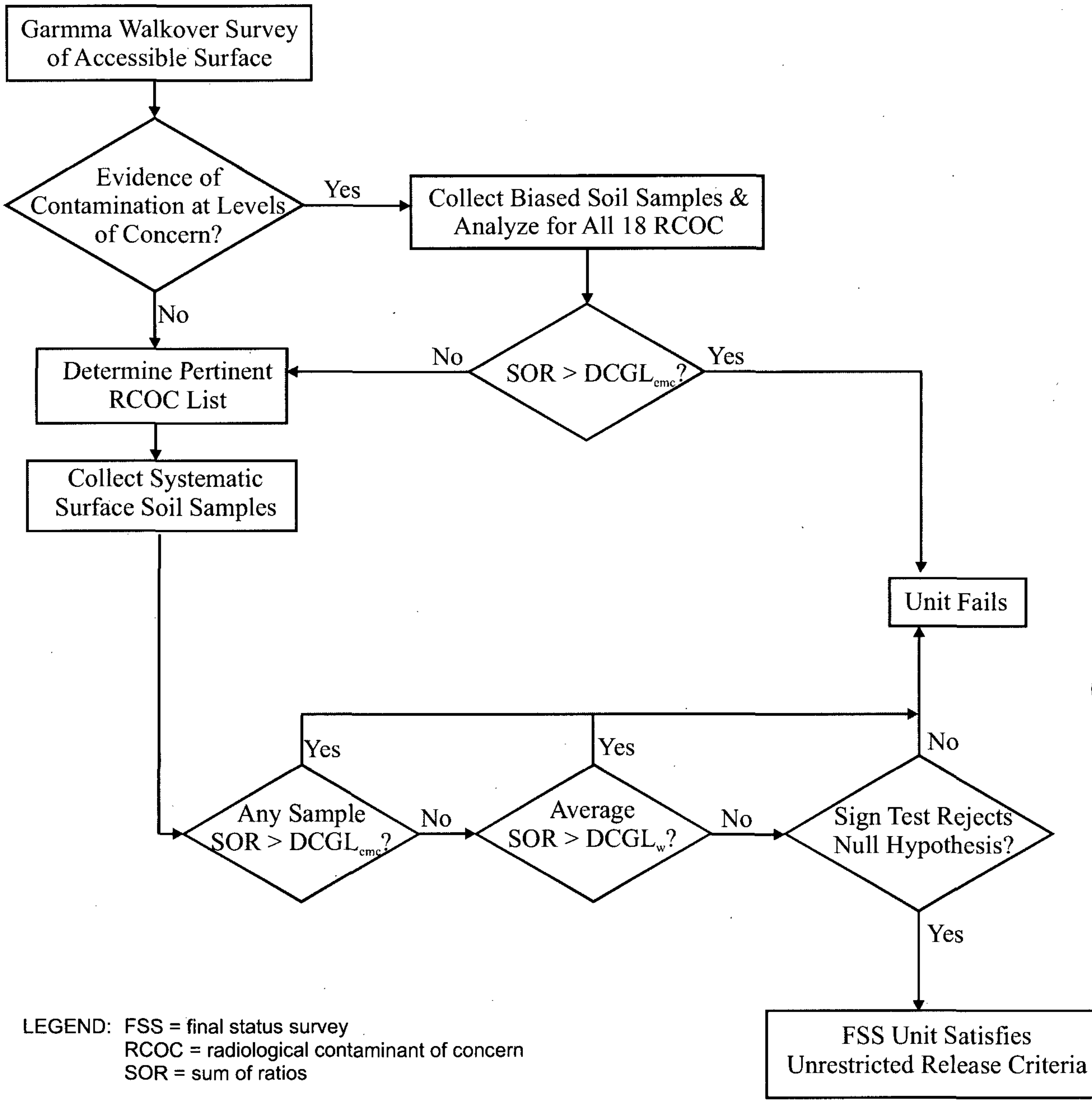
4.0 Documentation Requirements

Due to the complexity and time span of the Phase 1 decommissioning activities, it is expected that multiple Final Status Survey Reports will be prepared in accordance with Section 9.8 of this plan. Such reports, for example, may address a group of related survey units, such as those associated with the WMA 1 excavation, or a particular excavated soil laydown area. The use of multiple Final Status Survey Reports will facilitate independent confirmatory surveys and support periodic progress reports to interested stakeholders as the Phase 1 decommissioning activities take place.

Technical data packages will be prepared for individual survey units. Each Final Status Survey Report together with the related technical data packages will contain the information specified in Section 9.8 of this plan, including:

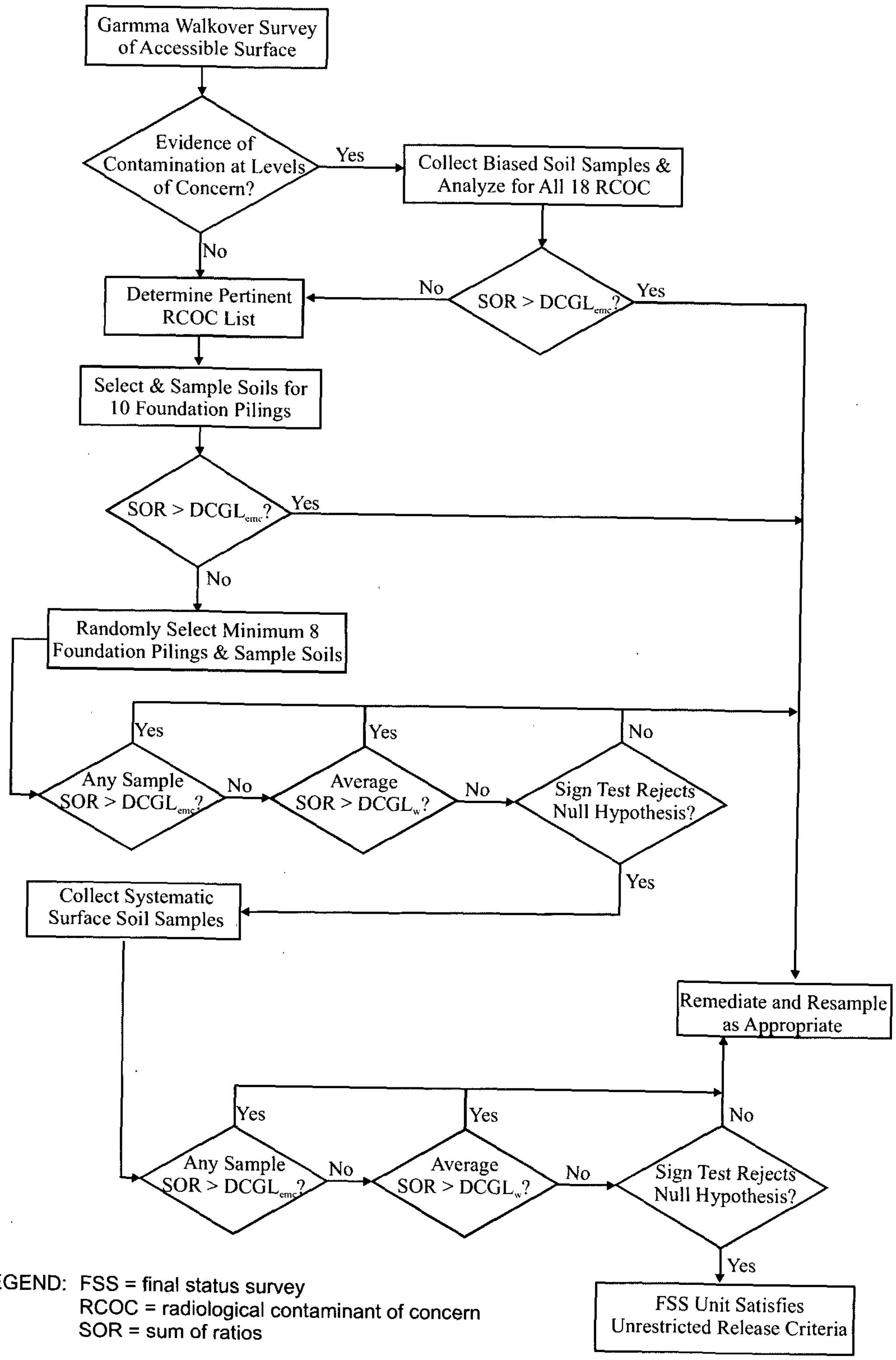
- An overview of the final status survey results;
- A description of the final status survey units comprising the area being evaluated, including any changes from what had been originally planned;
- A summary of the pertinent radionuclides of interest subset and the appropriate $DCGL_W$ and $DCGL_{EMC}$ standards;
- A description of the basis for sample numbers and the analyses used to support sample number determinations for each survey unit;
- A presentation of the gamma scan data for each survey unit, including a map showing the extent of coverage and discussion of the scan data;
- A presentation of the data collected for each survey unit, including a map or drawing of the survey units illustrating the random start systematic sample locations and the location of other samples (i.e., judgmental, biased, and miscellaneous sample data sets which will be reported separately from those samples collected for performing the statistical evaluation);
- A review of quality control parameters associated with data sets;
- A statistical analysis of the data sets with respect to the $DCGL_W$ values in the context of MARSSIM final status survey guidance;

- An evaluation of survey and sampling data to address $DCGL_{EMC}$ standards;
- A conclusion about whether $DCGL_W$ and $DCGL_{EMC}$ requirements have been met;
- A description of how ALARA practices were employed to achieve final activity levels; and
- If a unit fails to meet DCGL requirements, the reason for the failure, the implications for other final status survey units, the actions taken to correct the failure, and/or the implications for Phase II activities



LEGEND: FSS = final status survey
RCOC = radiological contaminant of concern
SOR = sum of ratios

Figure G-1. Decision Logic for Surface Soil and Sediment Survey Units



LEGEND: FSS = final status survey
RCOC = radiological contaminant of concern
SOR = sum of ratios

Figure G-2. Decision Logic for WMA 1 and WMA 2 Subsurface Soils