Department of Energy
West Valley Demonstration Project
10282 Rock Springs Road
West Valley, NY 14171-9799

September 16, 2009

Dr. Keith I. McConnell, Deputy Director
Decommissioning and Uranium Recovery Licensing Directorate
Division of Waste Management and Environmental Protection
Office of Federal and State Materials and Environmental Management Programs
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: Submission of Additional U.S. Department of Energy Responses to Requests for Additional Information for the Phase 1 Decommissioning Plan for the West Valley Demonstration Project from U.S. Nuclear Regulatory Commission Review

REFERENCES:

1) Letter (10087), K. I. McConnell to B. C. Bower, "Requests for Additional Information on Phase 1 Decommissioning Plan for the West Valley Demonstration Project," dated May 15, 2009

2) Letter MNM:100583 - 450.4, B. C. Bower to K. I. McConnell, "Submission of Revision 1 to the Phase 1 Decommissioning Plan (DP) for the West Valley Demonstration Project for U.S. Nuclear Regulatory Commission Review," dated March 16, 2009

3) Letter MNM:101194 - 450.4, B. C. Bower to K. I. McConnell, "Submission of U.S. Department of Energy (DOE) Responses to Requests for Additional Information (RAIs) for the Phase 1 Decommissioning Plan for the West Valley Demonstration Project for U.S. Nuclear Regulatory Commission Review," dated August 13, 2009

4) Letter (100126), C. V. Anderson to K. I. McConnell, "Submission of the Phase 1 Decommissioning Plan (DP) for West Valley Demonstration Project (WVDP) for U.S. Nuclear Regulatory Commission (NRC) Review," dated December 3, 2008

Dear Dr. McConnell:

This letter transmits the DOE responses to 6 of the 44 NRC RAIs resulting from the NRC technical review of the Phase 1 DP for the West Valley Demonstration Project, Rev. 1 (Reference 1). DOE submitted responses to the other 38 of the 44 RAIs to NRC on August 13, 2009 (Reference 3).

Enclosed are 20 paper copies of the RAI response package along with 20 compact disks. Each compact disk contains an electronic copy of the six RAI responses and two calculation

For Further Information

Please note that DOE's RAI responses and the proposed decommissioning approach are based on the preferred alternative in the Revised Draft Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center, which is referred to as the Decommissioning EIS. If changes to that document occur during the course of the National Environmental Policy Act process that affect the Phase I DP for the WVDP, such as changes to the preferred alternative, or if a different approach is selected in the Record of Decision, the DP will be revised as necessary to reflect the changes.

Please let DOE know if the NRC needs any additional references or other information for its review of the DOE responses to the RAIs. Please refer any questions about this submittal to Moira Maloney of my staff at (716) 942-4255.

Sincerely,

Bryan C. Bower, Director
West Valley Demonstration Project

Enclosures: DOE Responses to RAIs (20 copies) + 20 CDs

cc: C. P. Murnane, DOE-HQ, EM-3.3, FORS, w/enc.
M. J. Letourneau, DOE-HQ, EM-11, CLOV, w/enc.
T. K. Smith, DOE-HQ, EM-3.3, FORS, w/o enc.
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L. Camper, NRC, w/o enc.
C. Glenn, NRC, w/o enc.
R. Tadesse, NRC, w/o enc.
P. J. Bembia, NYSERDA, AC-NYS, w/enc. (6 copies)

MNM:101325 - 450.4

RESPONSES TO THE U.S. NUCLEAR REGULATORY COMMISSION REQUEST FOR ADDITIONAL INFORMATION ON THE WEST VALLEY DEMONSTRATION PROJECT PHASE 1 DECOMMISSIONING PLAN

GROUP 2 RESPONSES

September 15, 2009

Prepared by Washington Safety Management Solutions and
Science Applications International Corporation

for the

U.S. Department of Energy

West Valley, New York

As is the Decommissioning Plan itself, these responses are based on the assumption that the preferred alternative in the Revised Draft Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center (the Decommissioning EIS) will be selected in the Record of Decision. If changes to the Decommissioning EIS occur during the course of the National Environmental Policy Act process that affect the Decommissioning Plan, such as changes to the preferred alternative, or if a different approach is selected in the Record of Decision, the Decommissioning Plan and these responses would need to be revised or replaced in their entirety to reflect the changes.

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*These responses will be revised and resubmitted after completion of additional modeling. The calculation package for release of radioactivity from the bottom of the deep excavations related to RAI 5C9 will also be provided with that submittal.

Acronyms and Abbreviations

ALARA	as low as reasonably achievable
CFR	Code of Federal Regulations
DCGL	derived concentration guideline level
$DCGL_W$	derived concentration guideline level, wide
DOE	U.S. Department of Energy
DP	decommissioning plan
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
K_d	distribution coefficient
LTR	License Termination Rule
NDA	NRC-Licensed Disposal Area
NRC	Nuclear Regulatory Commission
RAI	request for additional information
RESRAD	Residual radioactivity [computer code]
SDA	State-Licensed Disposal Area
WMA	waste management area
WVDP	West Valley Demonstration Project

Units

cm	centimeter
cm^3	centimeter cubed
g	gram [mass]
kg	kilogram
L	liter
m	meter
millirem	0.001 Roentgen equivalent man
mL	milliliter
mrem	millirem
μCi	0.000001 curie
μL	0.000001 liter
pCi	10^{-12} curie
R	Roentgen
s	second
y	year

INTRODUCTION

The U.S. Department of Energy (DOE) submitted Revision 0 of the West Valley Demonstration Project (WVDP) Phase 1 Decommissioning Plan to the U.S. Nuclear Regulatory Commission (NRC) for review on December 3, 2008. DOE subsequently submitted Revision 1 of this plan to NRC for review on March 16, 2009. Revision 1 provided additional subsurface soil and groundwater characterization data and the results of additional groundwater modeling, along with several other minor changes.

NRC submitted the Request for Additional Information (RAI) on May 15, 2009 in a letter to Bryan Bower, the Director of the WVDP. This request consisted of 44 separate RAIs on various aspects of the Decommissioning Plan, including dose modeling.

NRC review of the Decommissioning Plan is being performed consistent with the provisions of Public Law 96-368, the WVDP Act of 1980, which provides authority for NRC to consult with DOE informally on matters related to the project. Consistent with the Act, and with a 1981 Memorandum of Understanding between DOE and NRC pertaining to the project, DOE has considered the NRC RAIs and is providing written responses to NRC.

DOE is responding to these RAI in two parts. Responses to the first group of 38 RAIs were provided on August 14, 2009. Responses to the remaining six RAIs are provided herein.

As discussed at the DOE-NRC meeting held on September 2, 2009, changes to the subsurface soil cleanup goals are necessary to account for diffusion of residual radioactivity from the bottom of the deep excavations. These changes will involve revising the responses to RAI 5C9 and RAI 5C15; these revised responses will be provided later after all analyses have been completed.

The responses are provided in the following format:

NRC RAI number: The NRC RAI number is specified

Subject: DOE has added a brief statement of the RAI subject, for clarity.

RAI: A complete copy of the NRC RAI is provided.

Basis: A complete copy of the NRC basis for the RAI is provided.

NRC path forward: A complete copy of the NRC path forward is provided.

DOE response: The DOE response provides requested information and answers NRC questions.

Changes to the plan: Changes to be made are specifically identified with red text and change bars. (The two completely new appendices are not so marked, although they will be in Revision 2.)

References: References are included where appropriate.

The following calculation packages and the associated electronic files are being provided with this submittal to enable NRC staff to replicate the modeling:

- Well dilution and hydraulic gradient changes due to hydraulic barriers (RAI 5C3)
- Impacts of eroded source material to offsite receptor (surface soil and subsurface soil) (RAIs 5C4 and 5C6);

- Lagoon area erosion/recreationist-hiker scenario (revision to a previously submitted calculation package to provide additional information) (RAI 5C6);
- Contamination zone thickness/area sensitivity analysis (RAI 5C10);
- Revised deterministic DCGL calculations (RAI 5C12);
- Probabilistic uncertainty analysis (RAI 5C15);
- Gamma shielding factor calculations (RAI 5C17); and
- Residential gardener analyses (surface soil and subsurface soil models) (RAI 5C18).

Because additional modeling of releases from bottoms of deep excavations has not been completed, the calculation package(s) related to this modeling, which is associated with the response to RAI 5C9, will be submitted to NRC later.

As indicated on the cover sheet, if changes to the Decommissioning EIS occur during the course of the National Environmental Policy Act process that affect the Decommissioning Plan, such as changes to the preferred alternative, or if a different approach is selected in the Record of Decision, the Decommissioning Plan and these responses would need to be revised or replaced in their entirety to reflect the changes.

RAI 5C1 (6)

Subject: Preservation of Decommissioning Options

RAI: DOE should indicate how its Phase 1 activities preserve all decommissioning options when a final decision is made on decommissioning the site. (Section 5.3, Page 5-43)

Basis: DOE relies on a limited site-wide dose assessment to show that the cumulative dose from multiple sources will meet unrestricted release criteria. The limited site-wide dose assessment considers the situation where a receptor is able to get exposed from multiple media (e.g., surface, subsurface, and streambed contamination) due to the receptor's ability to move from a farm on the North Plateau to contaminated stream beds where one might be exposed from recreational activities. However, the limited site-wide dose assessment does not address the possibility that a receptor may be exposed from multiple sources at a single location. For example, a receptor may potentially be exposed at a receptor location outside the immediate footprint of Waste Management Area (WMA) 1 and 2, where the exposure to a resident farmer from WMA 1 and 2 sources is currently being evaluated in deriving subsurface soil DCGLs. At other downgradient locations on the North Plateau, the receptor will likely be exposed to multiple sources. The most obvious point of exposure from multiple sources would be in groundwater and surface water locations downgradient from North and South Plateau source areas where contaminants will ultimately seep or discharge. The combined dose assessment would then consider both the cumulative impacts of multiple receptor locations and the cumulative impacts of multiple source areas at a single receptor location in deriving DCGLs for a single source area.

Path Forward: DOE should provide information to demonstrate its understanding of how contaminants are released from source areas and are transported in the environment to downgradient exposure locations over the 1000 year compliance period. Using its current approach, DOE could calculate DCGLs for individual source areas that consider the cumulative impacts of multiple sources at downgradient receptor locations (e.g., attribute a portion of the dose standard at the downgradient receptor location to individual source areas) or demonstrate how DCGLs calculated at the source would bound the DCGLs calculated considering potential impacts at downgradient receptor locations using the aforementioned approach.

DOE could show how the current approach is adequate or bounding by providing quantitative evidence that: (i) Phase 1 source areas do not overlap in space and time with other sources of contamination; or (ii) their dose contributions are expected to be so small relative to the unrestricted dose standard, that it would not be practical to pursue additional clean-up of Phase 1 sources to ensure that unrestricted release is preserved as a decommissioning option at the end of Phase 2.

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DOE Response: DOE has evaluated this matter in light of the original modeling described in Revision 0 and Revision 1 to the DP and the additional modeling performed in connection with the responses to other RAIs. These evaluations have led to the conclusion that dose contributions from the Phase 1 source areas under current plans will be so small compared to the unrestricted dose standard that it would not be consistent with ALARA principles to provide for additional remediation of these sources, and it would not be necessary to support the site-wide removal alternative if that approach were to be selected for Phase 2 of the decommissioning.

Release and Transport of Contaminants to Downgradient Locations

Long-term unmitigated erosion could transport low levels of residual radioactivity from areas remediated in Phase 1 of the decommissioning into Erdman Brook and the portion of Franks Creek on the project premises. Diluted amounts of this radioactivity could move downstream to locations where dose impacts to offsite receptors could occur. Among the alternative exposure scenarios that have been evaluated to help ensure that the Phase 1 cleanup goals bound potential future doses are the impacts of unmitigated long-term erosion of surface soil and subsurface soil on the north plateau on offsite receptors.

The response to RAI 5C4 shows that the surface soil DCGLs bound the impact on an offsite receptor from radioactivity in eroded surface soil that could reach the streams on the project premises. Likewise, the response to RAI 5C6 shows that the subsurface soil DCGLs in Revision 1 to the DP bound the impacts of deep gully erosion in the area of lagoons 1, 2, and 3 to an offsite receptor.

Information provided in the responses to RAI 5C4 and 5C6 demonstrates a clear understanding of how contaminants can be released from source areas and transported in the environment to downgradient exposure locations over the 1000 year compliance period.

For WMA 1, WEPP erosion estimates were used consistent with the EIS that predicted that approximately 0.4 m of soil would be eroded over a 1000 year period due to normal sheet and rill erosion. As discussed in the response to RAI 5C4, the resulting surface soil DCGLs for an offsite receptor as a result of this erosion were more than 3 orders of magnitude higher than the DCGLs developed for the base case resident farmer scenario for all of the radionuclides of interest.

For WMA 2, peak CHILD model erosion predictions were used to examine a scenario whereby Lagoons 1 and 3 were overtaken by gullies. This would likely occur at some point during the 1000 year compliance period without any attempt to arrest erosion along Erdman Brook. As discussed in the response to RAI 5C6, the resulting subsurface soil DCGLs for an offsite receptor as a result of this erosion were more than an order of magnitude higher than the DCGLs developed for the base case resident farmer scenario for all of the radionuclides of interest.

Exposures from Multiple Sources at a Single Location

The DP did not evaluate exposures to a potential receptor located at a single location from multiple source areas. However, the Phase 1 removal actions are expected to result in lower potential doses to offsite and onsite receptors based on the results of the long-term performance assessment presented in the Decommissioning EIS (DOE 2008).

This long-term performance assessment evaluated potential exposures to both offsite and onsite receptors from multiple source areas within the project premises for the site-wide close-in-place and no action alternatives. These evaluations considered both indefinite continuation of institutional controls and the loss of institutional controls for both alternatives. The receptors and the locations evaluated included a resident farmer located on Cattaraugus Creek, on Buttermilk Creek, and on the north plateau. The performance assessment evaluated contributions to these receptors from the following source areas: Process Building, Vitrification Facility, Low-level Waste Treatment Facility, Waste Tank Farm, NDA, SDA, north plateau groundwater plume, and the cesium prong.

For the site-wide close-in-place alternative, the largest contributors of the estimated peak total effective dose to the receptors on Cattaraugus Creek and Buttermilk Creek were the SDA, followed by the north plateau groundwater plume, NDA, and the Process Building. The largest contributors to the estimated peak total effective dose to the resident farmer using contaminated groundwater on the north plateau for the site-wide close-in-place alternative was the north plateau groundwater plume (846 mrem/y) followed by the waste tank farm (556 mrem/y), Process Building (366 mrem/y) and the Low-level Waste Treatment Facility (110 mrem/y). Since the Phase 1 decommissioning actions will remove approximately 8,000 curies from the Process Building, 1,900 curies from the Vitrification Facility, 700 curies from WMA 2, and a significant portion of the 100 curies from the north plateau groundwater plume, the Waste Tank Farm, SDA, and NDA will continue to be the largest dose contributors to potential offsite and on-site receptors after Phase 1 decommissioning activities have been completed.

Site-Wide Removal Alternative

The Phase 2 site-wide removal alternative would include the removal of the Waste Tank Farm, NDA, the non-source area of the north plateau groundwater plume, and other facilities remaining after the completion of Phase 1. The removal actions would be designed to meet the 25 mrem/y unrestricted release criteria in 10 CFR 20.1402. Dose modeling would be performed prior to decommissioning to develop DCGLs that would support the Phase 2 site-wide removal actions. Surface soil and streambed sediment exceeding DCGLs would also be removed and disposed of offsite. The development of the Phase 2 DCGLs would also consider the impact of the dose contributions from the WMA 1 and WMA 2 excavations that were remediated during Phase 1. However, the dose contributions from these Phase 1 areas will be so small compared to the unrestricted release criteria that their dose contribution will not preclude a site-wide removal alternative that meets the unrestricted release criteria in 10 CFR 20.1402.[1]

The hydraulic barriers to be installed during Phase 1 of the decommissioning would not be necessary in the case of the site-wide removal alternative. They would be removed to restore the natural groundwater flow conditions and to alleviate the necessity for long-term maintenance of the barrier walls and French drain.

Consequently, the hydraulic barriers would have no impact on DCGLs if the site-wide removal alternative were to be selected for Phase 2 of the decommissioning.

Site-Wide Close-in-Place Alternative

The Phase 2 site-wide close-in-place alternative for the WVDP may include the in-place closure of the Waste Tank Farm, NDA, the non-source area of the north plateau groundwater plume, and other facilities remaining after completion of Phase 1. The in-place closure of the Waste Tank Farm and the NDA may include the installation of engineered multi-layer covers of natural and synthetic materials to limit infiltration of precipitation and subsurface hydraulic barrier walls to limit infiltration of groundwater into the closed facilities. The non-source area of the north plateau groundwater plume may be allowed to decay in-place as part of this alternative.

The Phase 1 removal of WMA 1 and WMA 2 facilities will not preclude selection of the Phase 2 site-wide close-in-place alternative as the Phase 1 decommissioning actions will remove approximately 8,000 curies from the Process Building, 1,900 curies from the Vitrification Facility, 700 curies from WMA 2, and a significant portion of the 100 curies from the north plateau groundwater plume. This inventory removal will result in an overall reduction of the potential doses to offsite and onsite receptors that were calculated in long-term performance assessment for the site-wide closure alternative in the Decommissioning EIS (DOE 2008).

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[1] Plans for revising the subsurface soil cleanup goals to ensure that this conclusion is valid are described in the response to RAI 5C9.

Releases of Key Radionuclides from the Bottom of the Deep Excavations

The response to RAI 5C3 describes the results of STOMP and other groundwater modeling performed to evaluate the potential impacts of the Phase 1 hydraulic barriers on flow fields and the impacts of the resulting flow field changes on the DCGLs. The impact of changes in the flow fields on the DCGLs were determined to be insignificant.

The response to RAI 5C9 presents an approach for adjustment of DCGLs for the subsurface soil scenario. Modeling of the groundwater flow system using the STOMP model will be used in combination with an FEIS release and dose model to establish dose-to-source ratios for the drinking water pathway. Dose to source ratios for the standard garden pathways will be established using the RESRAD model. Results of the two elements will be combined to derive adjusted DCGLs for the subsurface soil source.

Changes to the Plan: Appropriate changes to the plan are described in the responses to RAI 5C4, 5C6, and 5C9.

RAI 5C3 (8)

Subject: Flow field impact on DCGLs

RAI: The impact on the flow field of construction of permanent hydraulic barriers as part of Phase 1 activities should be considered in deriving DCGLs. (Section 5.2.1, Page 5-23 and 5-27)

Basis: The results of the flow and transport modeling in Appendix D indicate that the hydraulic barriers will have a significant impact on the flow field (i.e., reduced natural flow downgradient of the barriers and diverted flow upgradient of the barriers); however, consideration of the presence of these hydraulic barriers was neglected when calculating the surface and subsurface DCGLs (see page 5-23 and 5-27).

Because the impact of the hydraulic barriers on the flow field was not considered, it is not clear that RESRAD calculations are consistent with the amount of clean water that may actually be pumped from the aquifer. Additionally, DOE did not consider how contaminated water from other source areas might be drawn to a well at the given pumping rates and assuming the presence of the hydraulic barriers (e.g., extraction of contaminated groundwater from other source areas or contamination from the bottom of the excavation in the Lavery Till). Application of the RESRAD conceptual model for surficially deposited materials without consideration of actual site conditions (e.g., flow field and multiple sources of contamination) could lead to a significant under-prediction of the risk from groundwater dependent pathways if greater dilution in clean water is assumed then what could actually be supported in the real system.

Path Forward: As indicated on page 5-41 of the DP, DOE should evaluate the impact of changes to the flow field (e.g., flow directions and productivity) during Phase 1 due to remedial activities. DOE should demonstrate that well bore dilution is not significantly overestimated with the parameter set selected in RESRAD in the surface and subsurface DCGL calculations in comparison to expected dilution in the real system given the presence of hydraulic barriers and other sources of contamination. DOE could use the three-dimensional STOMP model constructed for Appendix D analysis, to evaluate the impact of hydraulic barriers and other sources of contamination on the assumed dilution factors.

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DOE Response: DOE has used the three-dimensional near-field STOMP model for the north plateau discussed in Appendix D to the DP to evaluate the impact of hydraulic barriers on the assumed dilution factors for the phased decommissioning alternative as described below.

Before describing this evaluation and its results, it should be noted that the hydraulic barriers to be installed during Phase 1 of the decommissioning would not be necessary if the site-wide removal alternative were selected for Phase 2 of the decommissioning. They would be removed to restore the natural groundwater flow conditions and to alleviate the necessity for long-term maintenance, especially maintenance which would be associated with the French drain. Consequently, the hydraulic barriers would have no impact on DCGLs if the site-wide removal alternative were to be selected for Phase 2 of the decommissioning.

If the site-wide close-in-place alternative were to be selected for Phase 2 of the decommissioning, the hydraulic barriers installed during Phase 1 would remain in place. The key question under these circumstances would be whether the hydraulic barriers would influence the directions of flow through the aquifer in a manner inconsistent with the aquifer well dilution concept incorporated into the RESRAD model used to establish DCGLs.

This issue has been evaluated using the STOMP three-dimensional near-field flow model. The results show that groundwater flow patterns with the hydraulic barriers in place would not be inconsistent with the RESRAD model and would therefore not impact the calculated DCGLs.

In the first step in the evaluation process, simulations of groundwater flow were conducted to determine if well dilution factors calculated using STOMP and RESRAD were consistent for comparable conditions. In a second step, the STOMP simulations were completed to investigate the influence of hydraulic barriers on the hydraulic gradient south of and within the excavation for removal of the Process Building and the source area of the north plateau groundwater plume.

Summary of STOMP Groundwater Modeling Results

The primary results of the STOMP modeling were as follows:

- The RESRAD dilution model provides a reasonable match to dilution predicted by the more sophisticated STOMP model for a well located at the down-gradient edge of the contaminated zone (RESRAD non-dispersion model) and a conservative estimate for a well located in the center of the contaminated zone (RESRAD mass balance model),
- The presence of the engineered barriers would not cause significant changes in the hydraulic gradient upgradient of the WMA 1 excavation, and
- Pumping of a well in the area of the WMA 1 excavation would cause only a minor decrease in flow downward into the unweathered Lavery till.

The results of the simulations with respect to the well dilution factor and the impacts of the hydraulic barriers on the hydraulic gradient are discussed below.

Well Dilution Factor

Table 5C3-1 shows the estimated impacts of differing contamination zone areas and well pumping rates on the well dilution factor as estimated by STOMP and by RESRAD.

Table 5C3-1. Estimates of Well Dilution Factor Variability

Size of Contaminated Area (m^2)	Well Pumping Rate (m^3/y)	Well Dilution Factor			
		STOMP		RESRAD(1)	
		Mass Balance	Non-Dispersion	Mass Balance	Non-Dispersion
92	249	0.006	0.006	0.096	0.02
900	672	0.032	0.035	0.35	0.06
9,900	5,700	0.14	0.18	0.45	0.26

NOTE: (1) Hand calculated using RESRAD formulae and STOMP recharge and horizontal flow rate.

For the non-dispersion model, the predictions of STOMP and RESRAD are reasonably close while for the mass balance model the RESRAD assumption of complete capture of the source in the well pump rate produces a conservative underestimate of dilution by RESRAD.

Impacts of Hydraulic Barriers on Hydraulic Gradient

The impact of the presence of hydraulic barriers to be installed during Phase 1 of the decommissioning was investigated by comparison of the groundwater flow rates and water table conditions for three test cases. These cases were:

- Background conditions without the barrier wall or the French drain,
- Conditions following Phase 1 of the decommissioning with the barrier wall and French drain at design conditions, and
- Conditions following Phase 1 of the decommissioning with the barrier wall at design condition and French drain at degraded conditions (hydraulic conductivity of the degraded French drain is one-half the value of 10 centimeters per year adopted for the design condition).

In each of these cases, the recharge rate at the ground surface was 26 centimeters per year, the average value for the north plateau determined during calibration of both the Finite Element Heat and Mass Transfer Code (FEHM) site-wide and STOMP near-field groundwater flow models. The flow balances for these three cases are summarized in Table 5C3-2. The results indicate that the primary effect of the barriers is to divert flow through the French drain to discharge to Erdman Brook, thereby decreasing the northward flow through the thick bedded unit and slack water sequence to Franks Creek. The primary effect of degradation of the French drain is decrease of flow through the French drain to Erdman brook and increase in flow through the thick bedded unit to Erdman Brook. The two changes nearly offset each other.

Table 5C3-2. Summary of Flow Balances

Direction	Flow Rate (m^3/y)		
	No Barrier Wall or French Drain	**Barrier Wall and French Drain at Design Conditions**	**Barrier Wall at Design condition, French Drain at Degraded Conditions**
In			
Ground surface	107,624	107,624	107,624
South	7,304	7,304	7,304
Out			
Bottom	9,060	8,884	8,940
Quarry Creek	8,456	8,659	8,830
Franks Creek (TBU)	11,870	8,864	8,896
Franks Creek (SWS)	54,843	38,253	38,351
Erdman Brook (TBU)	15,238	14,881	17,658
Erdman Brook (FD)	-	21,700	18,378
North Plateau Ditch	15,445	13,664	13,852

LEGEND: FD = French drain, SWS = slack water sequence, TBU = thick bedded unit

The role of the hydraulic barriers in alteration of the configuration of the water table is illustrated in Figures 5C3-1, 5C3-2, and 5C3-3 for the three cases. At this level of detail, the difference between the case of no barriers (Figure 5C3-1) and presence of barriers (Figures 5C3-2 and 5C3-3) is clear, but little difference can found for comparison of design and degraded French drain.

A greater level of detail is discernable for the plot of the water table along a southwest-to-northeast line passing through the center of the Process Building excavation. The result is presented in Figure 5C3-4 for comparison of the background and engineered barriers cases. This plot shows that along this transect, presence of the hydraulic barrier wall increased the elevation of the water table but had little effect on hydraulic gradient.

Elevation of the water table along this transect for the case of design conditions of the barrier wall and French drain without a well and with a well pumping at 5,700 cubic meters per year is presented in Figure 5C3-5. The well was located at position of 280 meters on the horizontal axis of Figure 5C3-5. The results indicate that the presence of the well causes a minor general lowering of the water table and a local drawdown on the order of one meter within a radius of twenty-five meters.

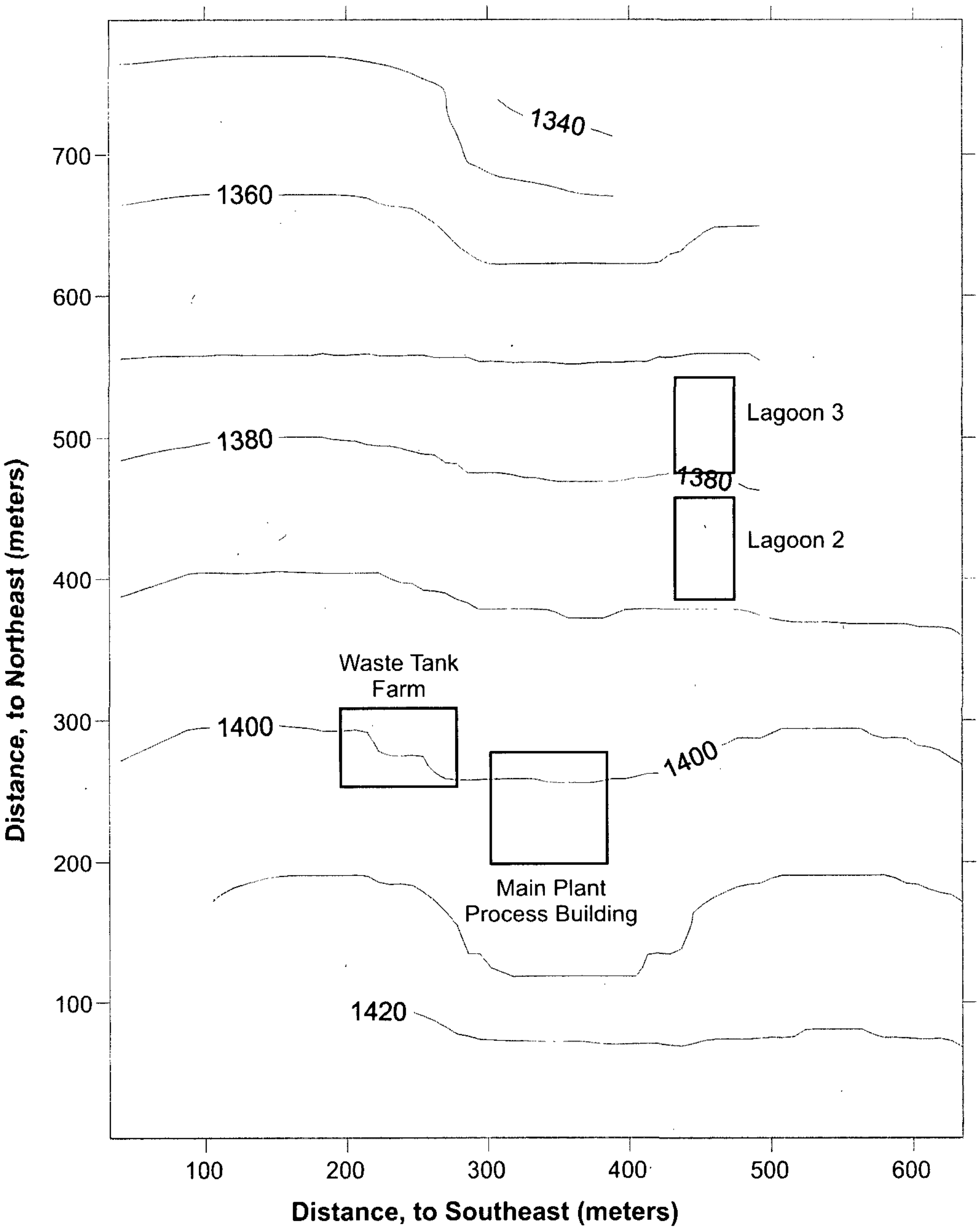


Figure 5C3-1. Water Table for Historical Conditions (no barrier wall, no pumping) (This figure is the same as the left figure in Figure D-9 of Appendix D.)

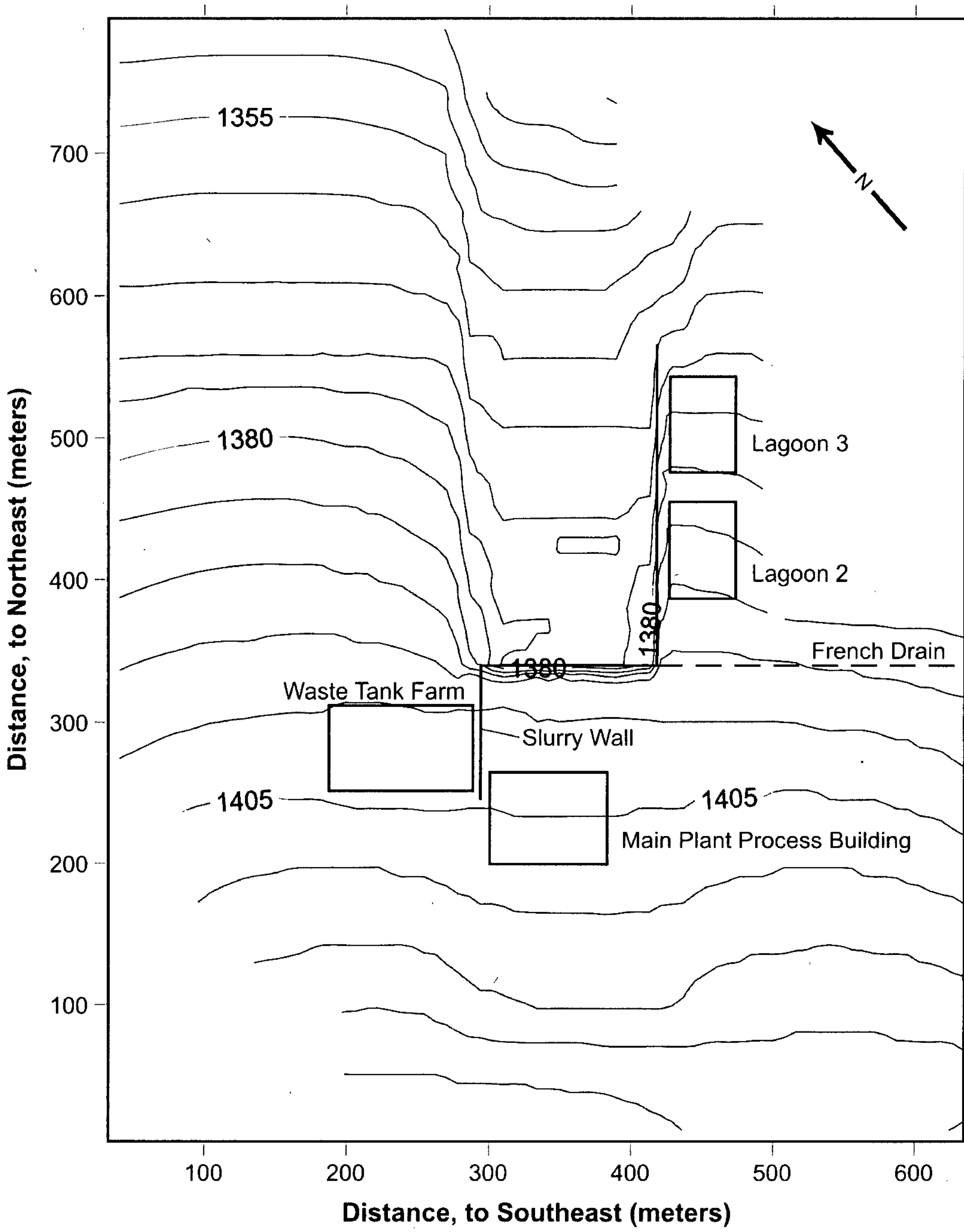


Figure 5C3-2. Water Table with the Phase 1 Hydraulic Barriers in Place with Hydraulic Conductivity of the French Drain at Design Value (10 cm/s, well pump rate = 5,700 cm^3/y)

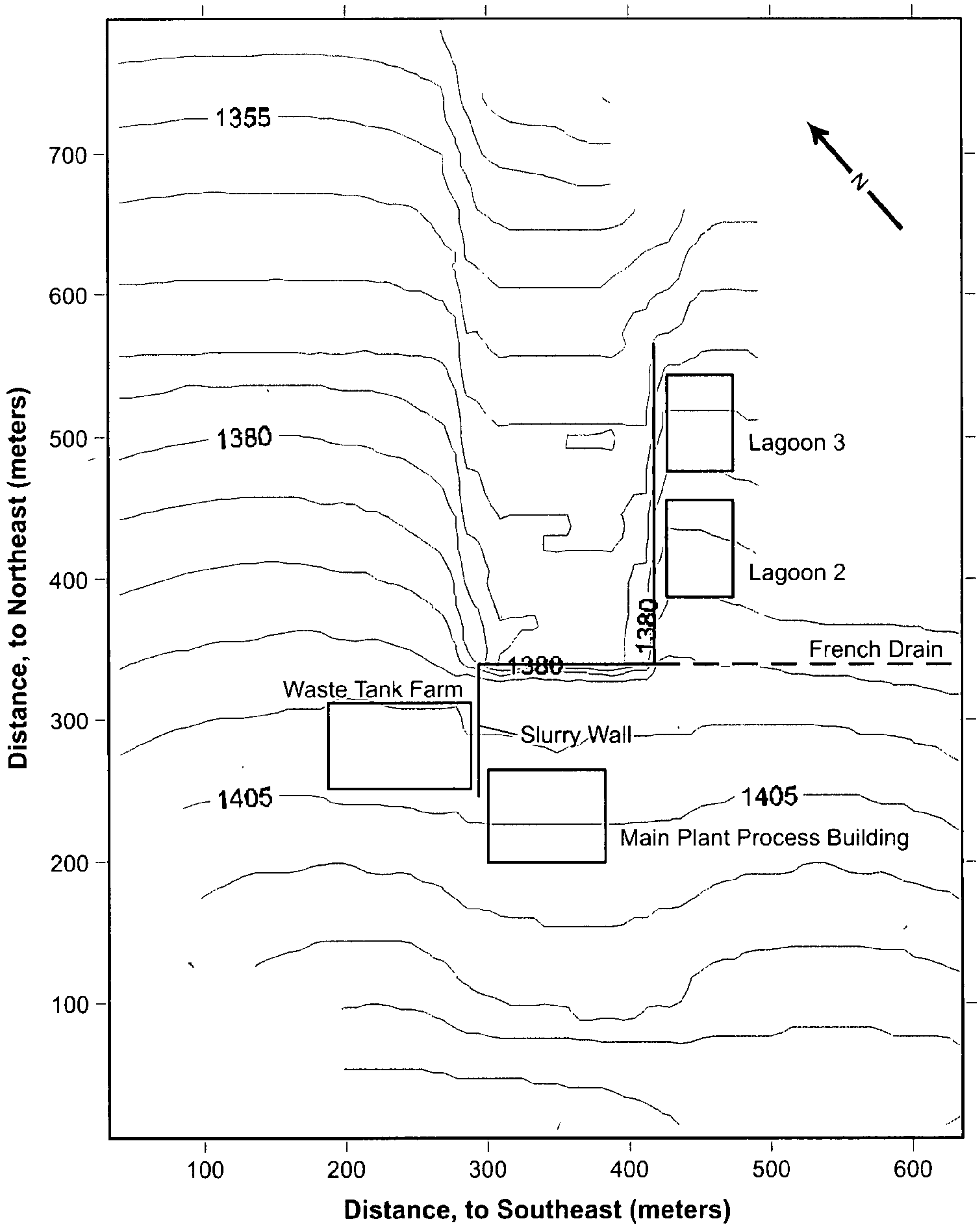


Figure 5C3-3. Water Table with the Phase 1 Hydraulic Barriers in Place with Hydraulic Conductivity of French Drain at Half of Design Value (well pump rate = 5,700 m^3 /y)

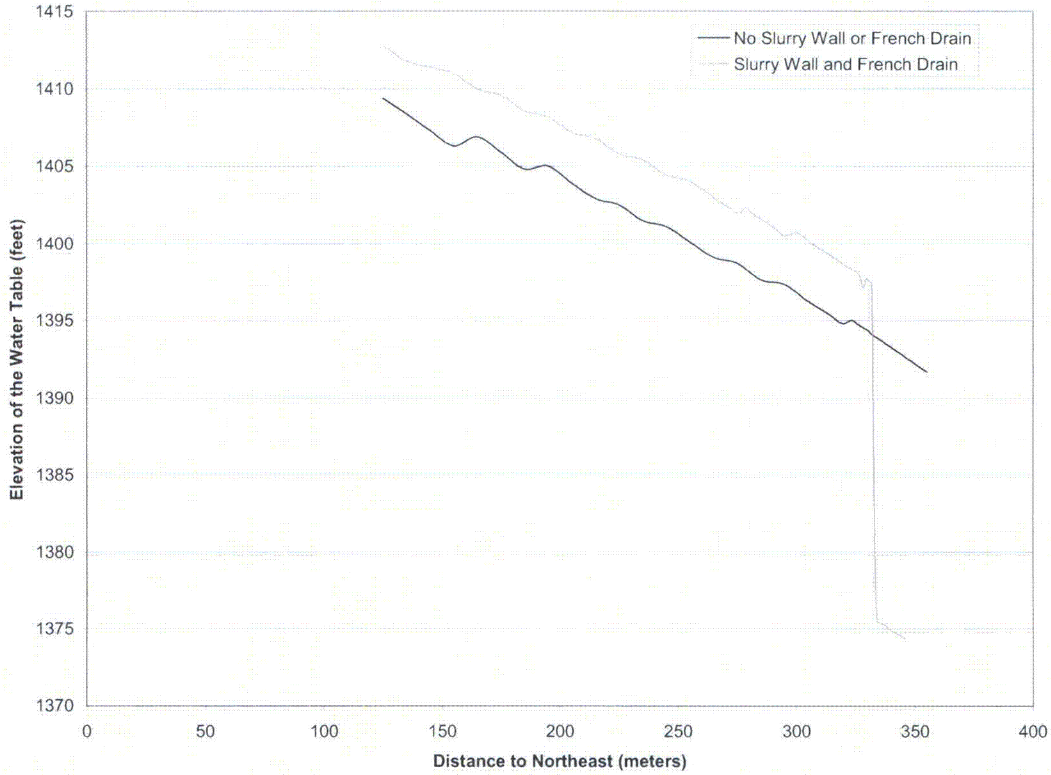


Figure 5C3-4. Influence of Presence of Engineered Barriers on Elevation of the Water Table along a Southwest-to-Northeast Transect Through the Process Building Excavation. (Note that there is an elevation drop of more than 20 feet across the hydraulic barrier.)

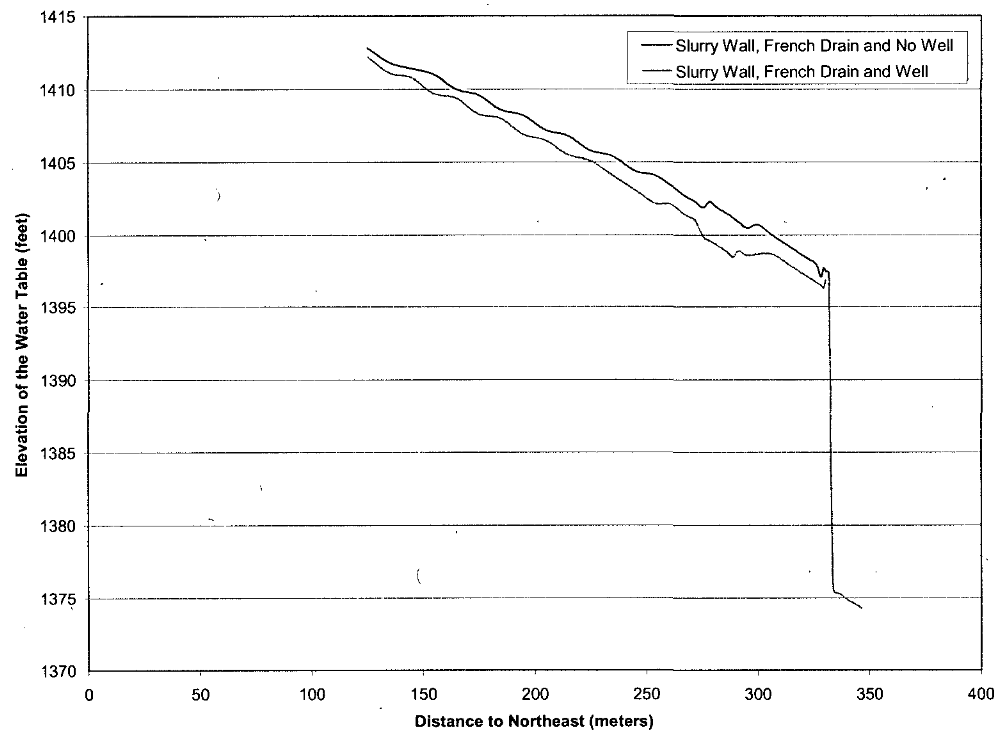


Figure 5C3-5 Influence of a Well on Elevation of the Water Table Along a Southwest-to-Northeast Transect Through the Process Building Excavation

Changes to the Plan: No changes are planned.

RAI 5C9 (14)

Subject: Consideration of subsurface contamination

RAI: DOE has not provided sufficient information to justify lack of consideration of subsurface contamination at the bottom of WMA 1 and 2 excavations when deriving subsurface soil DCGLs. Additional data collected on the extent of Lavery Till contamination as remediation proceeds may show greater extent of contamination than originally assumed, additional transport pathways not considered in the subsurface DCGL calculations (e.g., contamination of Lavery Till Sand or along H-piles in the Lavery Till), or greater accessibility of contamination at depth than what is expected. (Section 5.2.1, Page 5-23)

Basis: DOE presented several qualitative arguments (page 5-41) to justify lack of consideration of subsurface contamination at depth after contaminated subsurface soils are excavated from WMA 1 and 2. While some of the qualitative arguments regarding the relative inaccessibility of contamination in the Lavery Till to a potential receptor are compelling, additional data and calculations are needed to fully support the arguments presented. Because only one scenario is evaluated in deriving subsurface DCGLs (i.e., construction of a cistern), this scenario must be demonstrably conservative when considering other scenarios that may be just as, or more, likely. The amount of contamination assumed to be brought to the surface from construction of a cistern is relatively small and dilute[1] and may not be limiting for those radionuclides where water-dependent pathways may dominate the dose (e.g., existing contamination present in the saturated zone may be drawn from a well leading to water-dependent exposure pathways).

Additional information may be needed to support the hydrogeological conceptual model for contamination assumed to be present underneath WMA 1 and 2 used to derive subsurface DCGLs. Previous geologic interpretations showed contamination of a significant portion of the Lavery Till and Lavery Till Sand underneath the Main Plant Process building that could lead to pathways of exposure not considered in the current analysis. DOE should indicate how it plans to manage the risk associated with significantly greater contamination levels at depth along H-piles or within the Lavery Till then were assumed in the DCGL calculations.

Additional calculations or modeling should be performed to support the assumption regarding the expected lower relative risk of residual contamination at depth versus the risk associated with contamination assumed to be brought to the surface due to a cistern drilling scenario. This would include a quantitative evaluation of the potential for Lavery Till contamination to be transported to the Kent Recessional Sequence (KRS). DOE should present information on the relative risk of the cistern versus a ground/surface water transport scenario. DOE should also quantitatively evaluate the impact of pumping and the presence of hydraulic barriers on the potential migration of contamination from the top of the Lavery Till to a well located in the sand and gravel unit and present the relative risks associated with a cistern versus groundwater well scenario.

DOE should clarify how the residual risk from contaminated soil located just below 1 m (e.g., on the sides of the excavations) is appropriately accounted for when comparing residual concentrations to subsurface DCGLs which assume the contamination is mixed with clean soil at a ratio of one to ten (i.e., dilution factor of ten). DOE indicates in a footnote on page 5-4 that contamination on the sides of the excavation up- and cross-gradient from the source area is not

[1] Only one tenth of the soil column is assumed to be contaminated resulting from assumptions regarding the thickness of contamination in the Lavery Till at the bottom of the excavation and the amount of clean soil used to back-fill the excavation.

expected to be contaminated. This expectation should be confirmed in the field or enough data collected to evaluate the impact of contamination at intermediate depths on the dose calculations.

Path Forward: DOE could provide additional information such as borehole logs for those locations where the top of the Lavery Till was significantly lowered and the Lavery Till Sand eliminated underneath the process building in the vicinity of the source of the North Plateau groundwater plume. Additional cross-sections overlaying recent concentration data over reinterpreted geology underneath the process building would also provide additional confidence in the revised hydrogeological conceptual model.

DOE should provide additional details on how in-process or final status survey data will be collected at the bottom of excavations. A procedure should be in place to provide adequate assurance that the thickness of contamination at depth is less than assumed in the DCGL calculations and is present within the impermeable Lavery Till as assumed in the DCGL calculations. If the thickness of contamination is significantly greater than assumed and/or is present in more permeable sediments (e.g., Lavery Till Sand), then sufficient data should be collected to perform additional dose modeling to adequately assess risk. If DOE amends the DP to allow use of surrogate DCGLs to demonstrate compliance with LTR criteria at the bottom of the WMA 1 and 2 excavations, DOE should provide supporting information such as radioisotopic ratios within the Lavery Till used to derive the surrogate DCGLs. DOE should also indicate how it intends to update surrogate DCGLs based on collection of additional data obtained during in-process or final status surveys, if necessary.

As discussed in a preceding comment, it is recommended that DOE provide results of calculations or perform additional modeling (e.g., multi-dimensional groundwater modeling using STOMP) to show the impacts of (i) a pumping well, and (ii) hydraulic barriers on the flow field in the immediate vicinity of WMA 1 and 2 excavations and potential transport of contaminants from the Lavery Till to a the drinking water well located in the sand and gravel. DOE should also evaluate the potential risk associated with transport of contamination from the Lavery Till to the KRS or to surface water. This information could be used to provide additional support that the potential contributions from subsurface contamination to the overall risk from the site from other pathways of exposure (i.e., drilling scenario) are insignificant.

DOE should explain how contamination present on excavation sides will be remediated to ensure that unrestricted use criteria will be met.

****

DOE Response: DOE has given additional consideration to subsurface contamination at the bottom of the WMA 1 and WMA 2 excavations from the standpoint of additional groundwater modeling, available data on residual radioactivity in the area of these excavations, the potential for transport of residual contamination to the KRS, the potential for transport of this contamination to groundwater which is then used for drinking water and irrigation, and the potential for drawing this contamination into the hypothetical well postulated in the base-case conceptual model for development of subsurface soil DCGLs. These matters and related matters identified as issues of interest in the NRC path forward are discussed below.

Process Building Area Geology

The Lavery till sand is not located beneath the Process Building nor within the north plateau groundwater plume and previous interpretations of the extent of this unit have not suggested its location beneath the Process Building. Re-examination of borehole logs from the north plateau in

2007 resulted in a re-evaluation of the areal extent of the Lavery till sand. Copies of the borehole logs that were used to revise the extent of the Lavery till sand are attached. Table 5C9-1 (which appears at the end of the text) summarizes the revisions to the geologic interpretation of the boring logs used to delineate the extent of the Lavery till sand as described in Figure 3-64 of the DP.

From 1991 to 2007 the Lavery till sand was inferred to be present to the west, south, and southeast of the Process Building in a location that was hydraulically upgradient and cross-gradient to the north plateau groundwater plume (Figure 5C9-1). Earlier interpretations of the borehole logs considered a prominent clay-rich geologic horizon up to several feet in thickness as part of the unweathered Lavery till and the underlying sandy unit as the Lavery till sand.

Following the completion of the 1993 soil boring program to support the RCRA Facility Investigation, evaluation of the 1993 borehole data indicated that the sand and gravel unit was composed of two distinct subunits, the thick-bedded unit and the underlying slack water sequence which are separated by the prominent clay-rich geologic horizon mentioned earlier.

In 2007 it was noted that the elevation of the original Lavery till sand west and southwest of the Process Building was much shallower in elevation that the Lavery till sand to the southeast of the Process Building. It was determined that this western and southwestern portion was more consistent with the elevation of the slack water sequence of the sand and gravel unit and it was reclassified as part of the slack water sequence. As a result the areal extent of the Lavery till sand was substantially reduced and it is now located southeast of the Process Building away from the north plateau groundwater plume as shown in Figure 3-64 of the DP, which is reproduced here as Figure 5C9-2.

Soil samples have not been collected from the Lavery till sand. However, groundwater monitoring of Lavery till sand wells WNW0202, WNW0204, WNW0206, and WNW0208 does not suggest the presence of radioactive contamination in this unit.

Radioactivity in Subsurface Soil in the Areas of the Deep Excavations

To place the information that follows into context, it is useful to review available characterization data on radioactivity in subsurface soil in the areas of the deep excavations and planned additional characterization of those areas.

Limited soil sampling data currently exists for the Lavery till at the bottom of the WMA 1 and WMA 2 excavations as discussed in Section 4.2. Geoprobe® investigations in 1994, 1998, and 2008 collected soil samples from the upper several feet of the Lavery till at seven locations beneath the Main Plant Process Building and the results are summarized in Table C-4 of Appendix C. Low levels of radioactivity were detected in these samples with a maximum Sr-90 concentration of 59 pCi/g. Deeper soil samples were not collected from the Lavery till during these investigations as sampling was terminated shortly after reaching the Lavery till in accordance with the sampling and analysis plan for this project.

It is not known whether the radioactivity in the shallow Lavery till soil samples is an artifact of the Geoprobe® sampling method or the result of migration from contaminated groundwater from the source area of the north plateau groundwater plume (Hemann and Steiner 1999). Less data are available from WMA 2 as the only Lavery till sample was collected from borehole BH-5 in the vicinity of WMA 1. A representative cross-section showing the geology and recent Sr-90 concentration data beneath the Process Building is presented in Figure 4-8 of the DP.

Additional subsurface soil data will be collected from the Lavery till in WMA 1 and WMA 2 during the Phase 1 soil and sediment characterization program that will be defined in the Characterization Sample and Analysis Plan. This characterization program will provide additional information on the nature and extent of contamination within the project premises and guide the final design of the large excavations in WMA 1 and WMA 2. If this characterization data indicates that contamination at depth is greater than assumed in the subsurface soil DCGL calculations additional dose modeling will be performed and the subsurface soil DCGLs and cleanup goals will be revised, accordingly.

In-Process and Phase 1 Final Status Surveys

Samples of Lavery till will also be collected from the bottom of the WMA 1 and WMA 2 excavations during the in-process surveys and final status surveys as described in the responses to RAIs 9C3 and 9C4. In-process surveys will be performed when the WMA 1 and WMA 2 excavations reach a depth of approximately one foot (30 cm) into the Lavery till and will include gamma scans and the collection of biased soil samples six inches (15 cm) in depth in the Lavery till to evaluate whether the subsurface soil cleanup criteria have been met at the bottom of the WMA 1 and WMA 2 excavations. Systematic composite soil samples from the Lavery till will also be collected from the upper six inches (15 cm) and 3.3 foot (1 meter) depth intervals at the bottom of the WMA 1 and WMA 2 excavations during the final status surveys to document that the subsurface soil cleanup criteria have been achieved.

Risk Associated With Transport of Lavery Till Contamination to the KRS

The extent of contamination along the foundation pilings beneath the Main Plant Process Building is currently unknown. As discussed in the response to RAI 4C2 subsurface soil samples will be collected around representative Process Building foundation pilings located within the area impacted by the North Plateau groundwater plume once the Process Building and the sand and gravel overlying the Lavery till have been removed as part of the in-process and final status surveys. These samples will be taken in close proximity to the pilings several feet below the surface of the unweathered Lavery till as specified in the Characterization Sample and Analysis Plan and the Phase 1 Final Status Survey Plan to evaluate whether contamination has migrated downward around the pilings towards the KRS. If contamination exceeding the subsurface soil cleanup criteria is detected along the foundation pilings, additional soil will be removed until the soil cleanup criteria is achieved.

Risk Associated With Transport of Residual Lavery Till Contamination to Surface Waters

The risk associated with transport of residual contamination from the Lavery till to surface waters and to groundwater in the backfilled WMA 1 and WMA 2 excavations has been evaluated. Erosion modeling indicates that erosion will not impact the residual contamination in the Lavery till beneath WMA 1. The transport of residual contamination in the Lavery till from WMA 2 as a result of unmitigated gully erosion via surface waters to a downstream receptor on Cattaraugus Creek was evaluated and found to be less limiting than the resident farmer scenario as described in the response to RAI 5C6.

Radionuclide Ratios and the Use of Surrogate Radionuclides

Soil data collected during the soil characterization program will be used to identify radionuclide ratios within the Lavery till from the WMA 1 and WMA 2 excavations that may be used to develop surrogate DCGLs to demonstrate compliance with the subsurface soil cleanup goals. Based on available data, it is doubtful that these ratios will be consistent enough to permit use of an easy-to-measure surrogate radionuclide to identify the concentrations of Sr-90, which available data suggest will be the dominant radionuclide at the bottom of the deep excavations.

Impacts of Residual Radioactivity at the Bottoms of the Deep Excavations

The response to RAI 5C3 describes the results of additional groundwater modeling using the STOMP code and other models used in the EIS to evaluate the potential impacts of changes in flow fields associated with installation of the hydraulic barriers on the DCGLs. As explained in the response to that RAI, this impact is expected to be negligible.

The potential impact of movement of residual contamination from the upper layer of the Lavery till into groundwater of the backfilled excavations has been evaluated using a combination of flow modeling performed using the three-dimensional STOMP model and transport and dose modeling using the FEIS finite difference rectangular source model. The STOMP modeling determined the influence of pumping of a well on the direction and magnitude of groundwater flow at the backfill soil-Lavery till interface and established the magnitude and direction of flow of groundwater towards and around the well in the volume above the contaminated till.

This modeling showed that some residual radioactivity at the bottom of the deep excavations will diffuse upwards into the uncontaminated fill placed in the excavation and contaminate the groundwater in the backfilled excavation, resulting in contaminated water potentially being drawn into the hypothetical well included in the base-case conceptual model used to develop the subsurface soil DCGLs. This will result in increased predicted doses from water dependent pathways, especially from drinking water.

The FEIS transport-dose model established the time-dependent rate of diffusion of contamination upward into the uncontaminated backfill volume and using the STOMP groundwater and well flow rates calculated the dose due to consumption of drinking water produced from the well. Drinking water doses calculated using this approach will be combined with dose-to-source ratios calculated using RESRAD to establish subsurface soil DCGLs for the combined pathways.

Table 5C-9-2 shows the changes necessary to the subsurface soil DCGLs and cleanup goals to take into account releases of radioactivity from the bottoms of the remediated WMA 1 and WMA 2 excavations.

Table 5C-9-2 Impacts of ULT Releases on DCGLs and Cleanup Goals (pCi/g)

Nuclide	Limiting DCGL from Resident Farmer/Residential Gardener Scenario Analyses	Cleanup Goals Not Considering Excavation Bottom Releases	DCGL Considering Releases from Excavation Bottom	Cleanup Goals Considering Releases from Excavation Bottom
Am-241	7.1E+03	3.1E+03	To	To
C-14	3.7E+05	1.7E+05	be	be
Cm-243	1.2E+03	5.0E+02	completed(1)	completed(1)
Cm-244	2.3E+04	1.0E+04		
Cs-137(2)	4.4E+02	1.4E+02		
I-129	5.2E+01	2.4E+01		
Np-237	4.3E+00	1.9E+00		
Pu-238	1.5E+04	6.2E+03		

Table 5C-9-2 Impacts of ULT Releases on DCGLs and Cleanup Goals (pCi/g)

Nuclide	Limiting DCGL from Resident Farmer/Residential Gardener Scenario Analyses	Cleanup Goals Not Considering Excavation Bottom Releases	DCGL Considering Releases from Excavation Bottom	Cleanup Goals Considering Releases from Excavation Bottom
Pu-239	1.3E+04	5.5E+03		
Pu-240	1.3E+04	5.4E+03		
Pu-241	2.4E+05	1.1E+05		
Sr-90(2)	3.2E+03	1.4E+03		
Tc-99	1.1E+04	5.1E+03		
U-232	1.0E+02	3.3E+01		
U-233	1.9E+02	8.7E+01		
U-234	2.0E+02	8.9E+01		
U-235	2.1E+02	9.3E+01		
U-238	2.1E+02	9.3E+01		

NOTES: (1) *TO BE ADDED AFTER COMPLETION OF ADDITIONAL GROUNDWATER AND DOSE MODELING*

Remediation of Excavation Sides

Contamination present on the sides of the deep excavation will be remediated to ensure that unrestricted release criteria are met as specified in Section 7 of the DP.

Section 7 states on page 7-25 that remedial action surveys would be performed during the course of the work and soil on the bottom and sides of the excavation with radioactivity concentrations exceeding the cleanup goals would be removed and disposed of offsite as radioactive waste. The related footnote states that it is unlikely that the sides of the excavation that are not hydraulically downgradient will be contaminated. This footnote also states that in any case, the extent of soil remediation on the sides of the excavation would be limited by the excavation boundaries.

The Final Status Survey Conceptual Framework included in the response to RAI 9C4 describes how Phase 1 final status surveys will be performed on the sides of the deep excavations to document that the cleanup criteria are achieved.

Table 5C9-1. Borehole Log Geologic Picks Used to Re-Evaluate the Extent of the Lavery Till Sand in the North Plateau

Borehole	Original Geologic Unit	Original Top Elevation (ft)	Original Bottom Elevation (ft)	Revised Geologic Unit	Revised Top Elevation (ft)	Revised Bottom Elevation (ft)
302	S&G	0	16	S&G-TBU	0	17
	WLT	16	17	S&G-CLAY	17	23
	ULT	17	23			
	LTS	23	28	S&G-SWS	23	28
	ULT	28	>32	ULT	28	>32
402	S&G	0	14.5	S&G-TBU	0	15
	WLT	14.5	15	S&G-CLAY	15	24
	ULT	15	24			
	LTS	24	28.75	S&G-SWS	24	28.75
	ULT	28.75	>36	ULT	28.75	>36
404	S&G	0	14.75	S&G-TBU	0	14.7
	WLT	14.75	15.25	S&G-CLAY	14.7	24
	ULT	15.25	24			
	LTS	24	32	S&G-SWS	24	32
	ULT	32	>36.5	ULT	32	>36.5
410	S&G	0	14.75	S&G-TBU	0	14.7
	WLT	14.75	15.25	S&G-CLAY	14.7	24
	ULT	15.25	24			
	LTS	24	25	S&G-SWS	24	32
	ULT	25	62	ULT	32	62
	KRS	62	82	KRS	62	82
	BR	82	>82	BR	82	>82
11B	S&G	0	14.5	S&G-TBU	0	15
	WLT	14.5	15	S&G-CLAY	15	24
	ULT	15	24			
	LTS	24	28.75	S&G-SWS	24	28.75
	ULT	28.75	46	ULT	28.75	46
	KRS	46	66	KRS	46	66
	KT	66	>66	KT	66	>66
62DMB-16	S&G	0	26	F	0	3
				S&G-TBU	3	26
	ULT	26	27	S&G-CLAY	26	27
	LTS	27	40	S&G-SWS	27	40
	ULT	40	>40	ULT	40	>40
62DMB-17	S&G	0	17	F	0	3
				S&G-TBU	3	17
	ULT	17	25	S&G-CLAY	17	25

Table 5C9-1. Borehole Log Geologic Picks Used to Re-Evaluate the Extent of the Lavery Till Sand in the North Plateau

Borehole	Original Geologic Unit	Original Top Elevation (ft)	Original Bottom Elevation (ft)	Revised Geologic Unit	Revised Top Elevation (ft)	Revised Bottom Elevation (ft)
	LTS	25	31	S&G-SWS	25	31
	ULT	31	>42	ULT	31	>42
62PAH-71	S&G	0	17	S&G-TBU	0	17
	ULT	17	23	S&G-CLAY	17	23
	LTS	23	28	S&G-SWS	23	28
	ULT	28	>36.5	ULT	28	>36.5
63DMB-24	S&G	0	12	S&G-TBU	0	12
	ULT	12	20.5	S&G-CLAY	12	20.5
	LTS	20.5	25	S&G-SWS	20.5	25
	ULT	25	>42	ULT	25	>42
63DMB-25	S&G	0	18	S&G-TBU	0	17.5
	ULT	18	20	S&G-CLAY	17.5	20
	LTS	20	23	S&G-SWS	20	23
	ULT	23	52	ULT	23	52
	KRS	52	77	KRS	52	77
	BR	77	>77	BR	77	>77
70DMB-26	S&G	0	20	S&G-TBU	0	20
	ULT	20	24	S&G-CLAY	20	24
	LTS	24	32	S&G-SWS	24	32
	ULT	32	58	ULT	32	58
	KRS	58	>77	KRS	58	>77
70DMB-27	S&G	0	20	S&G-TBU	0	20
	ULT	20	24	S&G-CLAY	20	24
	LTS	24	28	S&G-SWS	24	28
	ULT	28	50	ULT	28	50
	KRS	50	>76	KRS	50	>76
74DMB-33	S&G	0	15	S&G-TBU	0	15
	ULT	15	43	ULT	15	68
	LTS	43	68			
	BR	68	>68	BR	68	>68
74DMB-39	S&G	0	15	S&G-TBU	0	15
	ULT	15	20	S&G-CLAY	15	20
	LTS	20	29	S&G-SWS	20	29
	ULT	29	53	ULT	29	53

Table 5C9-1. Borehole Log Geologic Picks Used to Re-Evaluate the Extent of the Lavery Till Sand in the North Plateau

Borehole	Original Geologic Unit	Original Top Elevation (ft)	Original Bottom Elevation (ft)	Revised Geologic Unit	Revised Top Elevation (ft)	Revised Bottom Elevation (ft)
	KRS	53	70	KRS	53	70
	BR	70	>70	BR	70	>70
74DMB-40	S&G	0	25	F	0	3
				S&G-TBU	3	25
	ULT	25	31	S&G-CLAY	25	30.5
	LTS	31	34	S&G-SWS	30.5	34
	ULT	34	63	ULT	34	63
	KRS	63	94	KRS	63	94
	KT	94	113	KT	94	113
	ORS	113	128	ORS	113	128
	BR	128	>128	BR	128	>128
UR-1	F	0	5	F	0	5
	S&G	5	23.5	S&G-TBU	5	23.5
	ULT	23.5	27	S&G-CLAY	23.5	27
	LTS	27	35.5	S&G-SWS	27	35.5
	ULT	35.5	>42	ULT	35.5	>42
UR-2	F	0	5	F	0	5
	S&G	5	23.5	S&G-TBU	5	23.5
	ULT	23.5	28	S&G-CLAY	23.5	28
	LTS	28	35.8	S&G-SWS	28	35.8
	ULT	35.8	>37	ULT	35.8	>37
UR-3	F	0	5	F	0	5
	S&G	5	20	S&G-TBU	5	20
	ULT	20	30.3	S&G-CLAY	20	30.3
	LTS	30.3	36	S&G-SWS	30.3	36
	ULT	36	>39	ULT	36	>39

LEGEND: BR - Bedrock
Clay – Clay Unit
F- Fill
KRS – Kent Recessional Sequence
LTS – Lavery till sand
S&G – Sand and Gravel Unit; subdivided into:
SWS –Slack Water Sequence
TBU – Thick-bedded Unit
ULT – Unweathered Lavery till
WLT – Weathered Lavery till

Figure 5C9-1. Pre-2007 Inferred Areal Extent of the Lavery Till Sand in the North Plateau

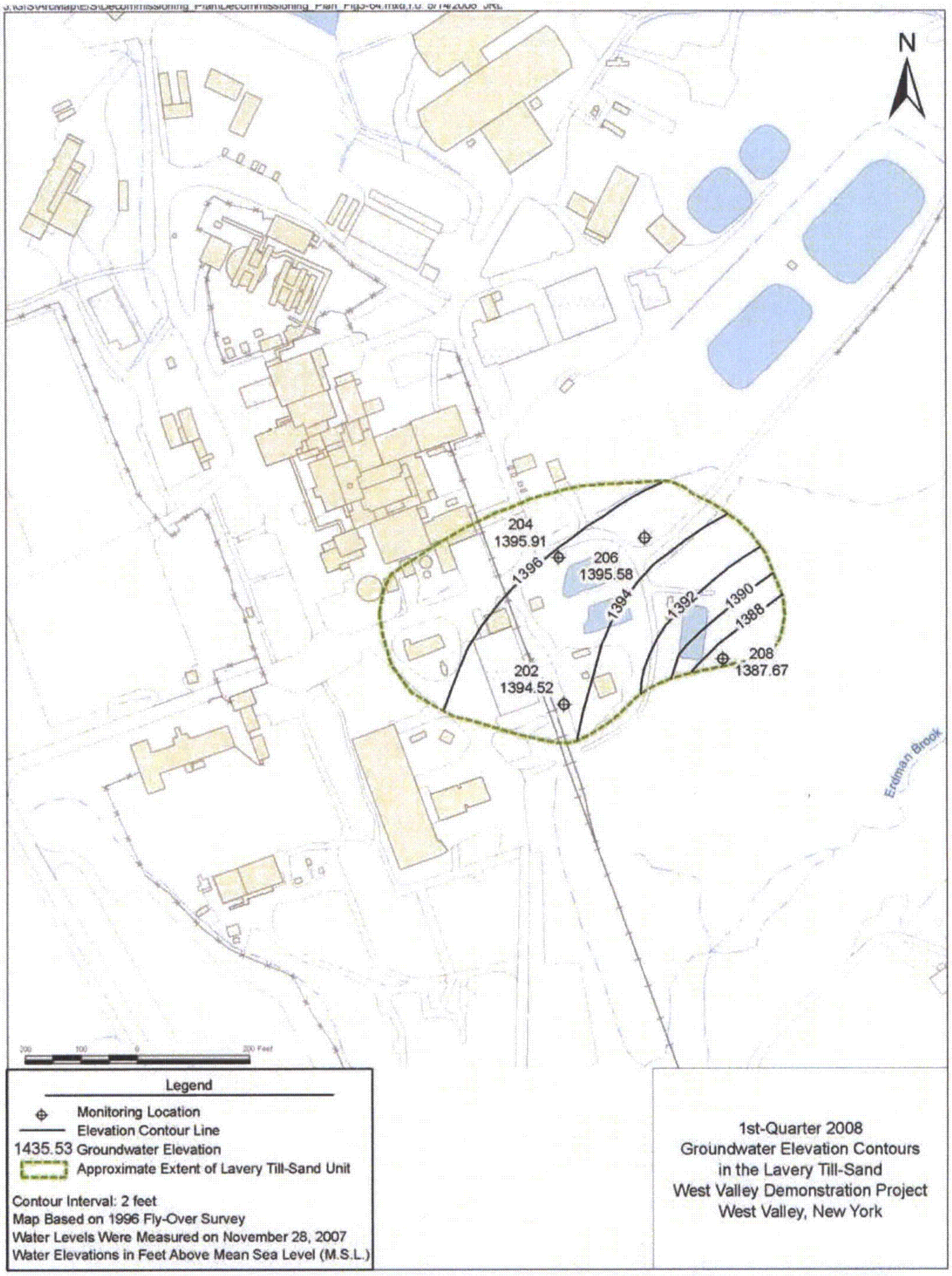


Figure 5C9-2 – Current Inferred Areal Extent of the Lavery Till Sand in the North Plateau

References:

Hemann and Steiner 1999, *1998 Geoprobe Investigation of the Core Area of the North Plateau Groundwater Plume*, WVDP-346, Revision 0. Hemann, M.R. and R.E. Steiner, II, West Valley Nuclear Services Company, June 11, 1999.

Changes to the Plan:

Section 3.5.2, Lavery Till-Sand Unit on page 3-48 will be modified as follows:

The Lavery till-sand unit is a lenticular shaped, silty, sand layer that is locally present within the Lavery till in the north plateau of the Center, immediately southeast of the Process Building. It is thought to be either a pro-glacial sand deposit or a reworked kame deposit.

The till-sand is limited in areal extent, occurring on the north plateau in an east-west band approximately 750 feet wide. It lies within the upper 20 feet of the Lavery till (Figure 3-6) and is up to seven feet in thickness.

Re-examination of borehole logs from the north plateau in 2007 resulted in a re-evaluation of the areal extent of the Lavery till sand. From 1991 to 2007 the Lavery till sand was inferred to be present to the west, south, and southeast of the Process Building in a location that was hydraulically upgradient and cross-gradient to the north plateau groundwater plume. Earlier interpretations of the borehole logs considered a prominent clay-rich geologic horizon up to several feet in thickness as part of the unweathered Lavery till and the underlying sandy unit as the Lavery till sand.

Following the completion of the 1993 soil boring program to support the RCRA Facility Investigation, the 1993 borehole data indicated that the sand and gravel unit was composed of two distinct subunits, the thick-bedded unit and the underlying slack water sequence which are separated by the prominent clay-rich geologic horizon mentioned earlier. In 2007 it was noted that the elevation of the original Lavery till sand west and southwest of the Process Building was much shallower in elevation that the Lavery till sand to the southeast of the Process Building. It was determined that this western and southwestern portion was more consistent with the elevation of the slack water sequence of the sand and gravel unit and it was reclassified as part of the slack water sequence. As a result the areal extent of the Lavery till sand was substantially reduced and it is now located southeast of the Process Building away from the north plateau groundwater plume as shown in Figure 3-64.

Changes to Section 5 are as follows:

TO BE COMPLETED AFTER DETAILS OF MODELING AND RESULTS ARE AVAILABLE.

Attachment

(1) Recent WMA 1 Boring Logs

SHEET 1 OF: 1	HOLE/WELL NO.: 0302
DATE STARTED: 12/11/89	SURFACE ELEVATION: 1,416.22
DATE FINISHED: 12/12/89	
DRILLER: Empire Soils Inv. Hamburg, New York	NORTHING 892,564.84
INSPECTOR: JTB	EASTING 480,547.64

BORING LOG

DAMES & MOORE

PROJECT: WVDP DOE/RCRA wells
JOB NUMBER: 10805-410-023

LOCATION: SW OF CSS
SSWMU Locale: 3

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6	6 / 12	12 / 18	18 / 24	DESCRIPTION / NOTES
	24/10	SS-1	6	6	12	24	Moist, brown, SILT, some fine to medium subangular gravel, little sand, trace clay, orange and green mottling. (GM)
	24/19	SS-2	12	14	19	15	
5	24/19	SS-3	9	13	10	16	Moist, light to dark, brown, silty SAND and fine to coarse GRAVEL, trace clay. (GM)
	24/15	SS-4	9	13	11	18	Saturated, brown. (GM)
	24/10	SS-5	8	11	11	15	
10	24/12	SS-6	6	16	18	12	Some silt. (GM/ML)
	24/11	SS-7	6	8	12	20	Saturated, brown, silty SAND and fine to coarse GRAVEL, little subangular shale fragments. (GP/ML)
15	24/16	SS-8	29	20	21	22	Saturated, light brown with red and orange mottling. (GP/ML)
	24/15	SS-9	6	9	17	19	Saturated, brown, SILT, little fine sand, trace clay and fine subangular gravel. Weathered till. (ML)
	24/22	SS-10	4	6	8	10	Wet, gray SILT, some clay, trace fine sand and fine to medium subangular gravel. Unweathered. (CL)
20	24/24	SS-11	5	11	6	6	Some to little sand. (CL) Wet, gray, SILT, little clay, little fine to medium sand and gravel, brown-red mottling. (CL)
	24/22	SS-12	4	6	25	18	Saturated, brown-orange, fine to coarse SAND and fine to coarse subangular GRAVEL, trace clay. (SP)
25	24/17	SS-13	3	8	11	11	
	24/22	SS-14	4	8	7	11	Little silt and clay. (SP/SM)
	24/17	SS-15	3	6	10	12	Saturated, brown-gray, sandy SILT, little clay, trace fine to medium gravel. Unweathered. (ML/CL)
30	24/21	SS-16	3	6	8	13	Saturated, dark gray, SILT, some clay, trace fine sand, trace fine to medium subangular gravel. (CL)
35							Augered to 30.0 ft. Sampled to 32.0 ft. The water level was measured at 17.1 ft. b.g.s.- While the bottom of the augers were 30.0 ft. b.g.s.. No radiation detected above background by R/S.

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84

SHEET 1 OF: 1		HOLE/WELL NO.: 0402
DATE STARTED: 11/9/89	# BORING LOG	SURFACE ELEVATION: 1,416.96
DATE FINISHED: 11/10/89		
DRILLER: Empire Soils Inv. Hamburg, New York	DAMES & MOORE	NORTHING 892,668.86
INSPECTOR: FJC		EASTING 480,504.59
PROJECT: WVDP DOE/RCRA wells		LOCATION: EAST OF TRAILER J
JOB NUMBER: 10805-410-023		SSWMU Locale: 4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6	6 / 12	12 / 18	18 / 24	DESCRIPTION / NOTES
0							Medium brown, silty GRAVEL and SAND. (GP)
5							Medium brown, SAND and GRAVEL, some silt. (SM)
10							
15							Medium brown, clayey SILT, trace gravel and sand. (ML)
							Moist, medium brown to dark gray, SILT, some clay, trace gravel, trace fine sand. (ML)
	24/24	SS-1	5	8	10	12	Dark gray, SILT, some clay, trace gravel. (ML)
20	24/22	SS-2	1	4	7	10	
	24/23	SS-3	2	7	16	23	
25	24/20	SS-4	4	4	7	14	Dark gray, fine SAND, trace silt. (SP) Dark gray, GRAVEL and SAND, trace silt. (GP) Dark gray, fine SAND, some silt, little gravel. (SP)
	24/9	SS-5	10	27	20	20	
	24/18	SS-6	18	10	32	37	Dark gray, SILT and CLAY, trace gravel. (ML/CL) Dark gray, SAND, little silt. (SM) Dark gray, SILT and CLAY, trace gravel. (ML/CL)
30	24/23	SS-7	2	6	12	18	
	24/24	SS-8	2	6	7	7	
35	24/20	SS-9	2	8	11	20	
							Augered to 34 ft. / Sampled from 18 to 36 ft.. The water level was measured at 28.25 ft. b.g.s.- While the bottom of the augers were 30.0 ft. b.g.s.. No radiation detected above background by R/S.

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84

See 0401 for sampling 0-18 feet

SHEET 1 OF: 3	# BORING LOG	HOLE/WELL NO.:	0410
DATE STARTED: 11/10/89		SURFACE ELEVATION:	1,417.15
DATE FINISHED: 11/29/89			
DRILLER: Empire Soils Inv. Hamburg, New York	DAMES & MOORE	NORTHING	892,834.68
INSPECTOR: JTB		EASTING	480,426.42
PROJECT: WVDP DOE/RCRA wells		LOCATION:	SOUTHWEST OF CTS
JOB NUMBER: 10805-410-023		SSWMU Locale:	4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6, 12 / 18	BLOWS ON SAMPLER 6 / 12, 18 / 24	LITHOLOGY	DESCRIPTION / NOTES
0–2						Damp, brown to red, SILT, trace fine sand and clay, trace angular gravel, some orange mottling. (ML)
5						Wet to saturated, brown, SILT and fine to coarse GRAVEL, trace fine to medium sand, orange mottling. (GM)
10						Wet, brown, SILT and fine to medium angular GRAVEL, trace fine to medium sand, trace clay, mottled. (GM)
15						Damp, brown, SILT, trace sand, oxidized. (ML)
						Damp, gray, SILT, little fine to medium angular to subangular gravel, trace clay, unweathered. (ML)
						Wet, gray, SILT and CLAY, trace angular to subangular gravel. (ML)
20	24/21	SS-1	7 / 17	14 / 21		Saturated, gray, silty CLAY, trace fine sand and gravel. (CL)
	24/24	SS-2	8 / 15	12 / 20		
25	24/23	SS-3	6 / 10	8 / 14		Wet, gray, fine SAND, some silt, trace clay. (SM) Saturated, gray, CLAY, little silt, little very fine sand, trace gravel. (CL)
	24/23	SS-4	4 / 7	5 / 10		Wet, gray, fine SAND and SILT, little clay at 26.0 ft. b.g.s.
	24/24	SS-5	6 / 13	6 / 18		
30	24/23	SS-6	13 / 18	16 / 25		Saturated, gray, fine SAND and SILT, trace gravel and clay. (SM)
	24/15	SS-7	16 / 11	10 / 12		Wet, gray, SILT, little fine sand, trace clay, trace fine to medium subangular gravel. (ML)
35	24/3	SS-8	13 / 26	16 / 21		
	24/19	SS-9	7 / 11	7 / 13		
	24/14	SS-10	12 / 9	10 / 14		Wet, gray, SILT, little clay, trace fine sand, trace fine gravel. (CL)

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84
SEE 0403 FOR ADDITIONAL SAMPLING

SHEET 2 OF: 3 DATE STARTED: 11/10/89 DATE FINISHED: 11/29/89 DRILLER: Empire Soils Inv. Hamburg, New York INSPECTOR: JTB	# BORING LOG DAMES & MOORE	HOLE/WELL NO.: 0410 SURFACE ELEVATION: 1,417.15 NORTHING 892,834.68 EASTING 480,426.42

PROJECT: WVDP DOE/RCRA wells
JOB NUMBER: 10805-410-023

LOCATION: SOUTHWEST OF CTS
SSWMU Locale: 4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6	6 / 12	12 / 18	18 / 24	LITHOLOGY	DESCRIPTION / NOTES
	24/14	SS-11	WOR	WOR	15	19		Saturated, gray, silty CLAY, trace fine gravel. (CL)
	24/18	SS-12	7	11	20	30		
45	24/12	SS-13	10	23	38	39		Moist to wet, gray, SILT, little fine to medium gravel, trace fine sand, trace clay. (ML)
	24/11	SS-14	12	21	44	50		Moist, brown, SILT, little fine to coarse gravel and clay , trace fine sand. (ML)
	24/23	SS-15	WOR3	24	28	30		Moist, brownish-gray, SILT, some fine to coarse gravel, trace clay. (ML/CL)
50	24/24	SS-16	8	15	23	30		Moist, gray, SILT, little fine to medium subangular gravel. (ML)
	24/23	SS-17	8	17	20	21		
55	24/0	SS-18	12	18	22	31		
	24/24	SS-19	10	13	17	22		
	24/24	SS-20	11	17	20	22		
60	24/24	SS-21	WOR	WOR	11	17		Saturated, gray, silty CLAY, trace fine to medium gravel. (CL)
	24/18	SS-22	25	28	50	42		Damp, green, fine SAND, trace angular gravel (shale), little silt. (SP)
65	24/19	SS-23	10	50	36	19		
	24/20	SS-24	14	13	69	27		Wet, medium brown, SILT, some clay, trace fine to medium gravel. (ML)
	24/21	SS-25	8	15	18	21		Moist to wet, gray, SILT, little clay, trace gravel, trace sand. (ML)
70	24/13	SS-26	WOR6	7	11	18		
	24/24	SS-27	6	7	11	15		
75	24/24	SS-28	8	9	12	16		Moist to wet,brownish-gray, SILT, little clay, trace sand, blueish-gray mottling. (ML)
	24/17	SS-29	14	22	49	107		Moist, brown to green, silty SAND. (SM) Moist, gray, SILT and fine to coarse subangular GRAVEL, little fine to medium sand. (ML/GM)
	24/17	SS-30	25	33	34	30		

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84
SEE 0403 FOR ADDITIONAL SAMPLING

BORING LOG

DAMES & MOORE

SHEET 3 OF: 3	HOLE/WELL NO.: 0410
DATE STARTED: 11/10/89	SURFACE ELEVATION: 1,417.15
DATE FINISHED: 11/29/89	
DRILLER: Empire Soils Inv. Hamburg, New York	NORTHING 892,834.68
INSPECTOR: JTB	EASTING 480,426.42
PROJECT: WVDP DOE/RCRA wells	LOCATION: SOUTHWEST OF CTS
JOB NUMBER: 10805-410-023	SSWMU Locale: 4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6 , 12 / 18	BLOWS ON SAMPLER 6 / 12 , 18 / 24	LITHOLOGY	DESCRIPTION / NOTES
	24/14	SS-31	9 28	22 78		Moist to wet, gray, SHALE and GRAVEL, trace silt, trace sand. (GM)
	24/7	SS-32	200/.3			Moist to wet, gray, SHALE and SILT, little fine sand, thin-bedded, fissile. Shale bedrock.
85	24/0	SS-33	100/.2			Augered to 83.5 ft.. Sampled to 82.5 ft.. The water level was measured at 7 ft. b.g.s- while the bottom of the augers were 32 ft. b.g.s.. No radiation detected above background by R/S.
90						
95						
100						
105						
110						
115						

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84
SEE 0403 FOR ADDITIONAL SAMPLING

SHEET 1 OF: 2	# BORING LOG	HOLE/WELL NO.:	0411b
DATE STARTED: 3/27/90		SURFACE ELEVATION:	1,416.76
DATE FINISHED: 3/29/90			
DRILLER: Empire Soils Inv. Hamburg, New York	DAMES & MOORE	NORTHING	892,657.72
INSPECTOR: JTB		EASTING	480,509.12
PROJECT: WVDP DOE/RCRA wells		LOCATION:	WEST OF TRAILER J
JOB NUMBER: 10805-410-023		SSWMU Locale:	4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 , 12/18	BLOWS ON SAMPLER 6/12 , 18/24	LITHOLOGY	DESCRIPTION / NOTES
						Medium brown, silty GRAVEL and SAND. (OL/GP)
5						
						Medium brown, SAND and GRAVEL, some silt. (SM)
10						
15						Medium brown, clayey SILT, trace gravel, trace sand. (ML)
						Dark gray, SILT, some clay, trace gravel. (ML)
20						
						Dark gray, SILT, some clay, trace gravel. (ML)
25						Dark gray, fine SAND, trace silt. (SP) Dark gray, GRAVEL and SAND, trace silt. (GP/GM) Dark gray, fine SAND, some silt, little gravel. (SM)
30						Dark gray, SILT and CLAY, trace gravel. (ML/CL) Dark gray, SAND, little silt. (SM) Dark gray, SILT and CLAY, trace gravel. (ML/CL)
35	24/18	SS-1	4 7	5 8		Saturated, gray, SILT, some clay, little fine to medium sand, trace fine to medium subangular to angular gravel, slightly plastic, medium plastic. (ML/CL)
	24/18	SS-2	3 11	8 19		
	24/8	SS-3	7 18	7 24		Saturated, gray, SILT and CLAY, trace fine to medium subangular to angular gravel, medium stiff. (ML/CL)

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84
SEE 0401 & 0402 FOR ADD'L SAMPLING

SHEET 2 OF: 2	BORING LOG	HOLE/WELL NO.: 0411b
DATE STARTED: 3/27/90		SURFACE ELEVATION: 1,416.76
DATE FINISHED: 3/29/90		
DRILLER: Empire Soils Inv. Hamburg, New York	DAMES & MOORE	NORTHING 892,657.72
INSPECTOR: JTB		EASTING 480,509.12

PROJECT: WVDP DOE/RCRA wells

JOB NUMBER: 10805-410-023

LOCATION: WEST OF TRAILER J

SSWMU Locale: 4

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 / 12/18	BLOWS ON SAMPLER 6/12 / 18/24	LITHOLOGY	DESCRIPTION / NOTES
	24/15	SS-4	17 / 23	17 / 30		Wet, dark gray, SILT, some clay, trace fine to coarse subangular to subrounded gravel, trace fine sand, slightly plastic, dense. (ML/CL)
	24/24	SS-5	20 / 35	30 / 31		
45	24/24	SS-6	31 / 34	30 / 38		
	24/18	SS-7	53	100 / 100/.2		Saturated, greenish-gray, mostly fine to coarse GRAVEL and fine to medium SAND, trace silt, trace clay. (GM)
	24/3	SS-8				Saturated, gray, medium to coarse GRAVEL, trace silt, trace clay, trace fine sand. (GM)
50	24/18	SS-9	68 / 84	52 / 59/.4		Wet, gray, black, greenish, medium SAND. (SM)
	24/10	SS-10	80	100/.3		Moist, greenish, fine to coarse GRAVEL, little silt, trace sand. Dry, medium to coarse GRAVEL, trace fine sand, trace silt, dense, undisturbed till. (GM)
55	24/12	SS-11	39 / 48	59 / 36		Wet, greenish-gray, silty SAND and fine to medium subangular to subrounded GRAVEL, trace clay. (GM)
	24/18	SS-12	9 / 17	21 / 23		
	24/12	SS-13	15 / 14	15 / 11		Saturated, greenish-gray, fine to medium GRAVEL and fine to medium SAND, little silt, trace clay. (GM)
60	24/8	SS-14	12 / 20	16 / 21		
	24/10	SS-15	28 / 21	15 / 23		
65	24/6	SS-16	30 / 30	31 / 38		Saturated, greenish-gray, silty SAND and fine to medium GRAVEL, trace clay, loose. (GM)
	24/12	SS-17	5 / 14	9 / 17		Moist to wet, gray, SILT and CLAY, trace fine to medium subangular to subrounded gravel, medium stiff. (ML/CL)
	24/18	SS-18	5 / 16	7 / 15		
70						Augered to 68.0 ft.. Sampled to 70.0 ft.. The water level was measured at 44.8 ft. b.g.s. - while the bottom of the augers were at 68.0 ft. b.g.s.. No radiation was detected above background by R/S.
75						

CLASSIFICATION: VISUAL (Modified Burmister),USCS

METHOD OF SAMPLING: ASTM D1586-84

SEE 0401 & 0402 FOR ADD'L SAMPLING

BORING LOG

Dames & Moore

HOLE/WELL NO.:	UR-1	SHEET 1 OF:	2
DATE STARTED:	9/27/91	SURFACE ELEVATION:	1408.10
DATE FINISHED:	9/30/91	GROUNDWATER DEPTH:	1
DRILLER:	EMPIRE SOILS HAMBURG, NY	MEASUREMENT DATE:	9/30/91
		NORTHING:	892694.05
INSPECTOR:	F. J. COHEN	EASTING:	480857.12
PROJECT:	UR EXPANSION	LOCATION:	WVDP
JOB NUMBER:	10805-509	SWMU Locale:	3

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 ; 12/18	BLOWS ON SAMPLER 6/12 ; 18/24	UNIT	LITHOLOGY	DESCRIPTION / NOTES
0–5					S/G Unit		Gravelly fill at surface-augered to 5 ft.
5	24/15	SS-1	14 ; 18	16 ; 12	S/G Unit		Dry to damp medium to light brown SILT, some gray and white medium angular Gravel, some medium to coarse Sand, little clay. Crumbly. Some rust mottling. (GM)
10	24/10	SS-2	12 ; 19	13 ; 18	S/G Unit		Dry, light brown fine SAND, some medium to coarse subangular gray Gravel. (SP)
15	24/14	SS-3	10 ; 15	13 ; 15	S/G Unit		Moist light brown to greenish brown fine to coarse, subangular to subrounded GRAVEL, some Sand and Silt. Loose when disturbed. Trace rust mottling. (GM)
20	24/17	SS-4	18 ; 10	10 ; 11	S/G Unit		
25	24/17	SS-5	23 ; 15	12 ; 18	UTILL		Moist light brown CLAY, little silt, trace fine to medium sand. Grades to dark gray, some Silt, fine silty sandy layering at 1/8" intervals. (CL)
	24/24	SS-6	10 ; 14	14 ; 14	Coarse Unit		Wet gray fine to medium SAND. (SP) Grades to moist gray CLAY with silty laminations. (CL) Grades to wet light brown fine SAND, little medium to coarse sand and fine gravel. (SP) Grades to dark brown, medium to coarse SAND. (SP)
30	24/12	SS-7	7 ; 3	3 ; 4	Coarse Unit		Moist light brown CLAY, little silt, little medium to coarse gravel. (CL) Grades to saturated light brown fine to medium SAND. (SW) Grades to medium to coarse SAND and fine to medium GRAVEL. (SW)
35	24/11	SS-8	5 ; 7	7 ; 6	UTILL		Damp brown CLAY, little silt. Grades to dark gray. Laminated, with fine silty sandy partings. (CL)
	24/12	SS-9	9 ; 14	12 ; 13	UTILL		

CLASSIFICATION: VISUAL (MODIFIED BURMISTER), USCS METHOD OF SAMPLING: ASTM D1586-84

HOLE/WELL NO.:	UR-1	# BORING LOG	SHEET 2 OF:	2
DATE STARTED:	9/27/91		SURFACE ELEVATION:	1408.10
DATE FINISHED:	9/30/91		GROUNDWATER DEPTH:	13
DRILLER:	EMPIRE SOILS HAMBURG, NY	Dames & Moore	MEASUREMENT DATE:	9/30/91
			NORTHING:	892694.05
INSPECTOR:	F. J. COHEN		EASTING:	480857.12
PROJECT:	UR EXPANSION		LOCATION:	WVDP
JOB NUMBER:	10805-509		SWMU Locale:	3

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 12/18	BLOWS ON SAMPLER 6/12 18/24	UNIT	LITHOLOGY	DESCRIPTION / NOTES
	24/16	SS-10	14 / 8	10 / 12			Damp to moist gray-green fine to medium GRAVEL, some Clay and Silt. (GM/GC)
							Grades to damp dark gray CLAY and SILT, grades to fine sandy silty CLAY. (CL/ML)
45							Augered to 40 ft. Sampled to 42 ft. Water encountered at 5.5 ft. Boring grouted to surface.
50							
55							
60							
65							
70							
75							

CLASSIFICATION: VISUAL (MODIFIED BURMISTER), USCS | METHOD OF SAMPLING: ASTM D1586-8

BORING LOG

Dames & Moore

HOLE/WELL NO.:	UR-2	SHEET 1 OF:	1
DATE STARTED:	10/01/91	SURFACE ELEVATION:	1407.99
DATE FINISHED:	10/02/91	GROUNDWATER DEPTH:	13.2
DRILLER:	EMPIRE SOILS HAMBURG, NY	MEASUREMENT DATE:	10/02/91
		NORTHING:	892674.56
INSPECTOR:	J.T.B. & F.J.C.	EASTING:	480826.50
PROJECT:	UR EXPANSION	LOCATION:	WVDP
JOB NUMBER:	10805-509	SWMU Locale:	3

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 – 12/18	BLOWS ON SAMPLER 6/12 – 18/24	UNIT	LITHOLOGY	DESCRIPTION / NOTES
0							Gravelly fill at surface-augered to 5'.
5	24/16	SS-1	13 / 15	13 / 16	S/G UNIT		Wet grayish-brown very fine SAND and fine to medium subangular GRAVEL, little silt, loose. (SP) Grades to damp light brown-yellow very fine sandy SILT and fine to medium subangular GRAVEL, trace clay, firm to friable, oxidized, mottled, non-plastic. (Rock in end of spoon) (GM)
10	24/12	SS-2	20 / 11	10 / 9	S/G UNIT		Grades to moist. (GM)
15	24/15	SS-3	16 / 9	12 / 8	S/G UNIT		Moist coarse angular GRAVEL, some brown Silt and Clay, little coarse sand. (GM)
20	24/0	SS-4	6 / 3	5 / 7	S/G UNIT		
	24/3	SS-5	WOR / -	- / -	S/G UNIT		Grades to wet, some medium to coarse black, brown, gray Sand, little clay. (GW)
25	24/19	SS-6	6 / 9	7 / 10	UTILL		Moist gray CLAY, little silt and fine to medium sand, trace gravel. Grades to brown, layering at 1/8" intervals, some silty partings. (CL)
30	24/11	SS-7	6 / 6	7 / 5	Coarse Unit		5" Wet fine to coarse subangular SAND and medium to coarse black, pink, gray GRAVEL, some clay, little silt. (SW)
35	24/14	SS-8	20 / 10	17 / 9	Coarse Unit		Wet brown-gray SILT, some medium angular Gravel. (GM) Grades to wet gray-green fine to medium SAND, some medium to coarse subangular Gravel, little clay. (SW) Grades to moist gray CLAY, little silt, little medium gravel and sand. (CL)
							Augered to 37 ft.- Grouted to surface.

CLASSIFICATION: VISUAL (MODIFIED BURMISTER), USCS   METHOD OF SAMPLING: ASTM D1586-84

BORING LOG

Dames & Moore

HOLE/WELL NO.:	UR-3	SHEET 1 OF:	2
DATE STARTED:	10/02/91	SURFACE ELEVATION:	1407.77
DATE FINISHED:	10/04/91	GROUNDWATER DEPTH:	20
DRILLER:	EMPIRE SOILS HAMBURG, NY	MEASUREMENT DATE:	10/02/91
		NORTHING:	892684.95
INSPECTOR:	F.J.C.	EASTING:	480807.97
PROJECT:	UR EXPANSION	LOCATION:	WVDP
JOB NUMBER:	10805-509	SWMU Locale:	3

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0/6 — 12/18	BLOWS ON SAMPLER 6/12 — 18/24	UNIT	LITHOLOGY	DESCRIPTION / NOTES
0–5							Gravelly fill at surface-augered to 5'.
5	24/18	SS-1	6 9	9 7	S/G UNIT		Dry brown fine to coarse subangular GRAVEL, gray, brown, light brown fine to medium SAND, little brown clay. (GW)
10	24/10	SS-2	12 7	7 8	S/G UNIT		
15	24/12	SS-3	4 7	6 6	S/G UNIT		Grades to wet. (GW)
20	24/9	SS-4	19 12	12 12	UTILL		Moist light brown CLAY, some Silt, some medium to coarse sand and fine subangular gravel. (CL)
25	24/16	SS-5	12 13	8 13	UTILL		Grades to dark gray. (CL)
30	24/14	SS-6	9 4	7 5	Coarse Unit		Wet brown, gray, black subangular to subrounded GRAVEL and medium to coarse SAND, some Clay, little silt. (GC) Wet brown fine to medium SAND, some fine Gravel. (SW) Grades to gray-green, some Clay. (SC/GC)
35	24/15	SS-7	25 14	10 9	UTILL		Wet gray CLAY, some Silt. (CL) Grades to damp, little fine to medium gravel, trace sand. (CL)
	24/15	SS-8	8 22	12 23	UTILL		
							Augered to 39 ft.-Grouted to surface.

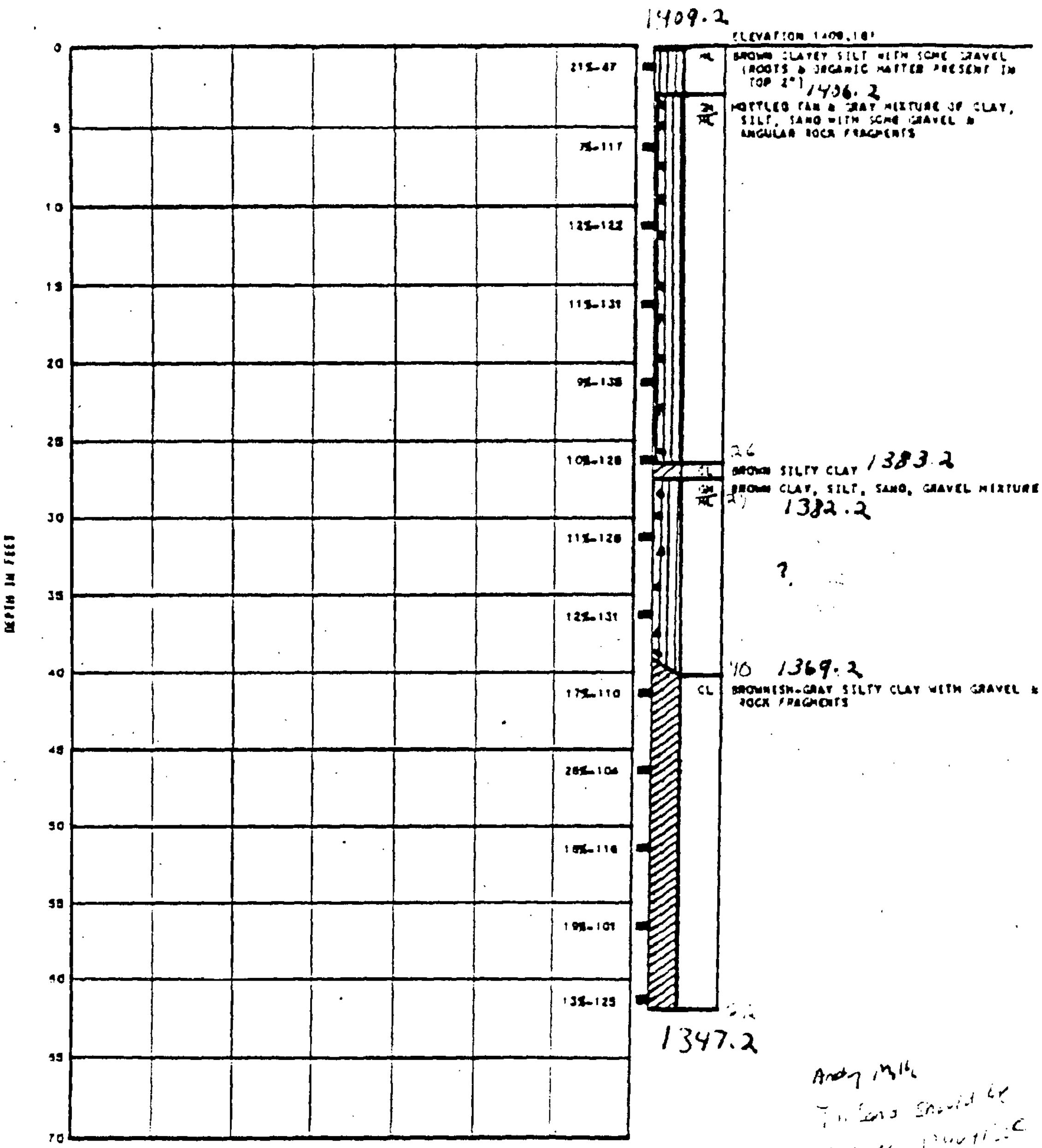
CLASSIFICATION: VISUAL (MODIFIED BURMISTER), USCS METHOD OF SAMPLING: ASTM D1586-84

16-62

o T/s

BORING 16

DRILLED 11-14,15,-62



Andy [illegible]
[illegible] should be between [illegible] [illegible] below the bottom of this boring and [illegible] rock [illegible] close to this bottom depth.

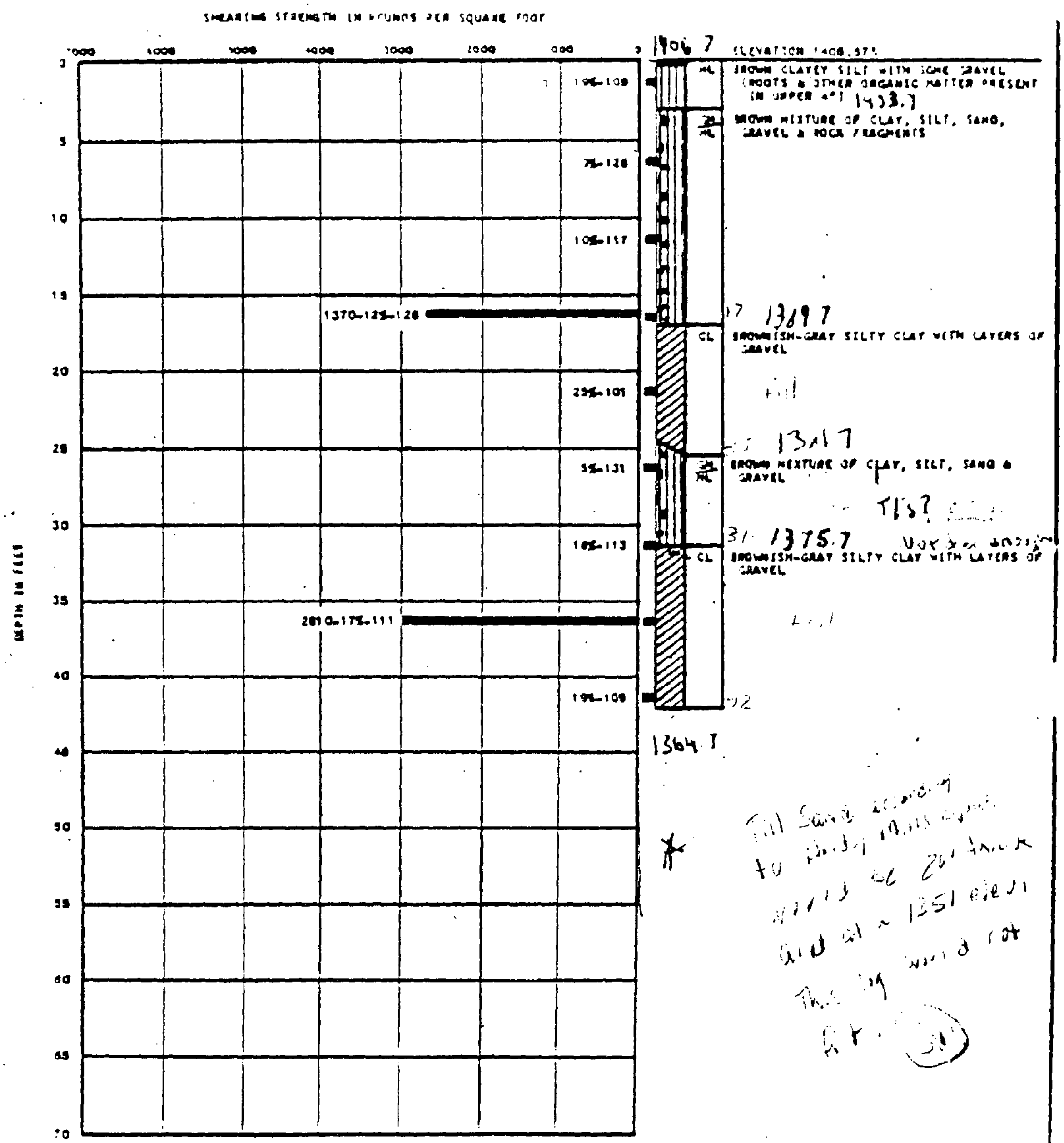
LOG OF BORINGS

LOG OF BORING 16

17-62

BORING 17

DRILLED 11-17-42



LOG OF BORINGS

LOG OF BORING 17

62-PAM63 Augered January 3, 1962. Lat 42°26'27", Long 78°37'58". Altitude 1,402.38 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-7 ft	Brown silt, trace to some sand and stone
7-40	Silt, some clay

62-PAM64 Augered January 3, 1962. Lat 42°26'27", Long 78°37'58". Altitude 1,407.13 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-6 ft	No samples taken; bottom of hole 6 ft (See log of PAM63)

62-PAM65 Augered January 4, 1962. Lat 42°26'40", Long 78°37'43". Altitude 1,433.10 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-5 ft	Brown silt, trace of clay and stone
5-16	Gray silt, some clay (soft and plastic)
16-21	Gray silt and angular shale fragments
21	Possible shale bedrock

62-PAM66 Augered January 4, 1962. Lat 42°26'50", Long 78°38'16". Altitude 1,388.74 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-5 ft	Moist brown silt, trace of clay
5-10	Wet gray silt and very fine sand
10-30	Wet gray silt, trace of very fine sand and clay
30-40	Wet gray silt, some clay (soft and plastic)

62-PAM67 Augered January 4, 1962. Lat 42°26'50", Long 78°38'16". Altitude 1,388.67 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-5 ft	Brown silt
5-7	Silt and very fine sand
7-9	Sand

62-PAM68 Augered January 5, 1962. Lat 42°26'41", Long 78°38'46". Altitude 1,395.40 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-10 ft	Moist brown silt, trace of clay
10-45	Moist gray silt, some clay, trace of stone (medium and plastic)

62-PAM69 Augered January 5-9, 1962. Lat 42°26'29", Long 78°39'17". Altitude 1,472.23 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-10	Moist brown silt, trace of clay
10-17	Dry brown silt, trace to some weathered shale
below 17	Probable shale bedrock

62-PAM70 Augered January 9, 1962. Lat 42°27'33", Long 78°39'30". Altitude 1,368.05 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-10	No samples taken; bottom of hole 10 ft (See log of PAM59)

62-PAM71 Augered January 10-11, 1962. Lat 42°27'01", Long 78°39'22". Altitude 1,422.52 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-17 ft	Brown silt, some stone and sand (hard)
17-23	Gray silt, trace of clay and stone (medium and plastic)
23-28	Gray sand and silt
28-36.5	Gray silt, trace to some clay, trace of stone and very fine sand (medium and plastic)

62-PAM72 Augered January 10,,1962. Lat 42°27'01", Long 78°39'22". Altitude 1,422.80 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-10 ft	No samples taken; bottom of hole 10 ft (See log of PAM71)

62-PAM73 Augered January 11, 1962. Lat 42°27'01", Long 78°39'22". Altitude 1,422.80 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-25 ft	No samples taken; bottom of hole 25 ft (See log of PAM71)

62-PAM74 Augered January 12, 1962. Lat 42°26'51", Long 78°39'22". Altitude 1,446.59 ft. Log from records of New York State Dept. of Public Works. Bureau of Soil Mechanics.

0-8 ft	Yellow brown silt, trace of sand and stone (hard)
8-17	Gray brown silt, trace to some weathered shale (very hard)
17-21	Brown silt, trace to some weathered shale and clay (very hard)
below 21	Probable shale bedrock

62-PAM75 Augered January 16, 1962. Lat 42°26'54", Long 78°38'00". Altitude 1,424.95 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

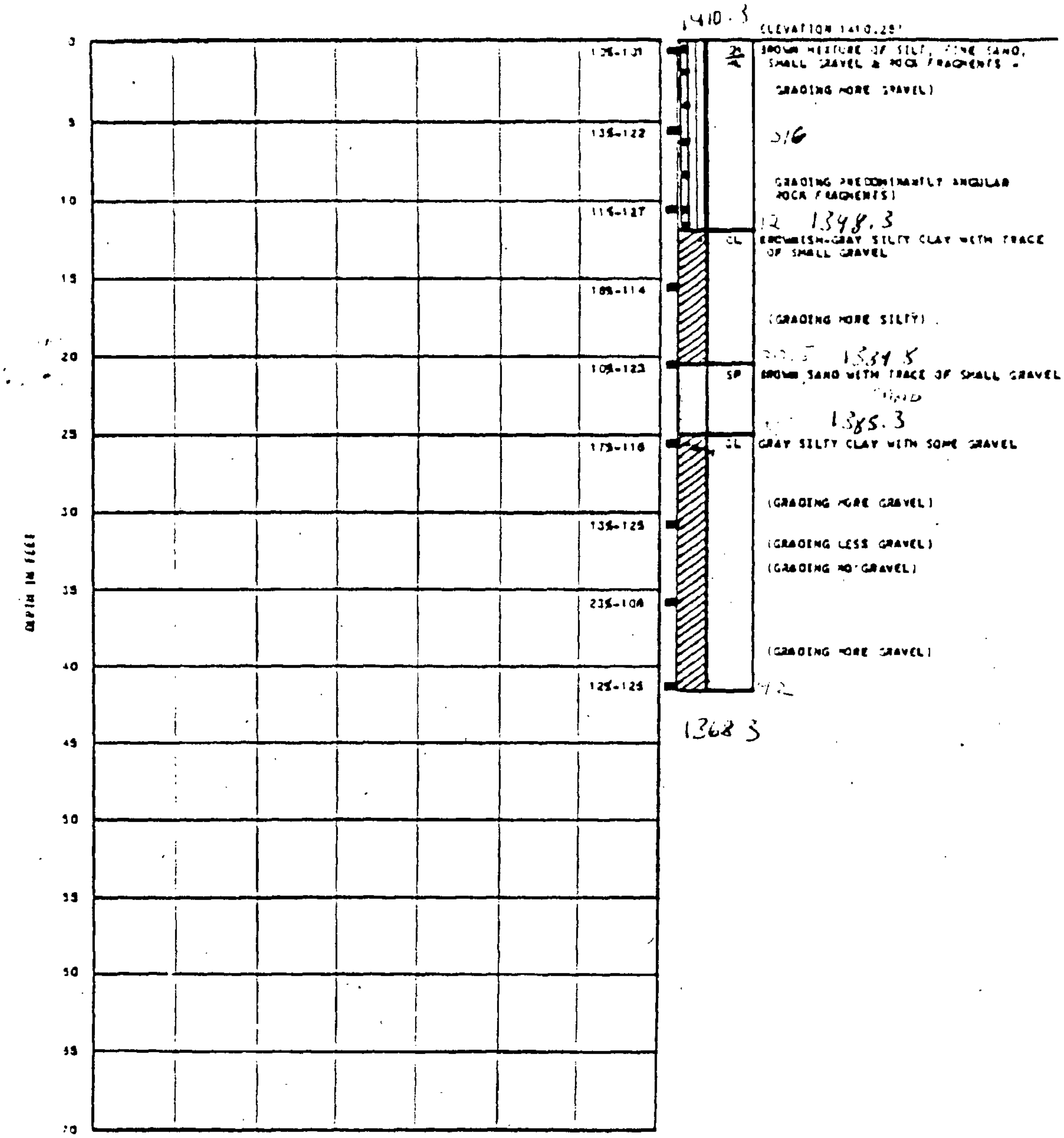
0-12 ft	No samples taken; bottom of hole 12 ft (See log of PAM95)

62-PAM76 Augered January 10, 1962. Lat 42°26'17", Long 78°39'56". Altitude 1,823.00 ft. Log from records of New York State Dept. of Public Works, Bureau of Soil Mechanics.

0-5 ft	Brown silt, trace of clay and stone
5-9	Gray brown silt, trace of shale fragments (angular) and clay
below 9	Probable shale bedrock

24-63

BORING 24



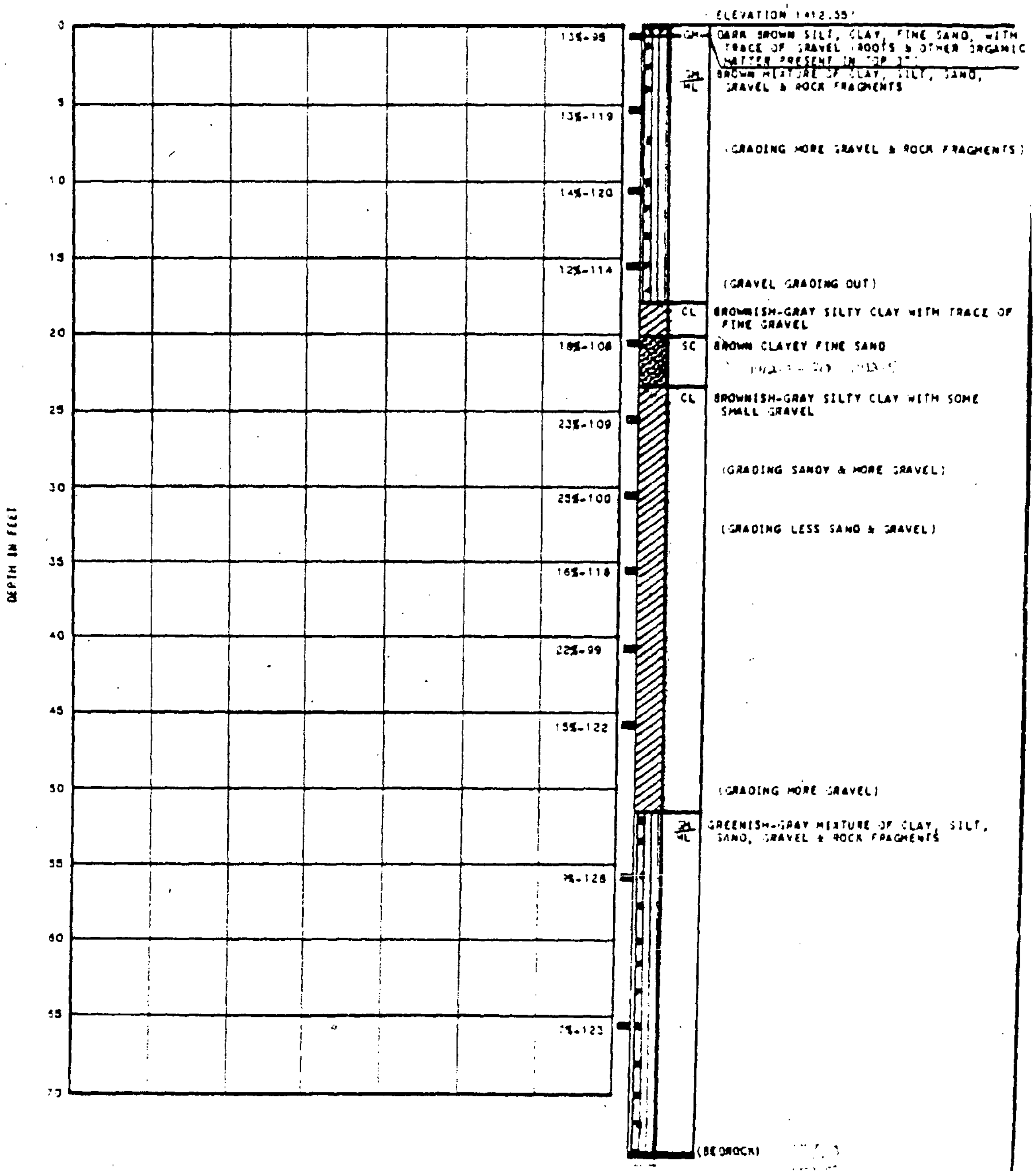
LOG OF BORINGS

LOG OF BORING 24

25-63

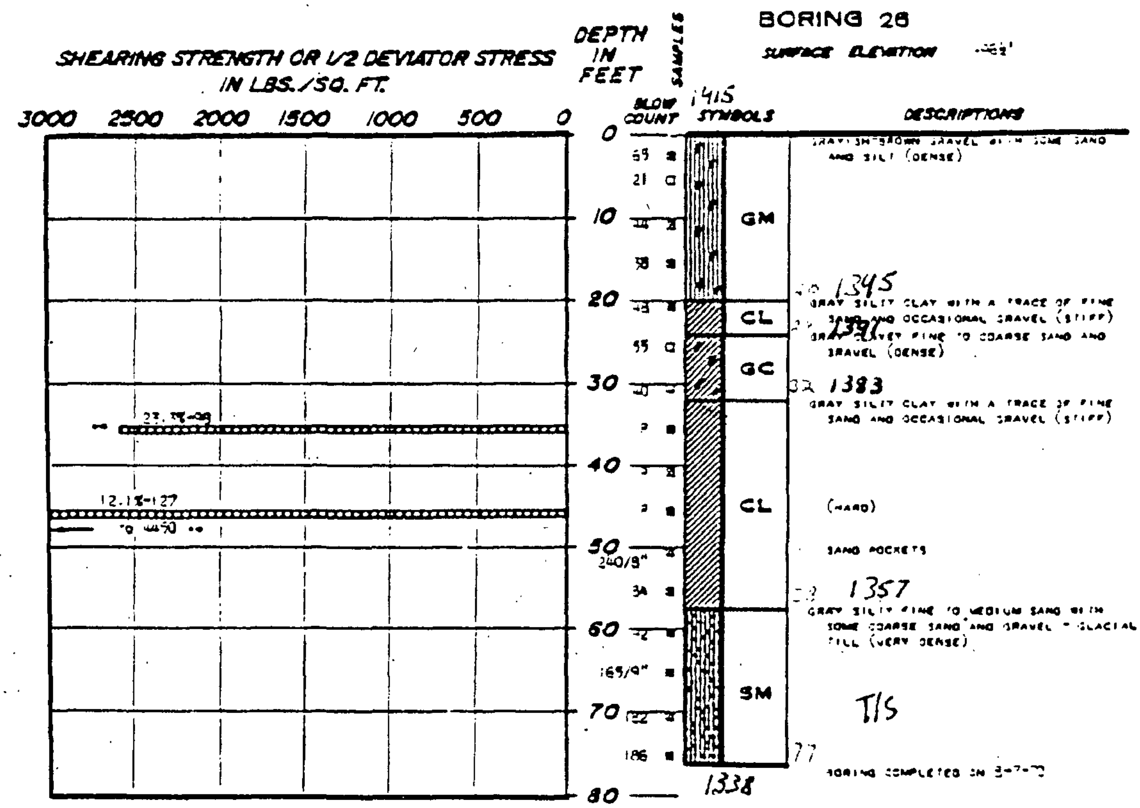
BORING 25

DRILLED 2-3-63



LOG OF BORINGS

LOG OF BORING 25



62+63 to 70+71

NOTES:

THE FIGURES IN THE COLUMN LABELED "BLOW COUNT" REFER TO THE NUMBER OF BLOWS REQUIRED TO DRIVE THE DAMES & MOORE SOIL SAMPLER, OR A STANDARD SPLIT-SPOON SAMPLER, A DISTANCE OF ONE FOOT USING A 100-POUND HAMMER FALLING 24 INCHES. THE DAMES & MOORE SAMPLER IS 3¼" O.D. AND APPROXIMATELY 2½" I.D. THE STANDARD SPLIT-SPOON SAMPLER IS 2" O.D. AND [illegible] I.D.

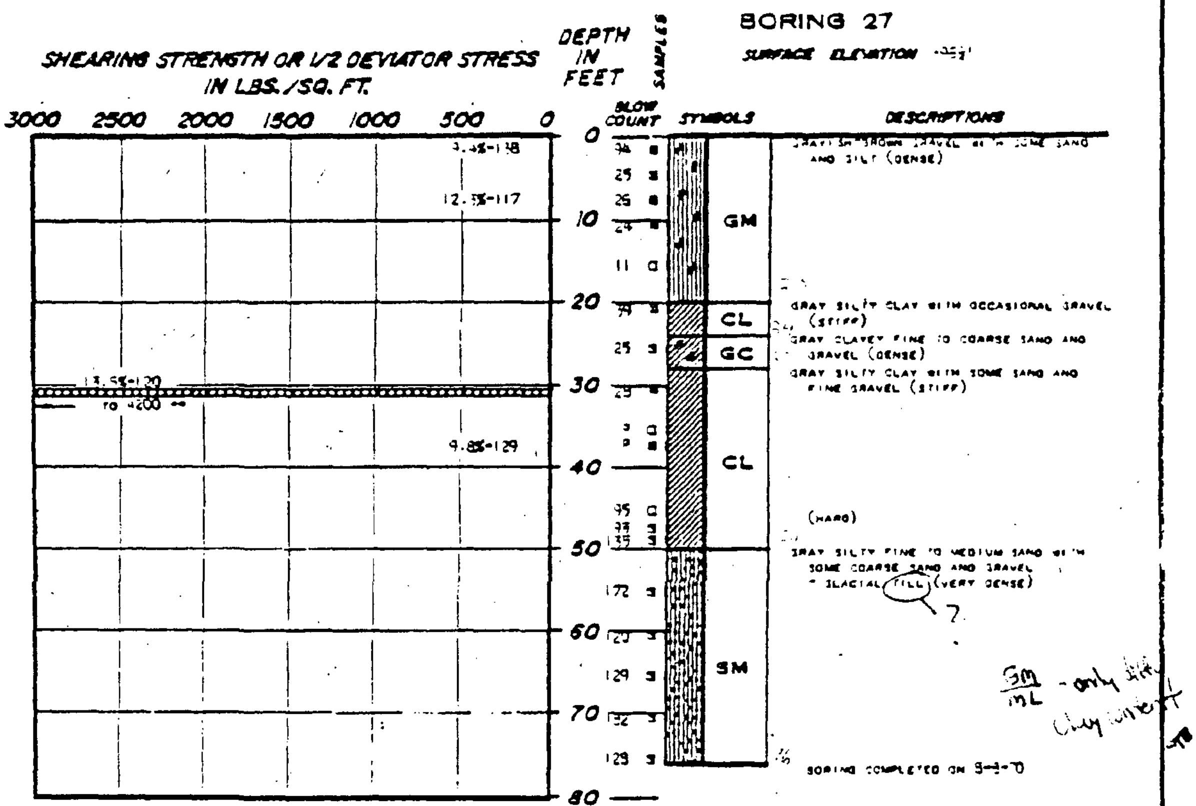
THE LETTER "P" IN THE "BLOW COUNT" COLUMN INDICATES THAT THE SAMPLER WAS ADVANCED BY MEANS OF HYDRAULIC PRESSURE, WITHOUT DRIVING.

ELEVATIONS REFER TO PLANT DATUM.

THE DISCUSSION IN THE TEXT OF THE REPORT IS NECESSARY FOR A PROPER UNDERSTANDING OF THE NATURE OF THE SUBSURFACE MATERIALS.

LOG OF BORING 26

27 - 70



LOG OF BORING

LOG OF BORING 27

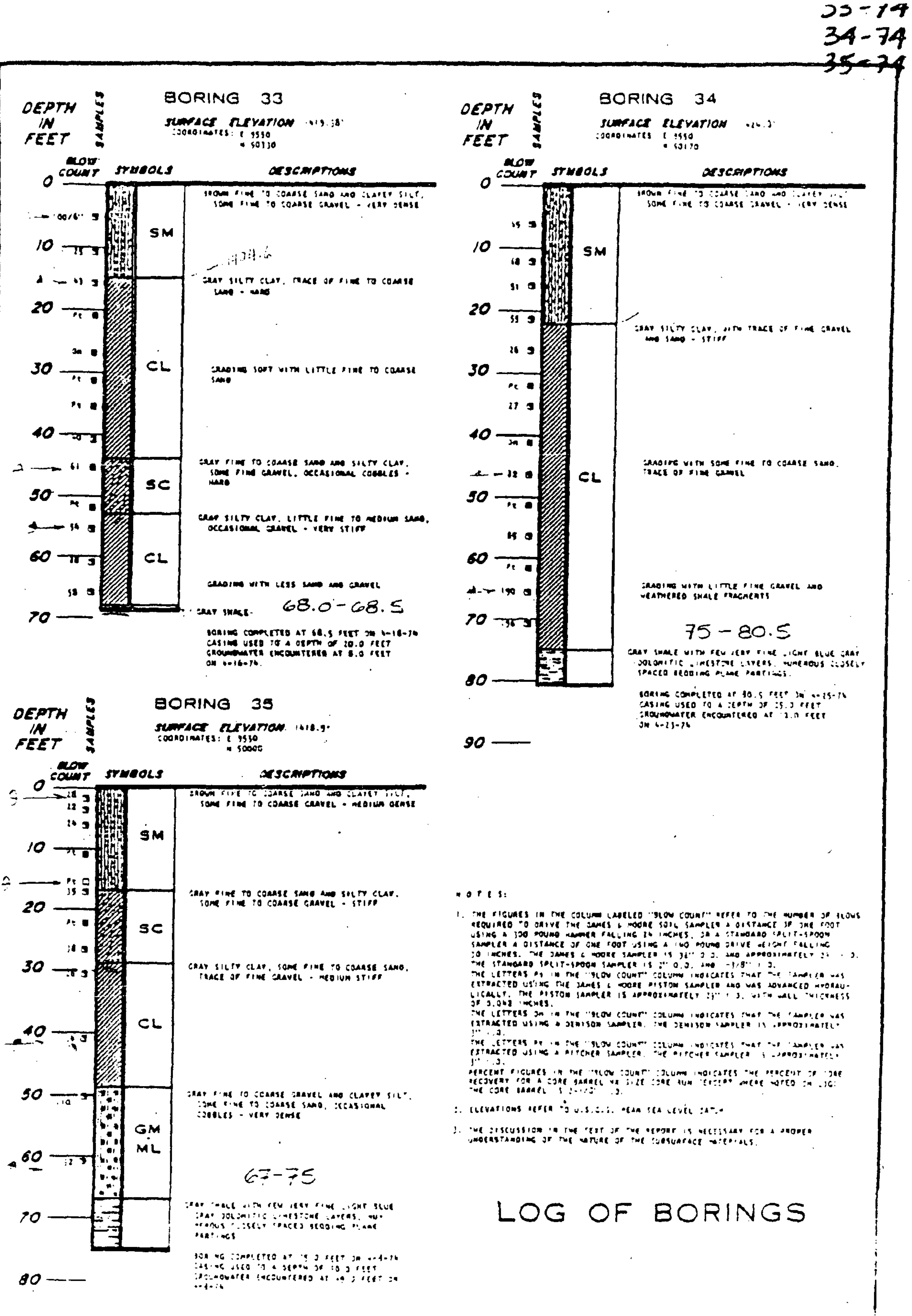
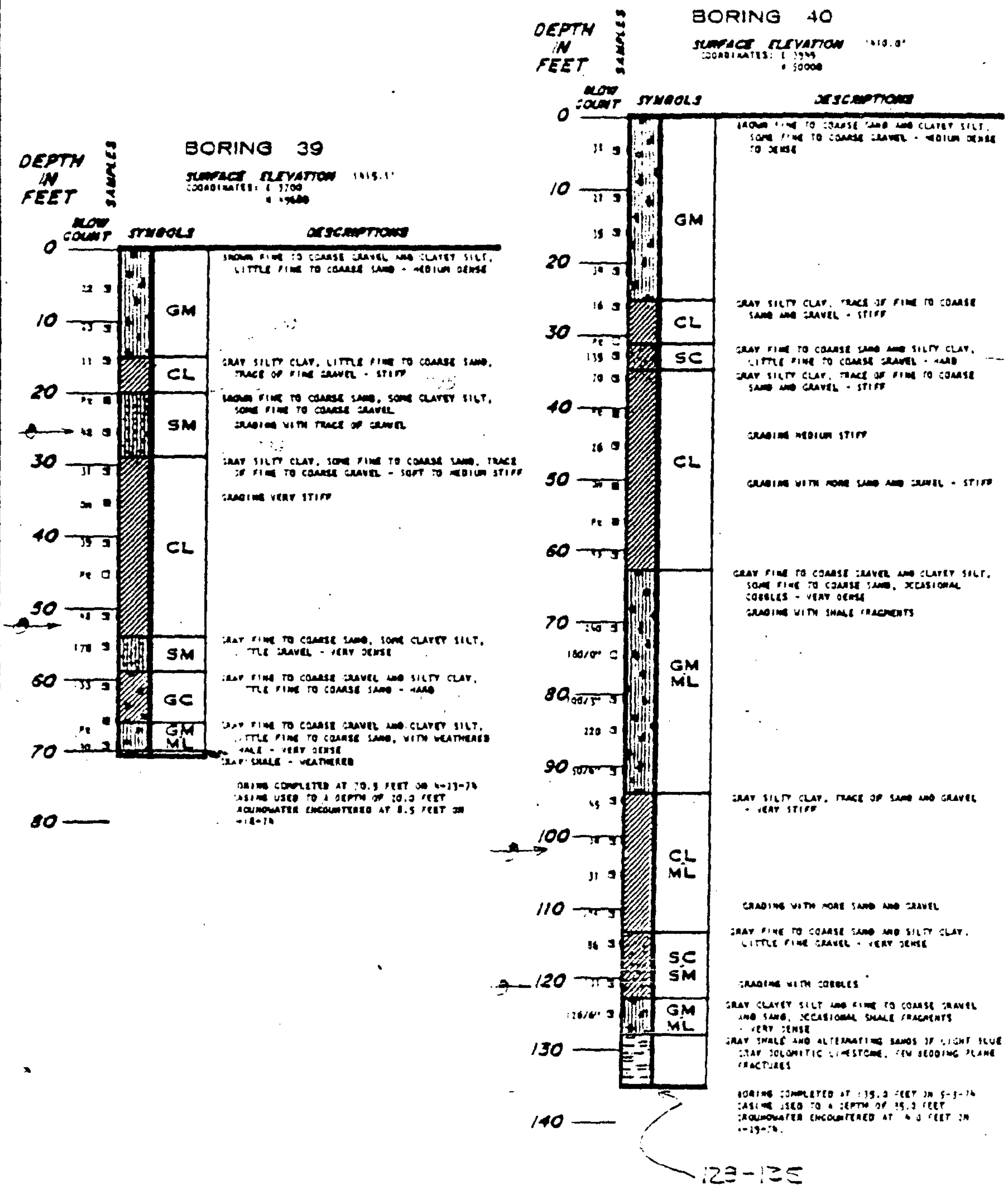


FIGURE A.3.6-B-27 LOG OF BORING 33, 34, & 35

39-74
40-74



LOG OF BORINGS

FIGURE A.3.6-B-29 LOG OF BORING 39 & 40

NOTES ON REVIEW OF THIS RESPONSE TO RAI 5C15

The following response to RAI 5C15 was prepared considering the preliminary results of the additional STOMP groundwater modeling that suggested the results of this modeling would not impact the DCGLs or cleanup goals. However, later STOMP modeling results have shown that upward diffusion of radioactivity from the bottoms of the remediated deep excavations will increase radioactivity concentrations in the well water, resulting in increased dose through the drinking water exposure pathway. Initial indications are that this exposure scenario will be more limiting that the base-case cistern installation, resident farmer scenario used for development of subsurface soil DCGLs.

Revision of the subsurface soil DCGLs and cleanup goals is expected to be necessary, reducing them by amounts to be determined by additional analyses. The preliminary dose assessments for the WMA 1 and WMA 2 excavated areas based on available data on radioactivity within the unweathered Lavery till will also have to be revised and are expected to increase. The additional analyses will entail a combination of STOMP groundwater modeling and RESRAD modeling.

The values in the tables of this response expected to be revised are highlighted (but not the similar tables in Appendix E).

Additional changes to the DP will be necessary. Some are being described in the response to RAI 5C9. Others will be included in a revised response to this RAI. Preparation of this revised response will be coordinated with the revision to the response to RAI 5C9.

RAI 5C15 (20)

Subject: Conservatism in model input parameters

RAI: DOE did not provide sufficient support that the selection of parameter values in the deterministic analysis is sufficiently conservative to demonstrate compliance with LTR criteria. (Section 5.2.4)

Basis: When performing deterministic analysis to demonstrate compliance with radiological criteria for license termination it is important to demonstrate that the selection of parameter values does not lead to a significant under-prediction of the potential risk to the average member of the critical group for a 1000 year compliance period. Due to the large number of radionuclides and limited characterization, it is difficult to select a global parameter set that is demonstrably conservative for the actual mix of radionuclides expected to remain at the site following remediation. For example, if water-dependent pathways dominate the dose, then distribution coefficients (K_ds) on the low end of the distribution (lower quartile) may be conservative. But, if water-independent pathways dominate the dose, then K_ds on the high end of the distribution (upper quartile) may be conservative. Several important parameter values were identified in the sensitivity analysis (e.g., distribution coefficients, various parameters/model affecting groundwater dilution, bioaccumulation factors); however, DOE did not evaluate the sensitivity of the results to all parameter values and it is not clear how DOE made changes to its selection of parameter values to ensure that the deterministic analysis is sufficiently conservative.

Path Forward: DOE should provide support that the selection of parameter values in the deterministic analysis does not significantly under-predict the potential risk associated with residual material remaining at the site following remediation. Using what limited characterization data is available, DOE should identify the key risk drivers and indicate how the parameter selection is conservative for these radionuclides. In the absence of sufficient information on radionuclide distributions, DOE should consider use of pathway- or radionuclide-dependent parameter sets that would tend to over-estimate rather than under-estimate the potential dose when considering the potential uncertainty associated with the dose calculations.

****

DOE Response: The DOE letter that forwarded Revision 0 of the DP to NRC for review (DOE 2008) noted that the issue regarding the sufficiency of conservatism in conceptual model input parameters was still under evaluation when Revision 0 was completed. To address this issue, DOE has performed probabilistic uncertainty analyses 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. DOE has also changed some of the input parameters in the conceptual models.

Input Parameter Changes and the Effects on the Deterministic Model Results

The input parameter changes apply to both the deterministic models and the probabilistic analyses. These parameter changes and the reasons for them are identified in the response to RAI 5C12, which provides a revised version of Appendix C.

The results of these changes on the deterministic DCGLs were as follows:

- The revised deterministic surface soil DCGLs were generally slightly lower than original DCGLs, as indicated in the response to RAI 5C4;

- The revised subsurface soil DCGLs were generally slightly higher than the original DCGLs, as indicated in the response to RAI 5C6; and
- The streambed sediment DCGLs were essentially the same as before, as indicated in the response to RAI 5C12.

Probabilistic Uncertainty Analyses

The probabilistic uncertainty analyses supplement the deterministic sensitivity analyses described in Section 5 of the DP. These analyses generated results that quantify the total uncertainty in the DCGLs resulting from the variability of key input parameters, and also provide perspective regarding 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.

The analyses were performed using the probabilistic modules of RESRAD version 6.4, which utilize Latin hypercube sampling, 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 were selected randomly from probability distribution functions for each parameter of interest. A new appendix was prepared for the DP to provide details of the analyses; a copy of this appendix is provided below following a description of the other changes being made to the DP as a result of the analyses.

Table 5C15-1 identifies the input parameters treated in a probabilistic manner during the analyses and the distribution used for each parameter.

Table 5C15-1. Probabilistic Parameter Distributions

Parameter	Distribution	Conceptual Model		
		Surface	Subsurface	Streambed Sediment
Contamination zone thickness	triangular	√		
Length parallel to aquifer flow	triangular	√		
Saturated zone hydraulic conductivity	triangular	√		
Well pumping rate	bounded normal	√	√	
Irrigation rate	bounded normal	√	√	
Indoor time fraction	triangular	√	√	
Outdoor time fraction	triangular	√	√	√
Unsaturated zone hydraulic conductivity	triangular	√		
Contaminated zone hydraulic conductivity	triangular	√		√
Root depth	uniform	√	√	
Precipitation rate	bounded	√	√	√

Table 5C15-1. Probabilistic Parameter Distributions

Parameter	Distribution	Conceptual Model		
	normal			
External gamma shielding factor(1)	triangular	√	√	
Biotransfer factors (plant/meat/milk)	triangular	√	√	√(2)
Kd values for each zone	bounded lognormal	√	√	√

NOTES: (1) Cs-137 and U-232 only.
(2) Fish transfer factor applies to the sediment model, but not milk transfer factor.

Table 5C15-2 summarizes the results of the analyses.

Table 5C15-2. Summary of Results of Probabilistic Uncertainty Analyses(1)

Nuclide	Surface Soil DCGLs (pCi/g)		Subsurface Soil DCGLs (pCi/g)		Streambed Sediment DCGLs (pCi/g)	
	Determ(2)	Peak-of-the-Mean(3)	Limiting Determ(4)	Peak-of-the-Mean(3)	Determ(5)	Peak-of-the-Mean(3)
Am-241	4.3E+01	2.9E+01	7.1E+03	6.8E+03	1.6E+04	1.0E+04
C-14	2.0E+01	1.6E+01	3.7E+05	7.2E+05	3.4E+03	1.8E+03
Cm-243	4.1E+01	3.5E+01	1.2E+03	1.1E+03	3.6E+03	3.1E+03
Cm-244	8.2E+01	6.5E+01	2.3E+04	2.2E+04	4.8E+04	3.8E+04
Cs-137(6)	2.4E+01	1.5E+01	4.4E+02	3.0E+02	1.3E+03	1.0E+03
I-129	3.5E-01	3.3E-01	5.2E+01	6.7E+02	3.7E+03	7.9E+02
Np-237	9.5E-02	2.6E-01	4.3E+00	9.3E+01	5.2E+02	3.3E+02
Pu-238	5.0E+01	4.0E+01	1.5E+04	1.4E+04	2.0E+04	1.2E+04
Pu-239	4.5E+01	2.5E+01	1.3E+04	1.2E+04	1.8E+04	1.2E+04
Pu-240	4.5E+01	2.6E+01	1.3E+04	1.2E+04	1.8E+04	1.2E+04
Pu-241	1.4E+03	1.2E+03	2.4E+05	2.5E+05	5.1E+05	3.4E+05
Sr-90(6)	6.4E+00	4.1E+00	3.2E+03	3.4E+03	9.5E+03	4.7E+03
Tc-99	2.6E+01	2.1E+01	1.1E+04	1.4E+04	2.2E+06	6.6E+05
U-232	5.9E+00	1.5E+00	1.0E+02	7.4E+01	2.6E+02	2.2E+02
U-233	1.9E+01	8.3E+00	1.9E+02	9.9E+03	5.7E+04	2.2E+04
U-234	2.0E+01	8.5E+00	2.0E+02	1.3E+04	6.0E+04	2.2E+04
U-235	1.9E+01	3.5E+00	2.1E+02	9.3E+02	2.9E+03	2.3E+03
U-238	2.1E+01	9.8E+00	2.1E+02	4.6E+03	1.2E+04	8.2E+03

NOTES: (1) Values shown in green are lower of the pair.
(2) Revised deterministic DCGLs based on parameter changes described in RAI 5C12.
(3) Probabilistic peak-of-the-mean DCGLs bases on analyses described in the new Appendix E.
(4) These values are the limiting DCGLs for subsurface soil from the penultimate column of Table 5C18-3 in the response to RAI 5C18.
(5) These are the revised DCGLs based on parameter changes described in RAI 5C12.
(6) These values reflect 30 years decay.

Table 5C15-2 shows that:

- For surface soil, the peak-of-the-mean probabilistic DCGLs are lower than the revised deterministic DCGLs for all radionuclides except Np-237.
- For subsurface soil, the limiting deterministic analysis results are more limiting than the peak-of-the-mean DCGLs for eight of the 18 radionuclides; and
- For streambed sediment, the peak-of-the-mean DCGLs are more limiting than the revised deterministic DCGLs.

For most radionuclides, the 95th percentile probabilistic DCGLs are lower than the peak-of-the-mean DCGLs. The peak-of-the-mean DCGLs are considered to be appropriate to compare with the deterministic DCGLs because 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 20, Subpart E (NRC 2006).

Revised Cleanup Goals

Section 5.4.1 of the DP describes how the cleanup goals were developed for Phase 1 of the decommissioning. Table 5-14 describes these cleanup goals, which serve as the soil and streambed sediment remediation criteria for the project.

To determine whether to revise these goals, DOE has considered the following information:

- The results of the probabilistic uncertainty analysis;
- The revised deterministic DCGLs resulting from the parameter changes described in the response to RAI 5C12;
- The results of alternative scenario analyses performed as recommended by NRC, especially the residential gardener analysis described in the response to RAI 5C18;
- The results of additional groundwater modeling to estimate the magnitude of potential releases of residual radioactivity from the bottoms of the remediated WMA 1 and WMA 2 excavations described in the response to RAI 5C1; and
- The results of additional groundwater modeling to estimate the potential impact of flow field changes associated with installation of WMA 1 and WMA 2 hydraulic barriers on the DCGLs as described in the response to RAI 5C3.

The surface soil cleanup goals are being revised based on the peak-of-the-mean DCGLs. These values are being reduced by 10 percent following the limited site-wide dose assessment apportionment process described in Section 5.4.1 of the DP. The resulting cleanup goals thus reflect a maximum dose of 22.5 mrem per year to a receptor exposed only to contamination in surface soil at the cleanup goal concentrations.

The subsurface soil cleanup goals are being revised based on the smaller of the limiting resident farmer-residential gardener deterministic analysis results and the peak-of-the-mean DCGLs. These values are being reduced by 10 percent following the process described in Section 5.3.2 of the DP and then by 50 percent more following the process described in Section 5.4.1 of the DP. The resulting cleanup goals equate to a maximum dose of 11.25 mrem per year to a receptor exposed only to radioactivity associated with contamination in subsurface soil at the bottom of the large WMA 1 or WMA 2 excavations at the cleanup goal concentrations.

The streambed sediment cleanup goals are being revised based on the peak-of-the-mean DCGLs. These values are being reduced by 90 percent following the process of Section 5.4.1 of the DP. The resulting cleanup goals equate to a maximum 2.5 mrem per year to an individual exposed only to contamination in the area of the streams.

Table 5C15-3 shows the resulting cleanup goals compared to those in Revision 1 of the DP.

Table 5C15-3. Cleanup Goals to be Used in Remediation in pCi/g[1]

Nuclide	Surface Soil		Subsurface Soil		Streambed Sediment	
	CG_w (old)	CG_w (new)	CG_w (old)	CG_w (new)	CG_w (old)	CG_w (new)
Am-241	4.9E+01	2.6E+01	2.9E+03	3.1E+03	1.6E+03	1.0E+03
C-14	3.1E+01	1.5E+01	1.9E+05	1.7E+05	3.4E+02	1.8E+02
Cm-243	4.2E+01	3.1E+01	5.1E+02	5.0E+02	3.6E+02	3.1E+02
Cm-244	9.4E+01	5.8E+01	8.8E+03	1.0E+04	4.7E+03	3.8E+02
Cs-137[2]	2.7E+01	1.4E+01	2.0E+02	1.4E+02	1.3E+02	1.0E+02
I-129	5.8E-01	2.9E-01	1.9E+02	2.4E+01	3.7E+02	7.9E+01
Np-237	9.6E-02	2.3E-01	1.7E+01	1.9E+00	5.4E+01	3.2E+01
Pu-238	5.8E+01	3.6E+01	5.5E+03	6.2E+03	2.0E+03	1.2E+03
Pu-239	5.2E+01	2.3E+01	5.0E+03	5.5E+03	1.8E+03	1.2E+03
Pu-240	5.2E+01	2.4E+01	5.0E+03	5.4E+03	1.8E+03	1.2E+03
Pu-241	1.6E+03	1.0E+03	9.8E+04	1.1E+05	5.2E+04	3.4E+04
Sr-90[2]	8.7E+00	3.7E+00	1.4E+03	1.4E+03	9.5E+02	4.7E+02
Tc-99	2.9E+01	1.9E+01	5.0E+03	5.1E+03	2.2E+05	6.6E+04
U-232	5.6E+00	1.4E+00	5.3E+01	3.3E+01	2.7E+01	2.2E+01
U-233	2.0E+01	7.5E+00	7.5E+02	8.7E+01	5.8E+03	2.2E+03
U-234	2.1E+01	7.6E+00	7.7E+02	8.9E+01	6.1E+03	2.2E+03
U-235	1.4E+01	3.1E+00	4.3E+02	9.3E+01	2.9E+02	2.3E+02
U-238	2.2E+01	8.9E+00	8.2E+02	9.3E+01	1.3E+03	8.2E+02

NOTES (1) The old cleanup goals are from Table 5-14 of Revision 1 to the DP. Green signifies the lower value.
(2) These cleanup goals apply in the year 2041 and later.

Changes to the Plan:

Add the following new subsection just before Section 5.3 on page 5-43:

5.2.5 Probabilistic Uncertainty Analysis

The probabilistic uncertainty analysis has been performed for each of the three conceptual models to supplement the deterministic sensitivity analyses just described. These probabilistic analyses generated results that quantify the total uncertainty in the DCGLs resulting from the variability of key input parameters, and also provide perspective regarding the relative importance of the contributions of different input parameters to the total uncertainty in the DCGLs. This information supports a risk-informed approach to establishing cleanup goals for Phase 1 of the decommissioning.

These analyses were performed using the probabilistic modules of RESRAD version 6.4, which utilize Latin hypercube sampling, 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 were selected randomly from probability distribution functions for each parameter of interest. The number of parameters treated probabilistically for each conceptual model was as follows: surface soil 102, subsurface soil 67, and streambed sediment 63, with these figures including the biotransfer factors and the K_d values for the 18 radionuclides of interest for each zone (contaminated, saturated, unsaturated) and media each model. Appendix E provides details of the analyses.

Table 5-11a summarizes the results of the analyses.

Table 5-11a. Summary of Results of Probabilistic Uncertainty Analyses(1)

Nuclide	Surface Soil DCGLs (pCi/g)		Subsurface Soil DCGLs (pCi/g)		Streambed Sediment DCGLs (pCi/g)	
	Determ(2)	Peak-of-the-Mean(3)	Limiting Determ(4)	Peak-of-the-Mean(3)	Determ(5)	Peak-of-the-Mean(3)
Am-241	4.3E+01	**2.9E+01**	7.1E+03	**6.8E+03**	1.6E+04	**1.0E+04**
C-14	2.0E+01	**1.6E+01**	**3.7E+05**	7.2E+05	3.4E+03	**1.8E+03**
Cm-243	4.1E+01	**3.5E+01**	1.2E+03	**1.1E+03**	3.6E+03	**3.1E+03**
Cm-244	8.2E+01	**6.5E+01**	2.3E+04	**2.2E+04**	4.8E+04	**3.8E+03**
Cs-137*	2.4E+01	**1.5E+01**	4.4E+02	**3.0E+02**	1.3E+03	**1.0E+03**
I-129	3.5E-01	**3.3E-01**	**5.2E+01**	6.7E+02	3.7E+03	**7.9E+02**
Np-237	**9.5E-02**	2.6E-01	**4.3E+00**	9.3E+01	5.2E+02	**3.3E+02**
Pu-238	5.0E+01	**4.0E+01**	1.5E+04	**1.4E+04**	2.0E+04	**1.2E+04**
Pu-239	4.5E+01	**2.5E+01**	1.3E+04	**1.2E+04**	1.8E+04	**1.2E+04**
Pu-240	4.5E+01	**2.6E+01**	1.3E+04	**1.2E+04**	1.8E+04	**1.2E+04**
Pu-241	1.4E+03	**1.2E+03**	**2.4E+05**	2.5E+05	5.1E+05	**3.4E+05**
Sr-90*	6.4E+00	**4.1E+00**	**3.2E+03**	3.4E+03	9.5E+03	**4.7E+03**
Tc-99	2.6E+01	**2.1E+01**	**1.1E+04**	1.4E+04	2.2E+06	**6.6E+05**
U-232	5.9E+00	**1.5E+00**	1.0E+02	**7.4E+01**	2.6E+02	**2.2E+02**
U-233	1.9E+01	**8.3E+00**	**1.9E+02**	9.9E+03	5.7E+04	**2.2E+04**
U-234	2.0E+01	**8.5E+00**	**2.0E+02**	1.3E+04	6.0E+04	**2.2E+04**
U-235	1.9E+01	**3.5E+00**	**2.1E+02**	9.3E+02	2.9E+03	**2.3E+03**
U-238	2.1E+01	**9.8E+00**	**2.1E+02**	4.6E+03	1.2E+04	**8.2E+03**

NOTES: (1) Values shown in boldface are lower of the pair of values being compared.
(2) Revised deterministic DCGLs based on parameter changes described in Appendix C.
(3) Probabilistic peak-of-the-mean DCGLs bases on analyses described in Appendix E.
(4) These values are the limiting DCGLs for subsurface soil from the residential gardener alternate scenario analysis discussed above.
(5) These are the revised DCGLs based on parameter changes described in Appendix C.

Table 5-11a shows that:

- For surface soil, the peak-of-the-mean probabilistic DCGLs are lower than the revised deterministic DCGLs for all radionuclides except Np-237.
- For subsurface soil, the limiting deterministic analysis results are more limiting than the peak-of-the-mean DCGLs for 10 of the 18 radionuclides; and
- For streambed sediment, the peak-of-the-mean DCGLs are more limiting than the revised deterministic DCGLs.

For most radionuclides, the 95th percentile probabilistic DCGLs are lower than the peak-of-the-mean DCGLs as shown in Appendix E. The peak-of-the-mean DCGLs are considered to be appropriate to compare with the deterministic DCGLs because 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 20, Subpart E (NRC 2006).

After consideration of the results of the probabilistic uncertainty analysis and the analyses of alternate exposures discussed previously, DOE has determined that it is appropriate to use the peak-of-the-mean DCGLs for surface soil and for streambed sediment, and to use the bounding DCGLs in the fourth and fifth columns of Table 5-11a for subsurface soil. That is, for subsurface soil, the lower of the DCGLs between the resident farmer-residential gardener analysis and the peak-of-the-mean value will be used for the 18 radionuclides of interest.

Change Table 5-12 on page 5-45 as follows:

Table 5-12. Limited Site-Wide Dose Assessment 1 Results (DCGLs in pCi/g)

Nuclide	Subsurface Soil $DCGL_W$ Values		Streambed Sediment $DCGL_W$ Values	
	Base Case(1)	Assessment(2)	Base Case(1)	Assessment(2)
Am-241	6.8E+03	6.1E+03	1.0E+04	1.0E+03
C-14	3.7E+05	3.4E+05	1.8E+03	1.8E+02
Cm-243	1.1E+03	1.0E+03	3.1E+03	3.1E+02
Cm-244	2.2E+04	2.0E+04	3.8E+04	3.8E+03
Cs-137(3)	3.0E+02	2.7E+02	1.0E+03	1.0E+02
I-129	5.2E+01	4.7E+01	7.9E+02	7.9E+01
Np-237	4.3E+00	3.9E+00	3.2E+02	3.2E+01
Pu-238	1.4E+04	1.2E+04	1.2E+04	1.2E+03
Pu-239	1.2E+04	1.1E+04	1.2E+04	1.2E+03
Pu-240	1.2E+04	1.1E+04	1.2E+04	1.2E+03
Pu-241	2.4E+05	2.2E+05	3.4E+05	3.4E+04
Sr-90(3)	3.2E+03	2.9E+03	4.7E+03	4.7E+02
Tc-99	1.1E+04	1.0E+04	6.6E+05	6.6E+04
U-232	7.4E+01	6.7E+01	2.2E+02	2.2E+01

Table 5-12. Limited Site-Wide Dose Assessment 1 Results (DCGLs in pCi/g)

Nuclide	Subsurface Soil $DCGL_W$ Values		Streambed Sediment $DCGL_W$ Values	
	Base Case(1)	Assessment(2)	Base Case(1)	Assessment(2)
U-233	1.9E+02	1.7E+02	2.2E+04	2.2E+03
U-234	2.0E+02	1.8E+02	2.2E+04	2.2E+03
U-235	2.1E+02	1.9E+02	2.3E+03	2.3E+02
U-238	2.1E+02	1.9E+02	8.2E+03	8.2E+02

NOTES: (1) The base case values from Table 5-11a.

(2) The results for the analysis of the combined resident farmed located in the area of remediated surface soil and the recreationist in the area of the streams.

(3) These DCGLs apply in the year 2041 and later.

Change Table 5-13 on page 5-46 as follows:

Table 5-13. Limited Site-Wide Dose Assessment 2 Results (DCGLs in pCi/g)

Nuclide	Surface Soil $DCGL_W$ Values		Streambed Sediment $DCGL_W$ Values	
	Base Case(1)	Assessment(2)	Base Case(1)	Assessment(2)
Am-241	2.9E+01	2.6E+01	1.0E+04	1.0E+03
C-14	1.6E+01	1.5E+01	1.8E+03	1.8E+02
Cm-243	3.5E+01	3.1E+01	3.1E+03	3.1E+02
Cm-244	6.5E+01	5.8E+01	3.8E+04	3.8E+03
Cs-137(3)	1.5E+01	1.4E+01	1.0E+03	1.0E+02
I-129	3.3E-01	2.9E-01	7.9E+02	7.9E+01
Np-237	2.6E-01	2.3E-01	3.2E+02	3.2E+01
Pu-238	4.0E+01	3.6E+01	1.2E+04	1.2E+03
Pu-239	2.5E+01	2.3E+01	1.2E+04	1.2E+03
Pu-240	2.6E+01	2.4E+01	1.2E+04	1.2E+03
Pu-241	1.2E+03	1.0E+03	3.4E+05	3.4E+04
Sr-90(3)	4.1E+00	3.7E+00	4.7E+03	4.7E+02
Tc-99	2.1E+01	1.9E+01	6.6E+05	6.6E+04
U-232	1.5E+00	1.4E+00	2.2E+02	2.2E+01
U-233	8.3E+00	7.5E+00	2.2E+04	2.2E+03
U-234	8.4E+00	7.6E+00	2.2E+04	2.2E+03
U-235	3.5E+00	3.1E+00	2.3E+03	2.3E+02
U-238	9.8E+00	8.9E+00	8.2E+03	8.2E+02

NOTES: (1) The base case values from Table 5-11a.

(2) The results for the analysis of the combined resident farmed located in the area of remediated surface soil and the recreationist in the area of the streams.

(3) These DCGLs apply in the year 2041 and later.

Change Table 5-14 on page 5-48 as follows:

Table 5-14. Cleanup Goals to be Used in Remediation in pCi/g(1)

Nuclide	Surface Soil(2)		Subsurface Soil(3)		Streambed Sediment(2)	
	CG_w	CG_{EMC}	CG_w	CG_{EMC}	CG_w	CG_{EMC}
Am-241	2.6E+01	3.9E+03	3.1E+03	2.0E+04	1.0E+03	3.3E+04
C-14	1.5E+01	2.0E+06	1.7E+05	8.1E+07	1.8E+02	1.1E+06
Cm-243	3.1E+01	7.6E+02	5.0E+02	4.0E+03	3.1E+02	3.2E+03
Cm-244	5.8E+01	1.2E+04	1.0E+04	6.4E+04	3.8E+03	4.5E+05
Cs-137(4)	1.4E+01	3.0E+02	1.4E+02	1.7E+03	1.0E+02	1.2E+03
I-129	2.9E-01	2.9E+03	2.4E+01	3.0E+04	7.9E+01	9.3E+04
Np-237	2.3E-01	3.1E+02	1.9E+00	2.3E+03	3.2E+01	1.7E+03
Pu-238	3.6E+01	7.6E+03	6.2E+03	4.0E+04	1.2E+03	2.7E+05
Pu-239	2.3E+01	6.9E+03	5.5E+03	3.6E+04	1.2E+03	2.5E+05
Pu-240	2.4E+01	6.9E+03	5.4E+03	3.6E+04	1.2E+03	2.5E+05
Pu-241	1.0E+03	1.3E+05	1.1E+05	6.8E+05	3.4E+04	1.1E+06
Sr-90(4)	3.7E+00	1.1E+04	1.4E+03	1.1E+05	4.7E+02	1.4E+05
Tc-99	1.9E+01	6.1E+04	5.1E+03	6.9E+05	6.6E+04	1.4E+07
U-232	1.4E+00	5.9E+01	3.3E+01	4.2E+02	2.2E+01	2.5E+02
U-233	7.5E+00	1.1E+04	8.7E+01	1.1E+05	2.2E+03	1.2E+05
U-234	7.6E+00	2.3E+04	8.9E+01	1.2E+05	2.2E+03	5.9E+05
U-235	3.1E+00	6.1E+02	9.3E+01	3.3E+03	2.3E+02	2.5E+03
U-238	8.9E+00	2.9E+03	9.3E+01	1.6E+04	8.2E+02	1.3E+04

NOTE: (1) These cleanup goals (CGs) are to be used as the criteria for the remediation activities described in Section 7 of this plan.

(2) The CG_W values for surface soil and streambed sediment are the same as the limited dose assessment DCGL values in Table 5-11. The CG_{EMC} values were producing by scaling the values provided in Table 5-8 and apply to 1 m^2 areas of elevated contamination.

(3) These CG_W values and CG_{EMC} values are the DCGL values in Table 5-8 reduced by a factor of 0.50 as discussed below.

(4) These cleanup goals apply in the year 2041 and later.

Change the preliminary dose assessments in Subsection 5.4.4 on page 5-51 as follows:

WMA 1, a peak-of-the-mean estimate of 1.9 mrem per year and a 95th percentile estimate of 2.8 mrem per year; and

WMA 2, a peak-of-the-mean estimate of 0.11 mrem per year and a 95th percentile estimate of 0.13 mrem per year.

Insert new Appendix E (copy provided below). Since the appendix is entirely new, a black font is used with no change bars.

References:

DOE 2008, Letter from DOE (C.V. Anderson) to NRC (K.I. McConnell), submitting Revision 0 of the WVDP Phase 1 Decommissioning Plan for NRC review, December 3, 2008.

NRC 2006, *Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria, Final Report,* NUREG 1757 Volume 2, Revision 1. NRC, Office of Nuclear Material Safety and Safeguards, Washington, DC, September, 2006.

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.

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[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 95th 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 (50th percentile) and the 95th percentile; and
- Preliminary dose estimates for the remediated WMA 2 excavation expressed as the peak of the mean and the 95th 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.

[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).

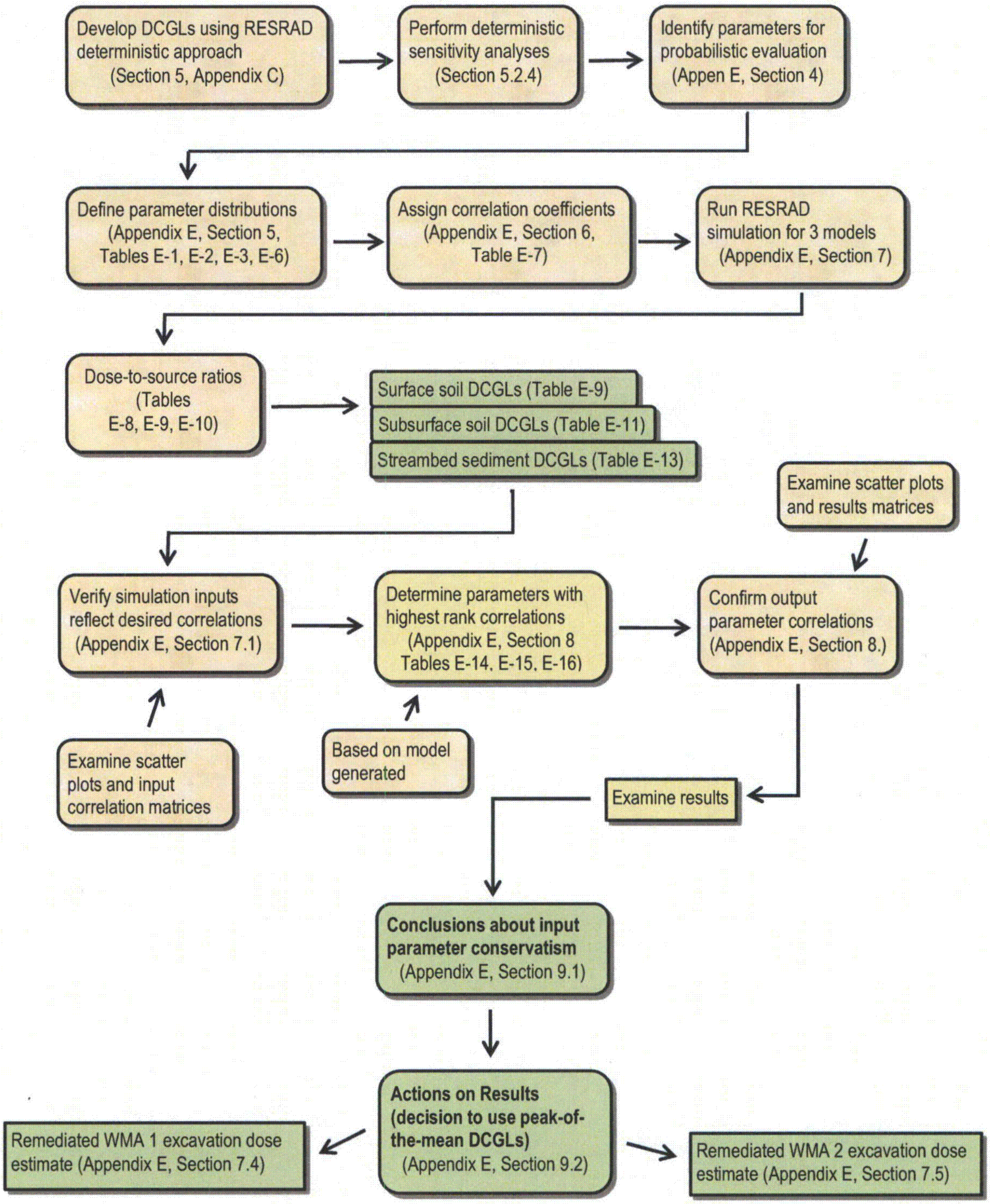

Figure E-1. Probabilistic Uncertainty Analysis Process

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
Pu-239	8.84E+02	2.73E-02	1.48E+01	9.86E-01	5.83E+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-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 DCGLs presented in Table E-11 reflect a 10 fold dilution of the source term (i.e. using $1/10^{th}$ 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 95^{th} 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	95^{th} 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
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

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
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%
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.

(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 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
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%
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 was a maximum of 1.9 mrem per year using the RESRAD deterministic method. 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.

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 was a maximum of 0.08 mrem per year using the

RESRAD deterministic method. 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.

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)
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)
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)

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

Nuclide	Parameter Ranking			Simulation No. (R^2)
	1	2	3	
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 3 radionuclides were below the deterministic DCGL by more than 10%. 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.

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. Changes in Section 5 made as part of Revision 2, including changes to the cleanup goals, reflect this decision.

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

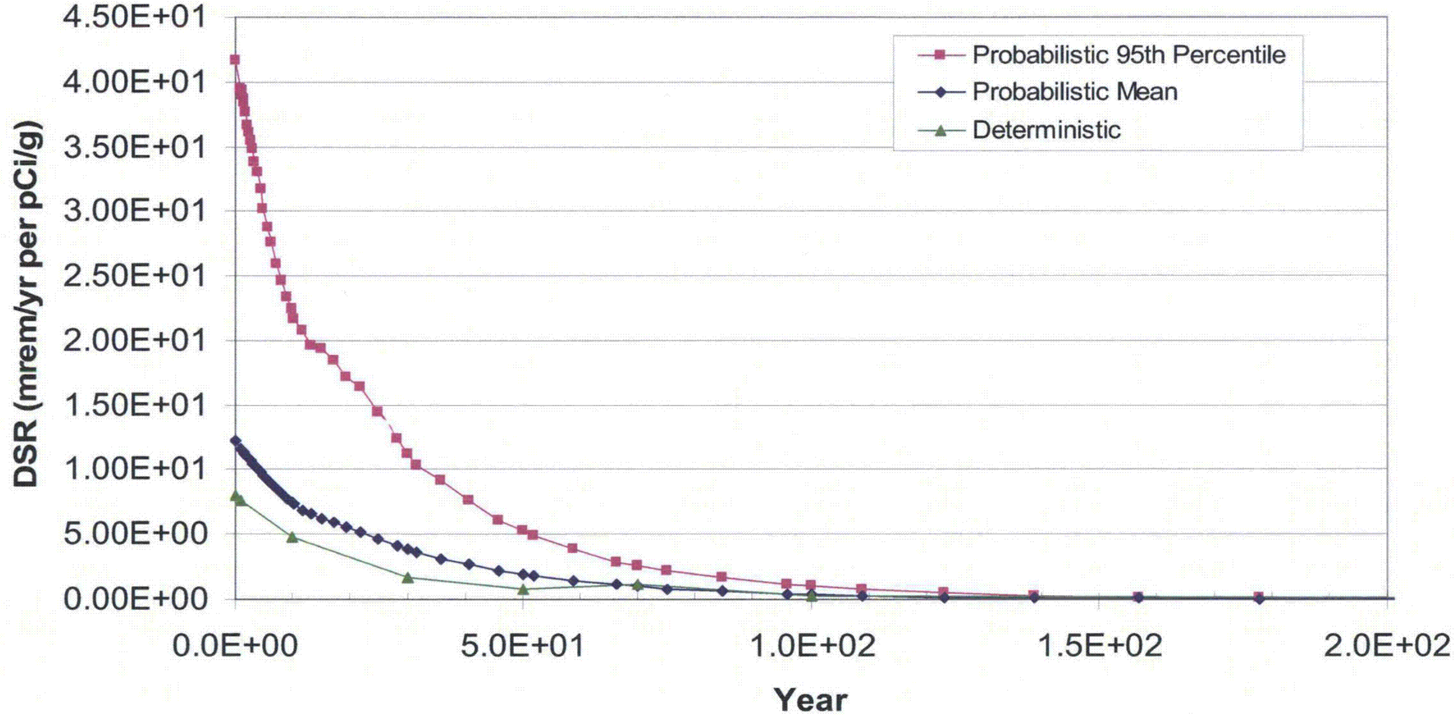

Figure Att-1. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Sr-90 – Surface Soil

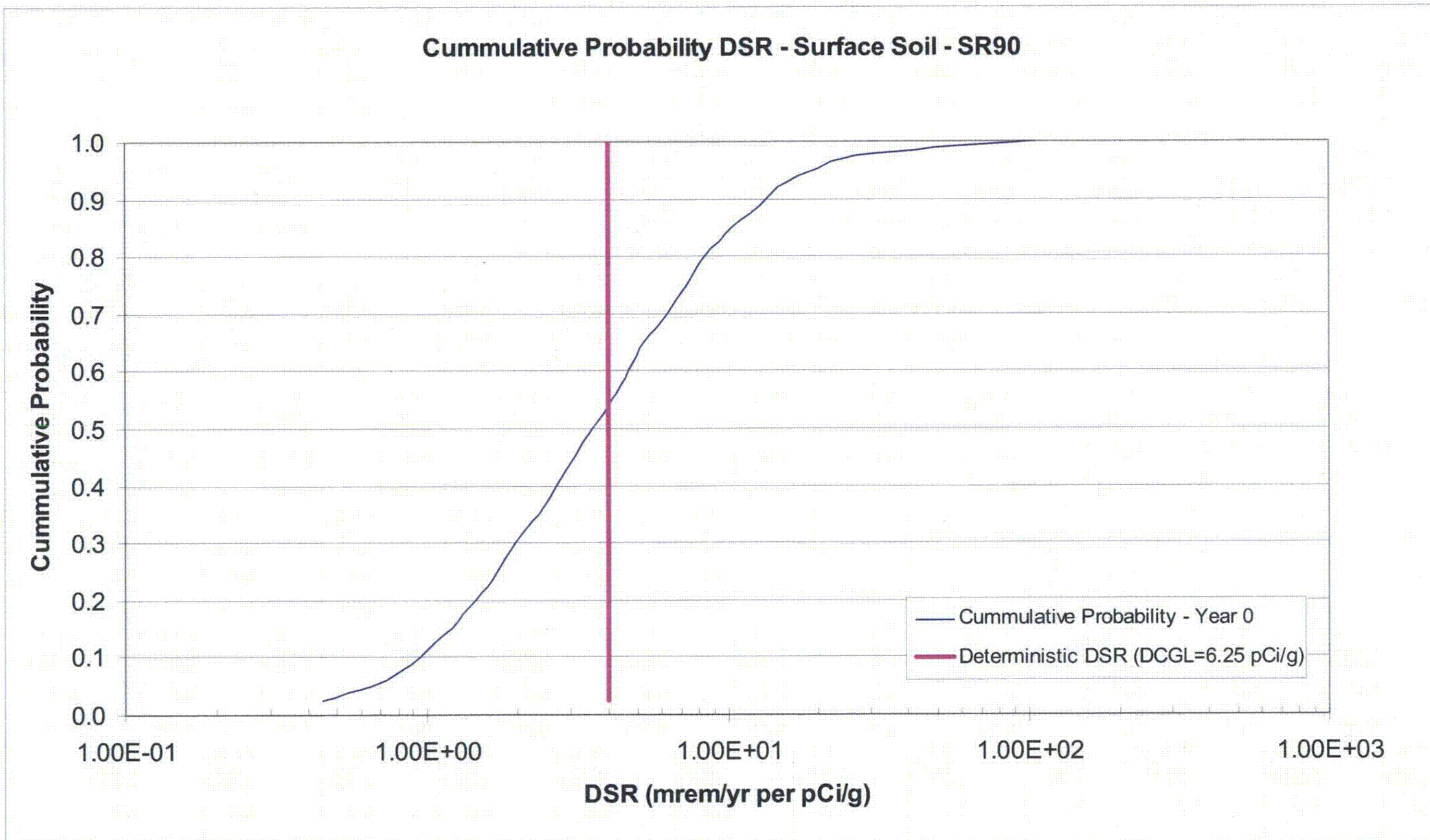

Figure Att-2. Cumulative Probability Dose-Source Ratio, Sr-90 – Surface Soil

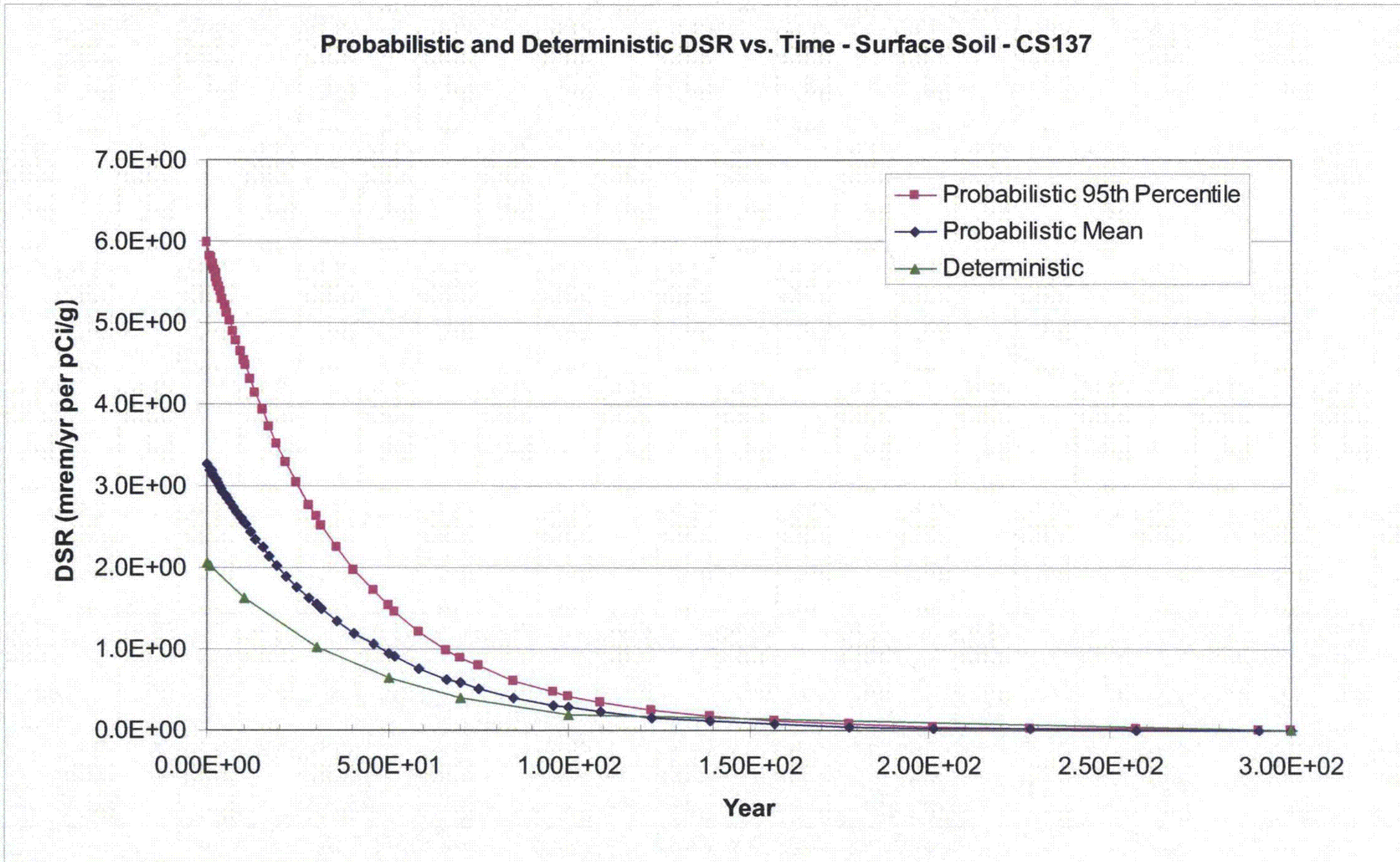

Figure Att-3. Probabilistic and Deterministic Dose-Source Ratio, Cs-137 – Surface Soil

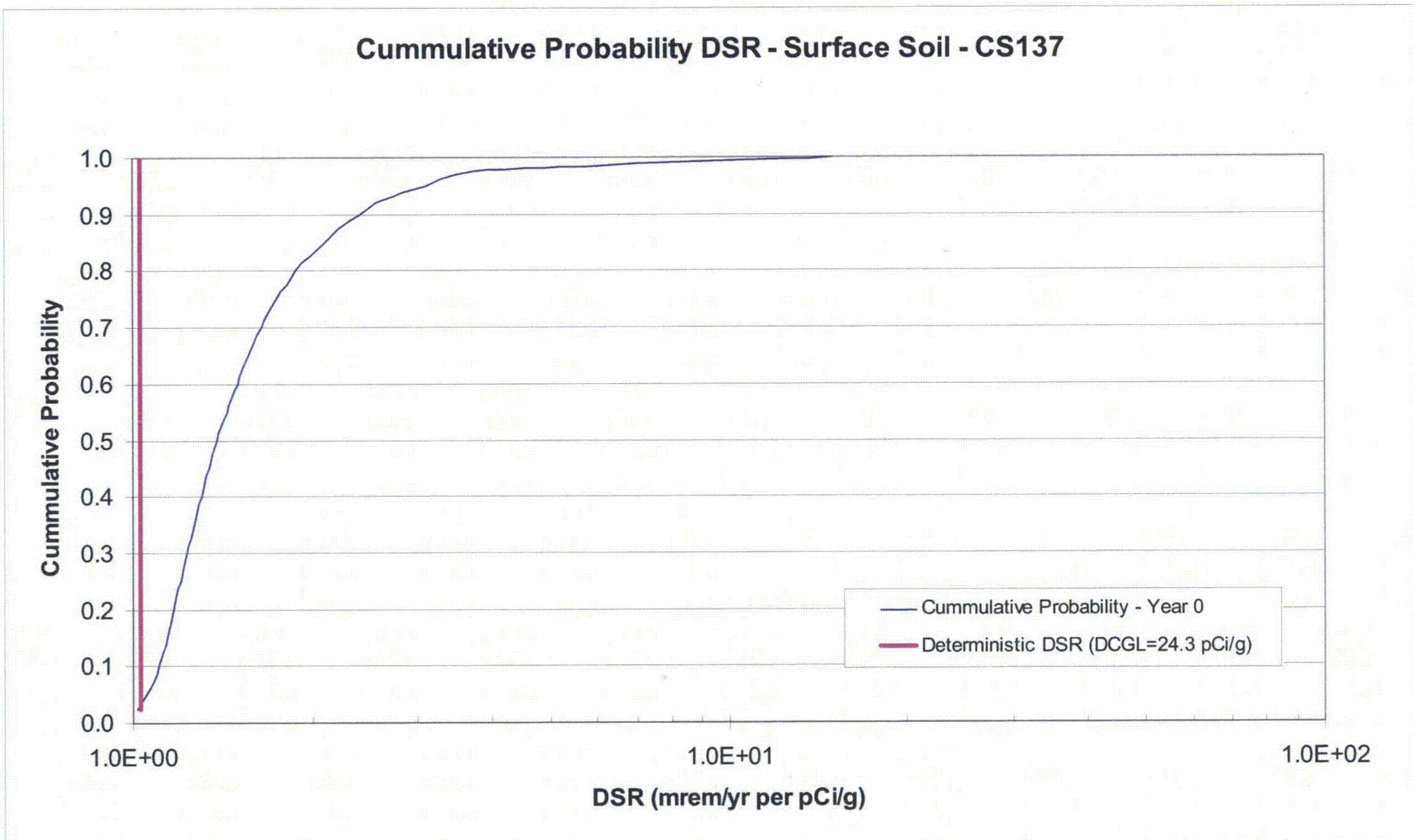

Figure Att-4. Cumulative Probability Dose-Source Ratio, Cs-137 – Surface Soil

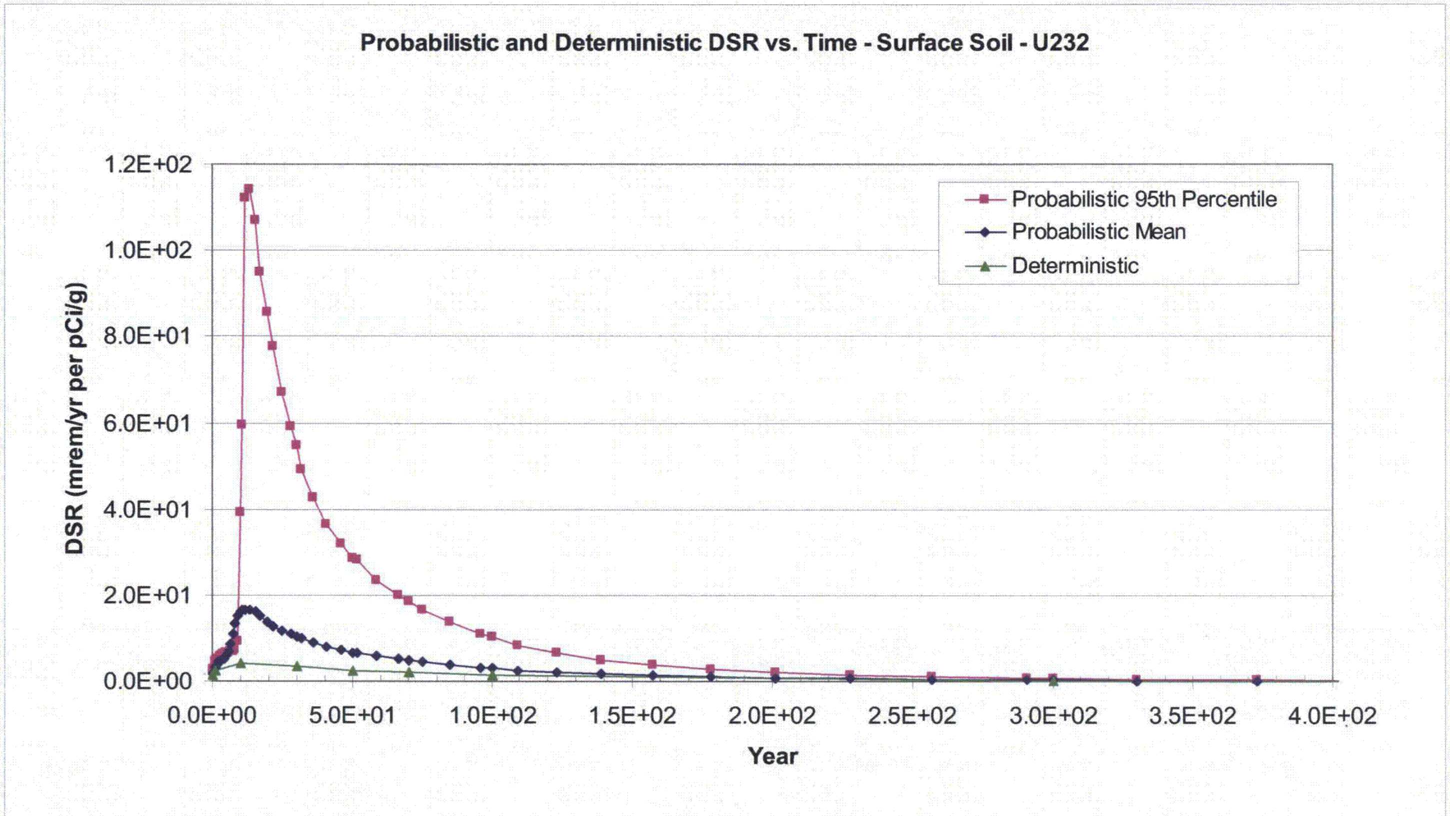

Figure Att-5. Probabilistic and Deterministic Dose-Source Ratio vs. Time, U-232 – Surface Soil

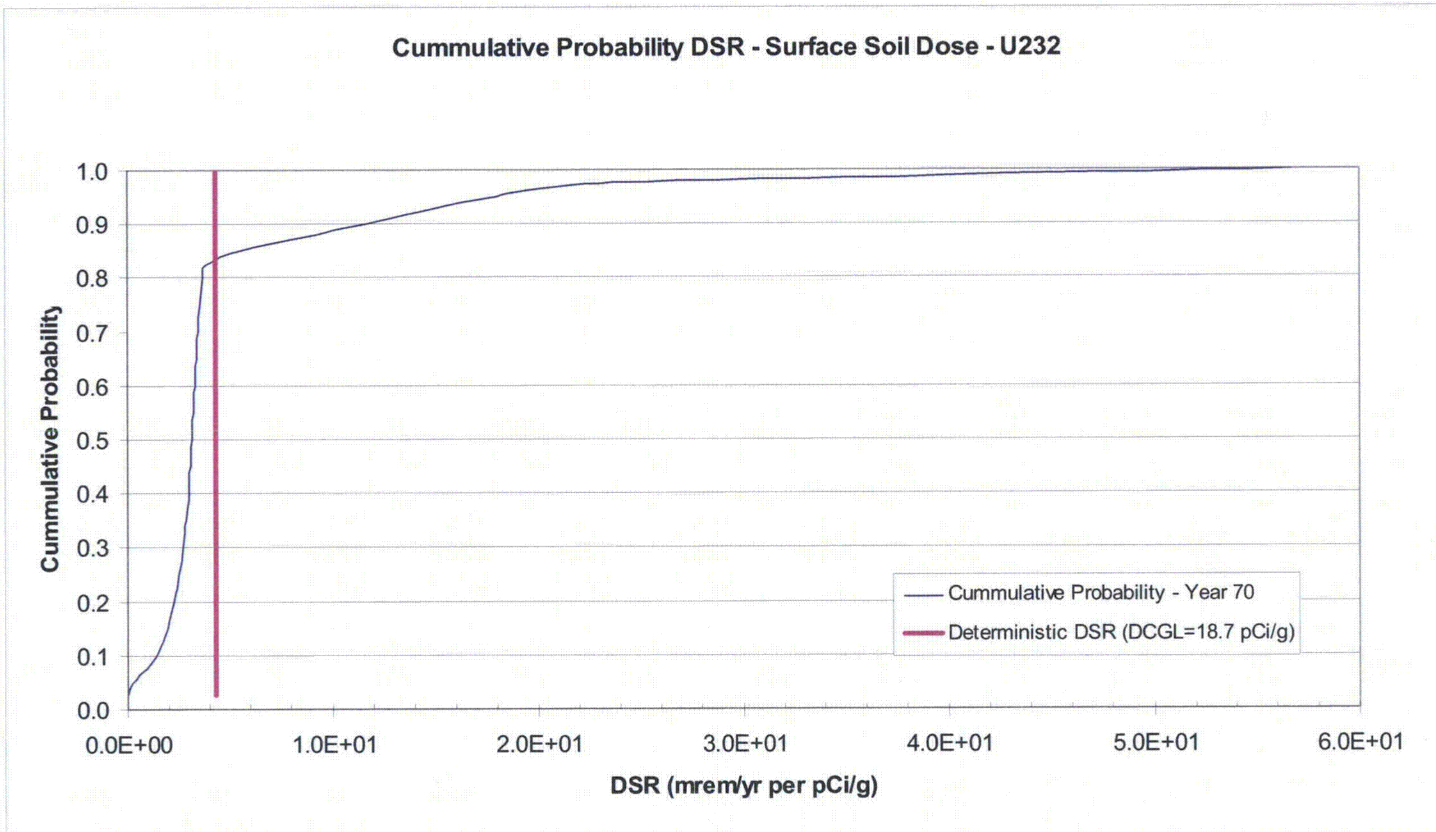

Figure Att-6. Cumulative Probability Dose-Source Ratio, U-232 – Surface Soil

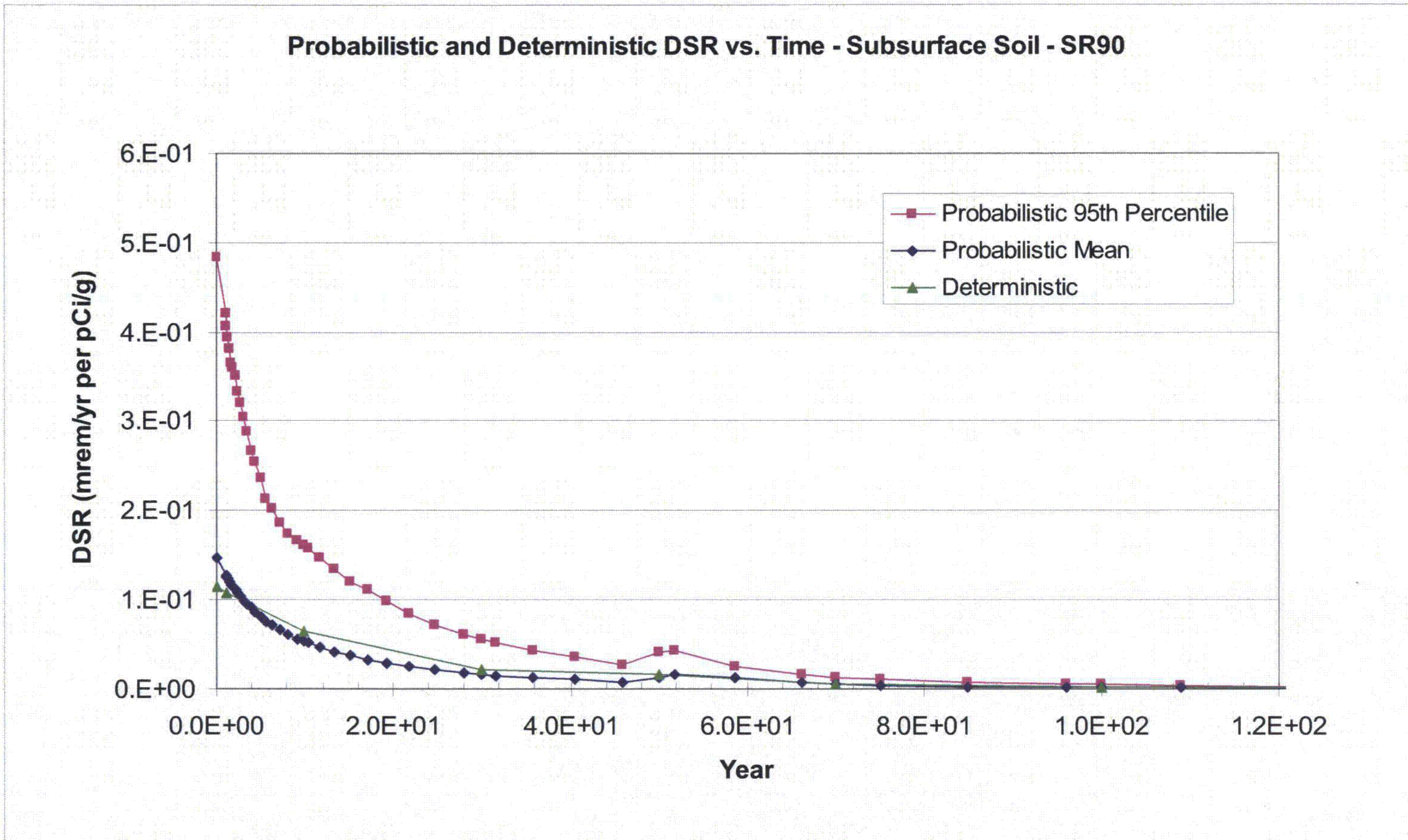

Figure Att-7. Probabilistic and Deterministic Dose-Source Ration vs. Time, Sr-90 – Subsurface Soil

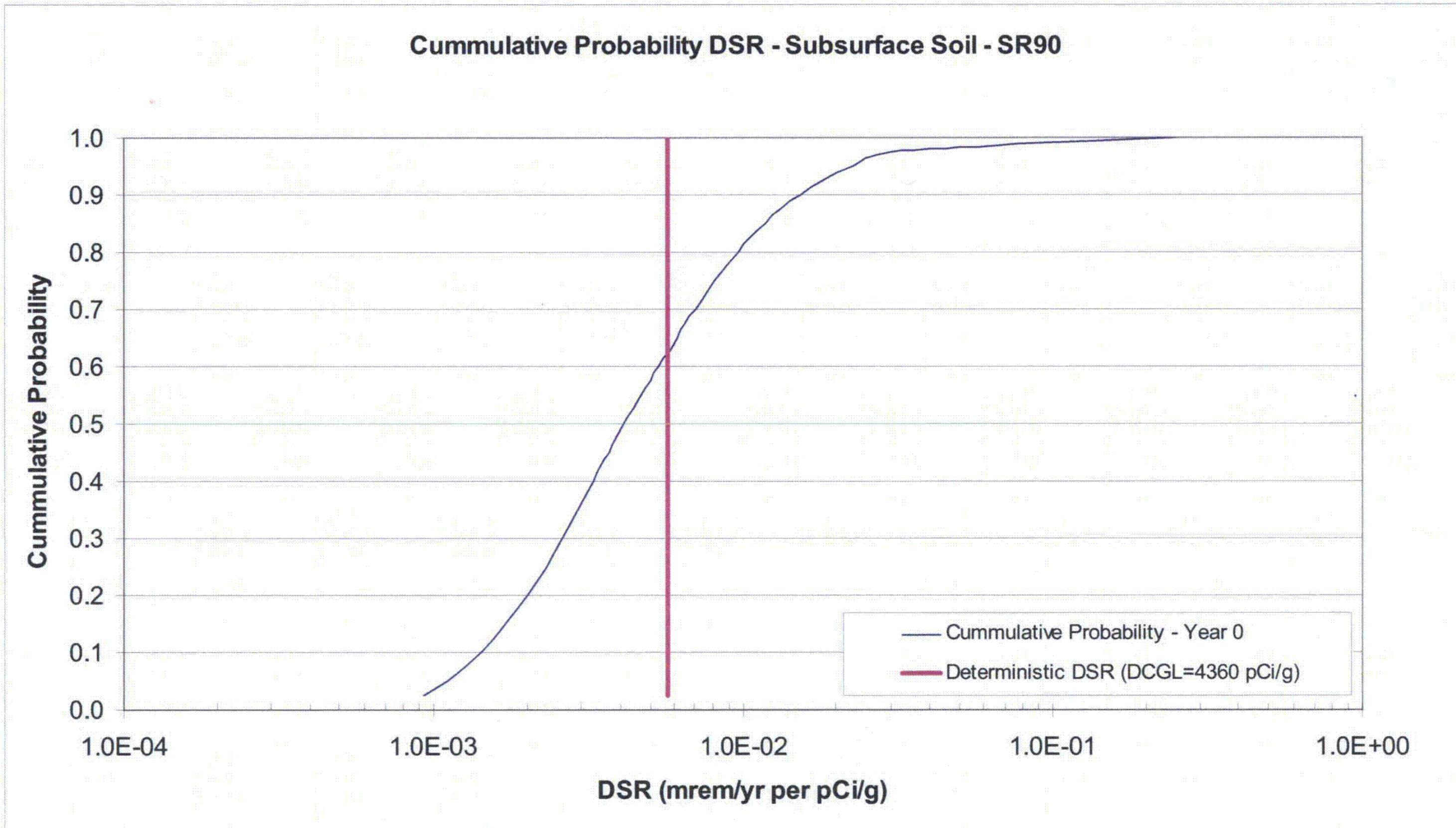

Figure Att-8. Cumulative Probability Dose-Source Ratio, Sr-90 – Subsurface Soil

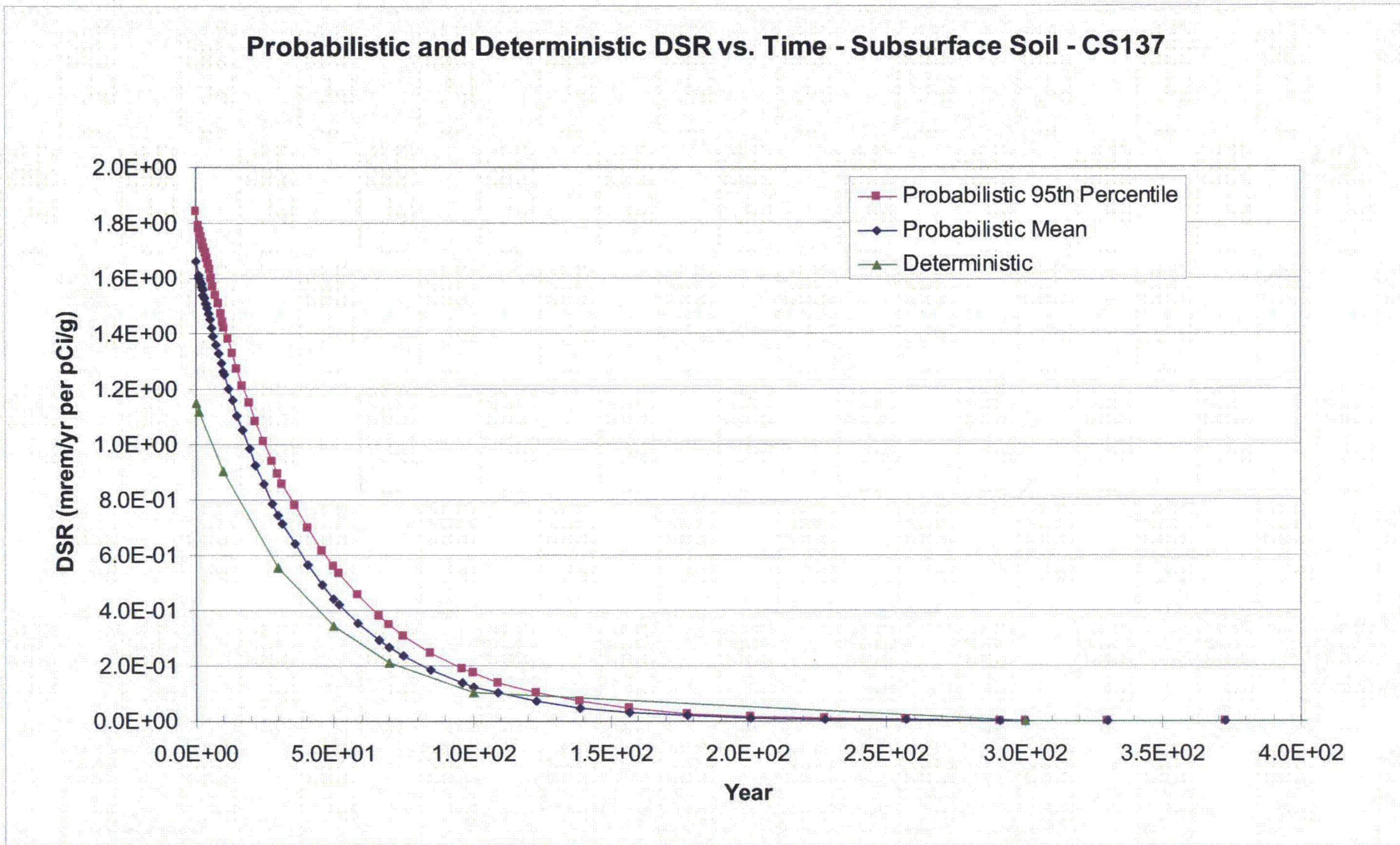

Figure Att-9. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Cs-137 – Subsurface Soil

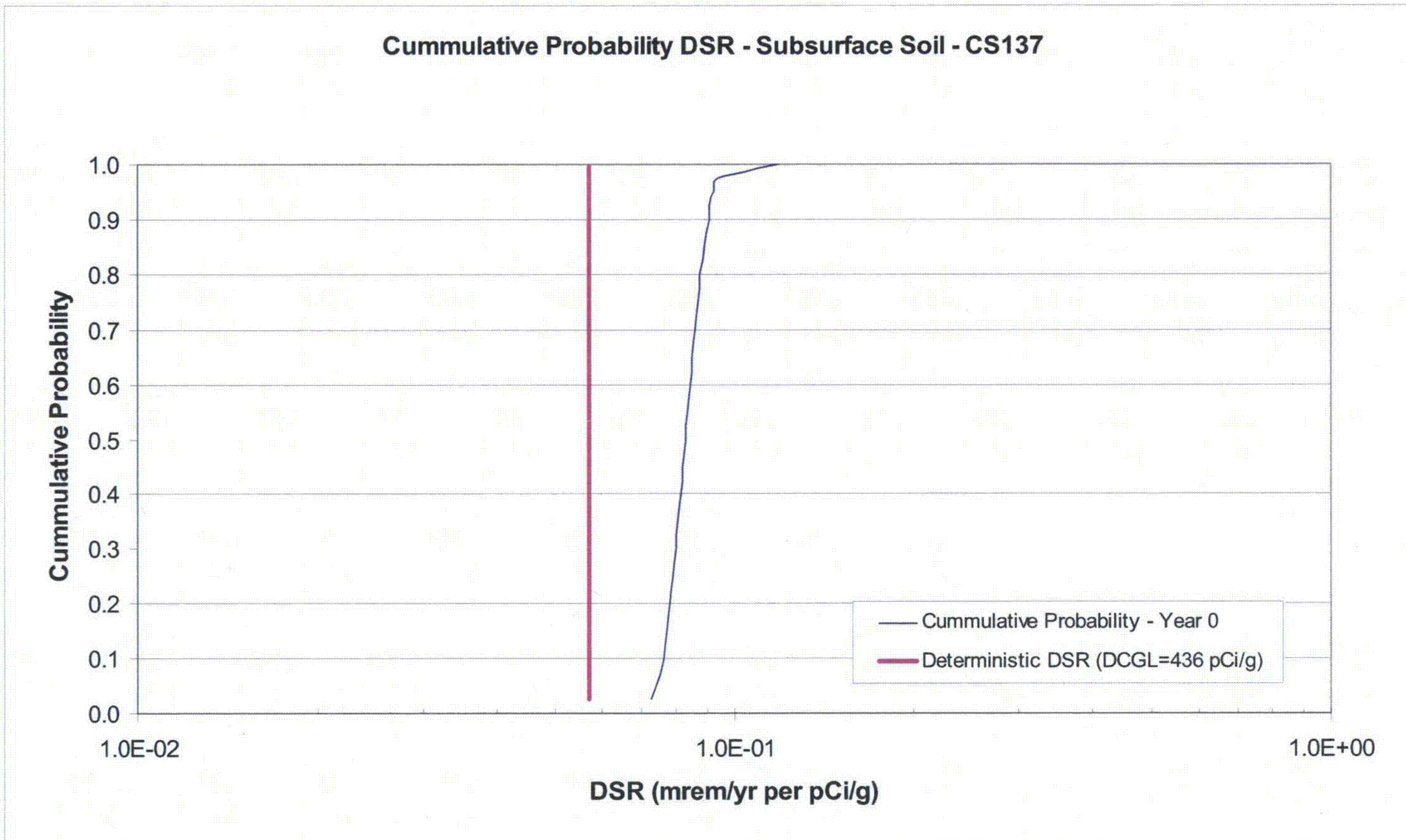

Figure Att-10. Cumulative Probability Dose-Source Ratio, Cs-137 – Subsurface Soil

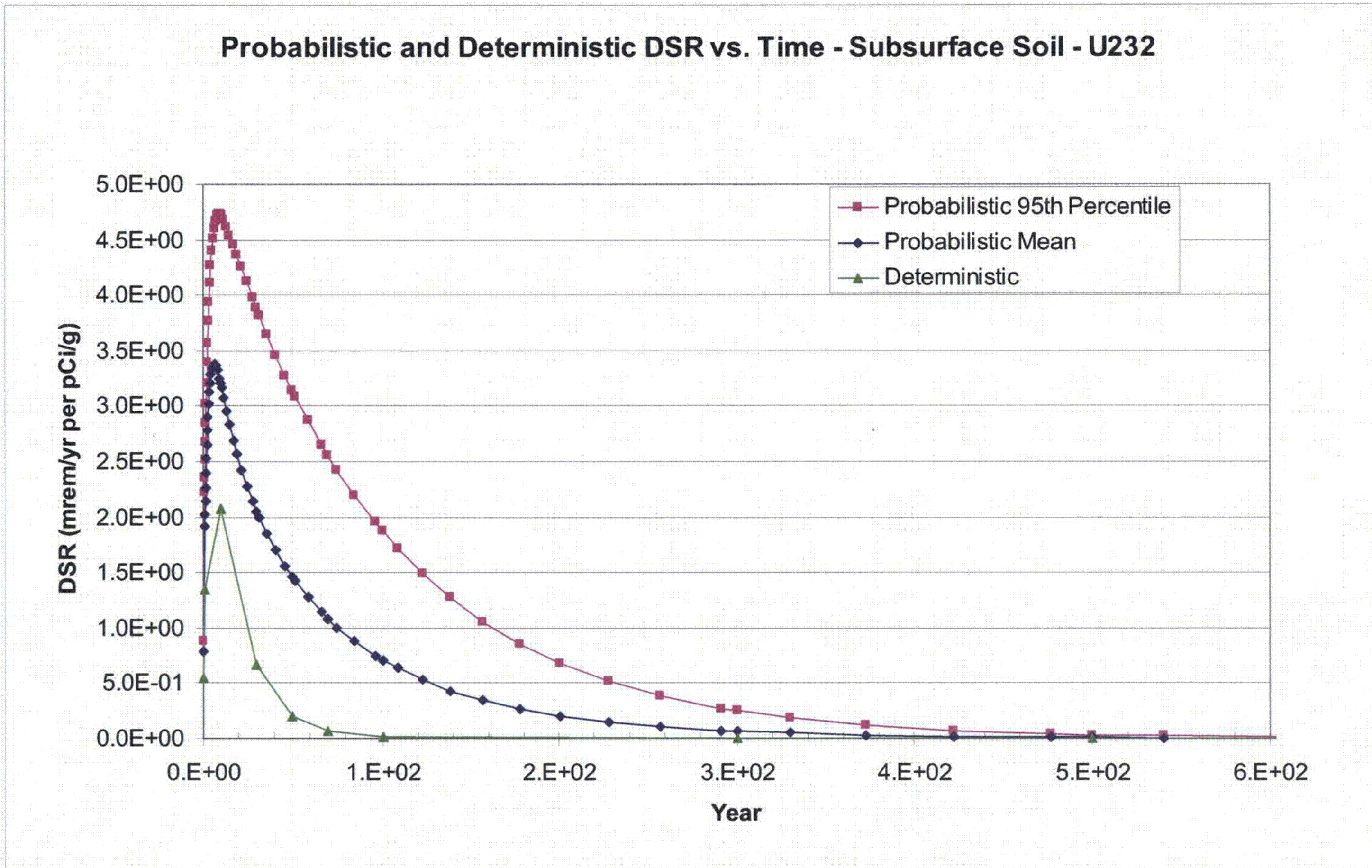

Figure Att-11. Probabilistic and Deterministic Dose-Source Ration vs. Time, U-232 – Subsurface Soil

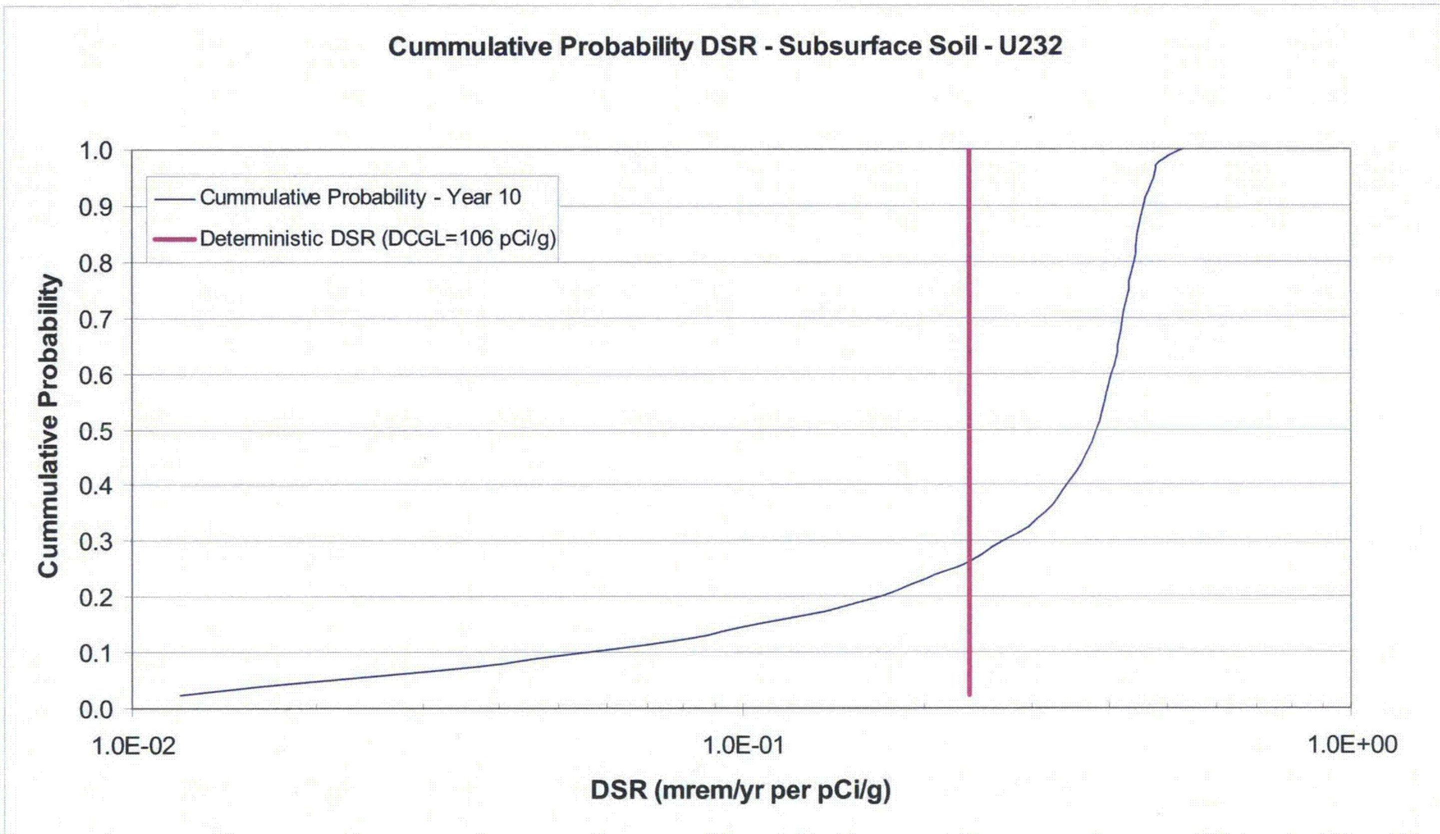

Figure Att-12. Cumulative Probability Dose-Source Ratio, U-232, Subsurface Soil

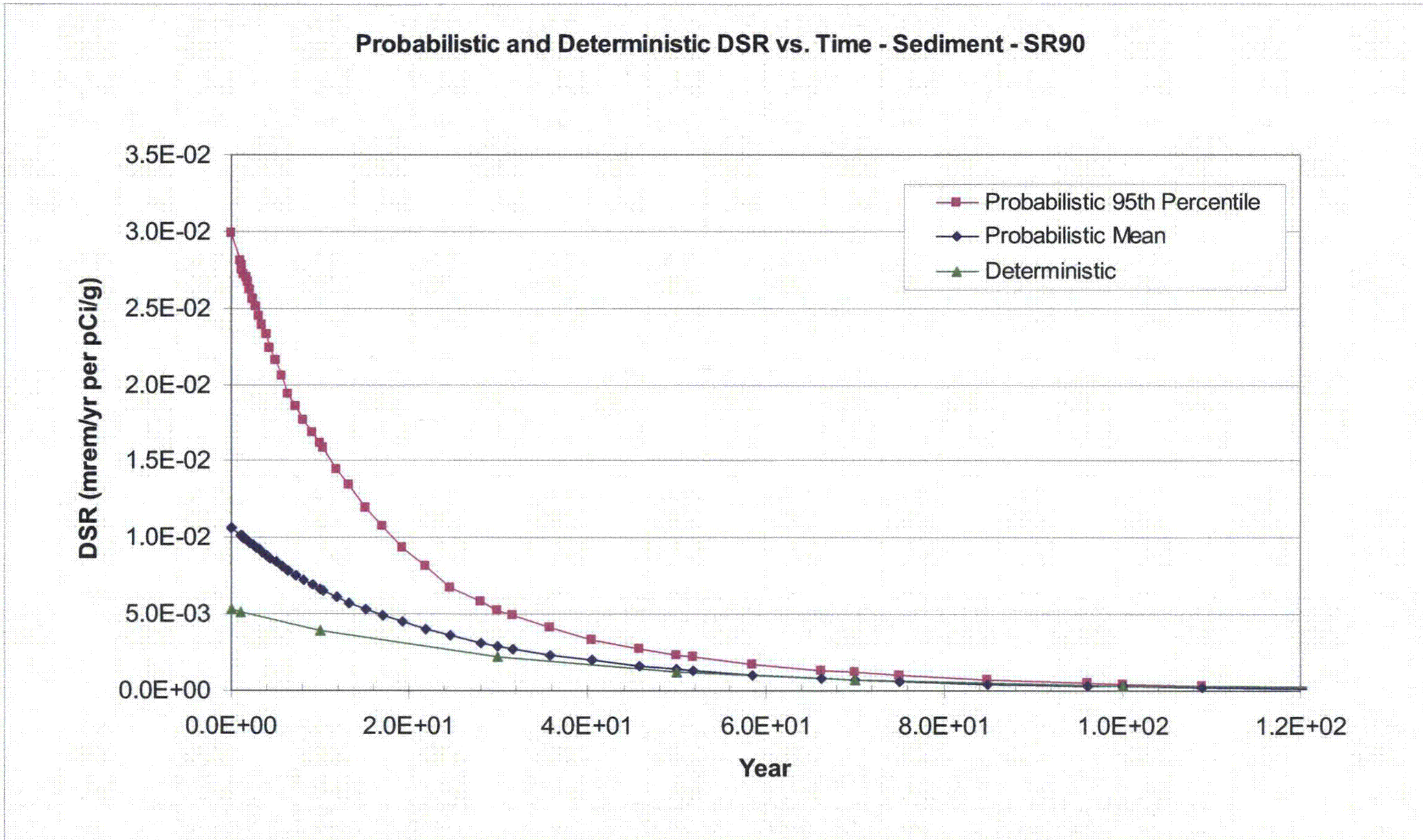

Figure Att-13. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Sr-90 – Streambed Sediment

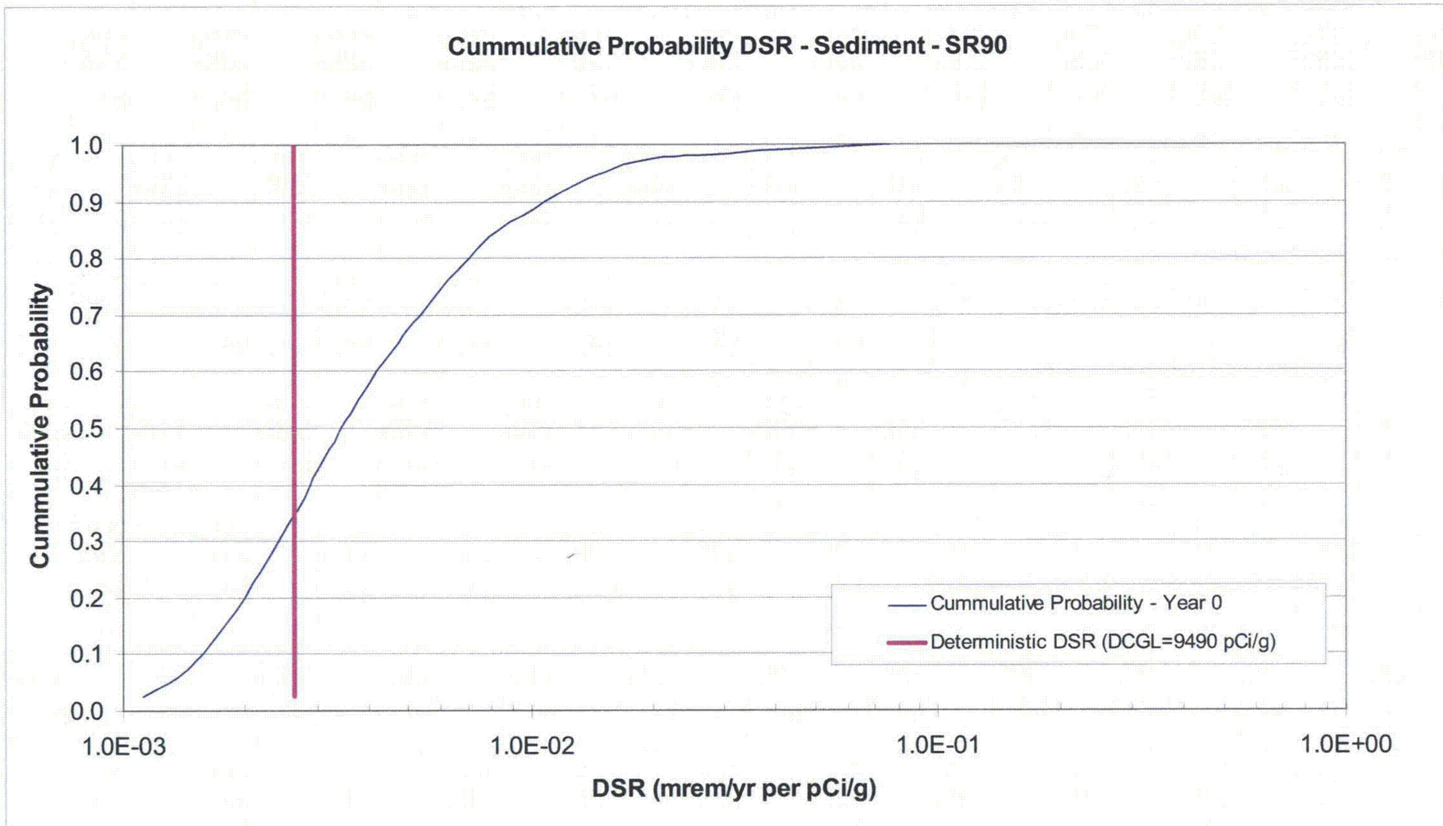

Figure Att-14. Cumulative Probability Dose-Source Ratio, Sr-90 – Streambed Sediment

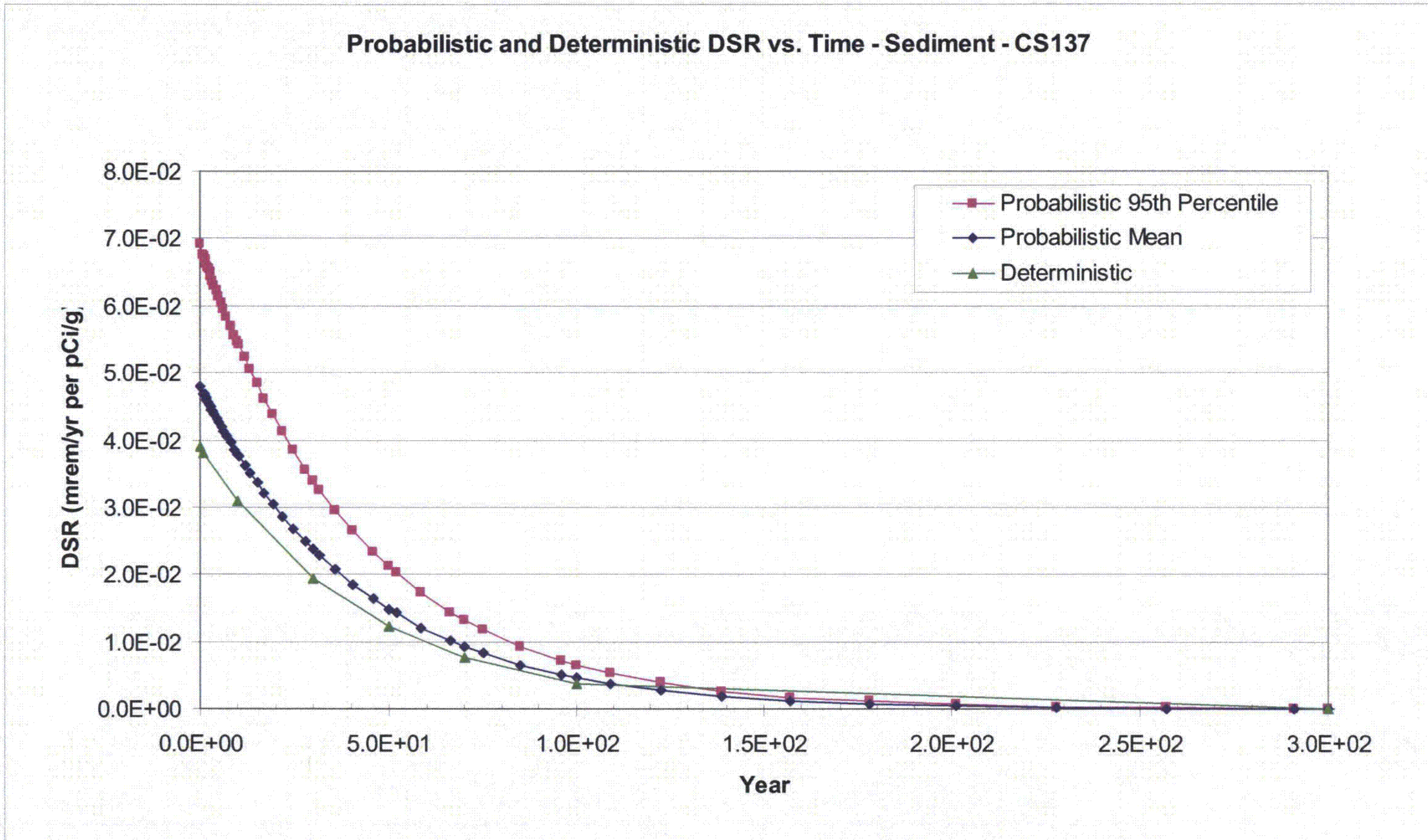

Figure Att-15. Probabilistic and Deterministic Dose-Source Ratio vs. Time, Cs-137 – Streambed Sediment

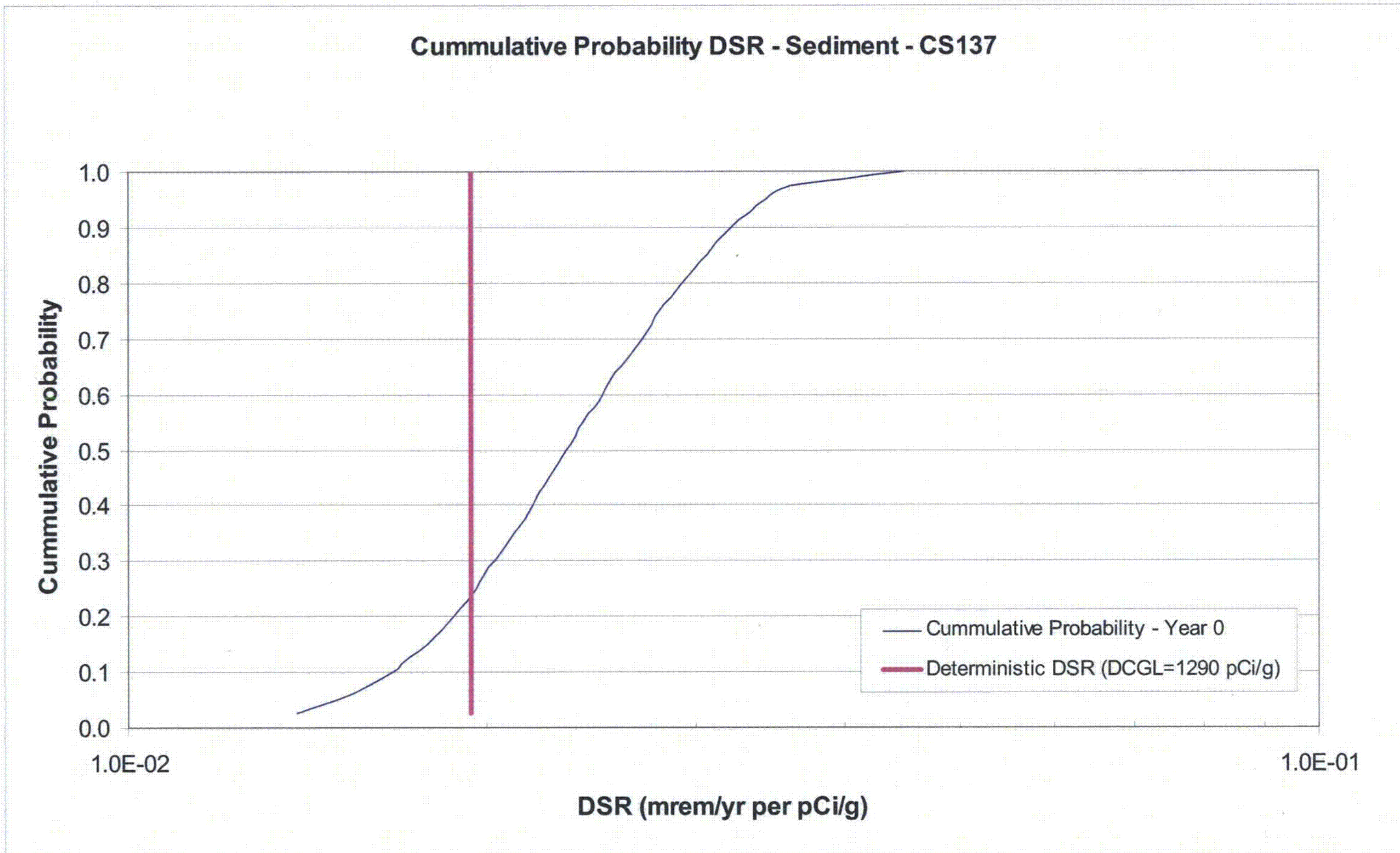

Figure Att-16. Cumulative Probability Dose-Source Ratio, Cs-137 – Streambed Sediment

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

RAI 5C16 (21)

Subject: *Conservatism in the selection of distribution coefficients*

RAI: DOE did not provide sufficient support that the selection of parameter values in the deterministic analysis is sufficiently conservative to demonstrate compliance with LTR criteria. This specific comment is related to DOE's selection of K_ds. (Section 5.2.4; Appendix C, Table C-2):

Basis: On page C-2 of the DP, a statement is made that K_d values were selected to represent the central tendency of the site-specific data or were based on specific soil strata characteristics, where available. When site-specific information is available, this information should be used to provide more realistic estimates of the potential risk. However, when site-specific information is not available or is uncertain, Appendix I of NRC decommissioning guidance, NUREG 1757, Vol. 2 (NRC, 2006), recommends conducting a sensitivity analysis to identify parameter values that have the most impact on dose and selecting conservative values for these parameter values to estimate dose (e.g., upper quartile of the distribution for those parameters positively correlated to dose).

With regard to the K_ds selected for the RESRAD analysis, it is not clear why Lavery Till K_ds are used for the contaminated zone in the subsurface DCGLs and for the sediment DCGLs (see Table C-2). While the contaminant is assumed to be bound to Lavery Till in the subsurface DCGL calculations, *this material is assumed to be uniformly mixed with uncontaminated sand and gravel* that is ten times the volume of the contaminated Lavery Till brought to the surface. Leaching would therefore occur primarily through the thickness of the sand gravel in the contaminated zone. Likewise, no basis is provided for the assumption that sediment sorptive properties are similar to the Lavery Till and depending on the radionuclide in question, this assumption may lead to a significant under-prediction in dose.

DOE's selection of Uranium K_ds is presented in Table C-2. The value used for the Lavery Till is 10 L/kg based on site-specific information, while the value assumed for sand and gravel is assumed to be 35 L/kg based on literature values. As the K_ds in the Lavery Till are generally higher than the K_ds assumed for the sand and gravel, it would appear that the sand gravel K_ds might be overestimated based on the site-specific values for the Lavery Till, if the values for the Lavery Till are fairly certain.

A footnote to Table C-2 indicates that the uncertainty in K_ds for progeny was not evaluated in the sensitivity analysis and RESRAD default values were used in all cases. As the risk from ingrowth of daughter products in many cases dominates the risk from the parent radionuclides, the sensitivity of results to daughter product K_ds should be evaluated and uncertainty appropriately managed with parameter values that tend to over-estimate rather than underestimate the potential dose in the deterministic analysis.

Path Forward: As K_ds for risk-significant radionuclides can have a large impact on dose, K_ds values should be selected that are expected to err on the side of over-predicting rather than under-predicting the potential dose in the deterministic analysis when site-specific information is not available, or is uncertain. Commensurate with the risk significance of the parameter values, DOE should provide a more comprehensive discussion on how the K_ds were conservatively selected from the expected uncertainty range and address the issues listed above. DCGL calculations are also expected to be complicated by the in-growth of progeny in decay chains. Impacts due to the selection of K_ds for daughter products were not studied but may also have a large impact on the DCGL calculations. Therefore, the uncertainty introduced by the selection of K_ds for daughter products should also be evaluated in the sensitivity analysis and managed with conservative assumptions.

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DOE Response: The K_d values used in the three conceptual models were evaluated and found to be reasonable. However, the K_d value for curium radionuclides and the K_d values for progeny were changed to those specified in NUREG/CR-5512 (Beyeler, et al 1999) for consistency with the Decommissioning EIS, as indicated in the response to RAI 5C12.

As noted in the basis for this RAI, K_d values for Lavery till soil were used for the contamination zone in the subsurface soil and streambed sediment models. In the case of the subsurface soil model, Lavery till material is brought to the surface and mixed into the hypothetical garden. In the case of the streambed sediment model, the streambeds of interest lie within the Lavery till layer.

To evaluate the impacts of use of the Lavery till K_d values in calculating the subsurface soil DCGLs, the deterministic model was run using sand and gravel layer K_d values for the contamination zone. The revised model did not produce significantly different results, with DCGLs that were similar to the DCGLs with the base-case model in most cases; somewhat lower DCGLs for I-129, U-232, and Np-237; and somewhat higher DCGLs for Tc-99, U-233, U-234, and U-238.

In the probabilistic uncertainty analyses described in the response to RAI 5C15, the K_d values for the 18 radionuclides of interest were treated as probabilistic parameters. A range of potential values was established for each K_d based on site-specific data and literature values and bounded lognormal distributions were assigned consistent with NRC guidance.

Consideration was given to treating progeny K_d values as probabilistic parameters. This approach was determined not to be necessary because the only progeny of significance from a dose standpoint is Am-241, which is one of the 18 radionuclides of interest. The lack of significance of other progeny was addressed in the response to RAI 5C2.

Changes to the Plan: Changes to the plan are described in the response to RAI 5C15.

Reference:

Beyeler, et al. 1999, *Residual Radioactivity from Decommissioning, Parameter Analysis*, NUREG/CR-5512, Vol 3, Draft Report for Comment. Beyeler, W. E., W. A. Hareland, F. A. Duran, T. J. Brown, E. Kalinina, D. P. Gallegos, and P. A. Davis, Sandia National Laboratories, Albuquerque, New Mexico, October 1999.

RAI 5C17 (22)

Subject: Gamma shielding factor

RAI: DOE did not provide sufficient support that the selection of parameter values in the deterministic analysis is sufficiently conservative to demonstrate compliance with LTR criteria. This specific comment is related to DOE's selection of external gamma shielding factor. (Section 5.2.4; Appendix C, Table C-1)

Basis: On page 5-32 of the DP, a statement is made that in the absence of site-specific, semi site-specific, and scenario-specific data, the most likely values among default RESRAD parameters defined by a distribution would be used or, in their absence, mean values from NUREG/CR-6697. Appendix I of NRC decommissioning guidance, NUREG 1757, Vol. 2 (NRC, 2006), recommends conducting a sensitivity analysis to identify parameter values that have the most impact on dose and the selection of conservative parameter values to estimate dose.

A single deterministic value of 0.27 for the external gamma shielding factor was used for all radionuclides. It is not clear that this parameter value is sufficiently conservative for all gamma energies and for important radionuclides such as Cs-137 and U-238 daughters where the external dose pathway dominates the dose. For example, NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning," Vol. 3 - Draft Report for Comment (Beyeler, et al., 1999), reports shielding factors for various gamma energies and materials. All of the tabulated values for the external gamma shielding factor are greater than 0.27 at the gamma energy of 0.662 MeV representative of Ba-137m (daughter of Cs-137).

Path Forward: DOE should demonstrate that its selection of parameters does not significantly underestimate the potential risk from residual radioactivity remaining at the site. When appropriate, DOE should consider using radionuclide-specific parameter sets that consider the most important parameter values for individual radionuclides (e.g., external shielding factor for Cs-137) and select parameter values that are expected to over — rather than under — estimate the potential dose.

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DOE Response: The probabilistic uncertainty analysis entailed treating selected input parameters in each of the three conceptual models in a probabilistic manner as described in the response to RAI 5C15. Analyses were performed in which external shielding factors for key gamma-emitting radionuclides Cs-137 and U-232 were treated in a probabilistic manner. These radionuclides were selected because they are the gamma-emitting radionuclides expected to have the largest dose contributions. Specific gamma shielding factors were developed for them as explained below.

Development of Gamma Shielding Factors

The gamma shielding factors used for these key radionuclides were developed consistent with methods presented in Section 7.10 of NUREG-6697 (Yu, et al. 2000). Information regarding percentages of homes constructed with various methods (slab, basement, crawlspace) and materials (brick/stone, wood/vinyl) was used, along with results of RESRAD-Build simulations to determine the range of possible gamma shielding factors and likely mean value for specific radionuclides.

Dose calculations performed with RESRAD-Build, version 3.4 assumed that the differing construction techniques and materials could be approximated with various thicknesses of concrete shielding. Shielding factors were generated by comparing the results with and without shielding, and adjusting for an assumed 50 percent of indoor time spent unshielded while in front of windows.

Probabilities of construction types were combined with the associated shielding factor to produce the most likely value. The results were assumed to represent a triangular distribution, defined by the minimum and maximum of the range, with a mean set equal to the most likely parameter value for each radionuclide.

Table 5C17-1 presents the results of the analysis for developing the shielding factors.

Table 5C17-1. Summary of Gamma Shielding Factor Calculation

Nuclide	Construction Type		Construction Type Probability	Indoor Dose (mrem)	Outdoor Dose (mrem)	Indoor Dose (Adjusted for Windows)	Shielding Factor	Probability Weighted Shielding Factor
	Basement	Exterior						
Cs-137	Crawlspace	Brick/Stone	0.07	0.177	3.13	1.65	0.53	0.04
	Slab/Basement	Brick/Stone	0.28	0.011	3.13	1.57	0.50	0.14
	Crawlspace	Wood	0.13	0.968	3.13	2.05	0.65	0.09
	Slab/Basement	Wood	0.52	0.057	3.13	1.59	0.51	0.27
							Most likely value =>	**0.53**
U-232	Crawlspace	Brick/Stone	0.07	0.835	8.36	4.60	0.55	0.04
	Slab/Basement	Brick/Stone	0.28	0.087	8.36	4.22	0.51	0.14
	Crawlspace	Wood	0.13	3.23	8.36	5.80	0.69	0.09
	Slab/Basement	Wood	0.52	0.339	8.36	4.35	0.52	0.27
							Most likely value =>	**0.53**

The construction probability was based on the following data presented in NUREG-6697 (Yu, et al. 2000, page 7-35):

(1) Construction types 20 percent crawlspaces, 43 percent slab, and 37 percent basement; and

(2) Exterior type 34.5 percent brick/stone and 65.5 percent wood/vinyl (stucco accounts for 17 percent, which is distributed between brick and wood).

The indoor and outdoor doses were estimated using RESRAD-Build for a unit 1 pCi/g concentration. The doses were adjusted assuming 50 percent of indoor time near windows is unshielded.

The RESRAD-Build model assumed the following thicknesses of shielding for construction types/materials: (1) crawlspace/brick (12.5 cm), (2) crawlspace/wood (5 cm), (3) basement/brick (25 cm), and (4) basement/wood (17.5 cm). The shielding factor was weighted based on the construction type specific probability and specific shielding factor.

Results

Table 5C17-2 shows the results of the analyses.

Table 5C17-2. DCGL Changes From Incorporation of Gamma Shielding Factor in Probabilistic Analysis (pCi/g)(1)

Nuclide	Surface Soil				Subsurface Soil			
	Previous Peak-of-the-Mean	Previous 95th Percentile	Revised Peak-of-the-Mean	Revised 95th Percentile	Previous Peak-of-the-Mean	Previous 95th Percentile	Revised Peak-of-the-Mean	Revised 95th Percentile
Cs-137	1.83E+01	8.68E+00	1.52E+01	7.95E+00	4.24E+02	3.52E+02	3.01E+02	2.72E+02
U-232	1.71E+00	2.29E-01	1.51E+00	2.33E-01	1.06E+02	7.27E+01	7.40E+01	5.43E+01

NOTE: (1) The previous results are with the gamma shielding factor treated as a deterministic parameter.

Changes to the Plan: The revised peak-of-the-mean and 95th percentile DCGLs were included in the changes to the plan described in the response to RAI 5C15.

References:

Yu, et al. 2000, *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes*, NUREG/CR-6697, ANL/EAD/TM-98. Yu, C., et al., Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois, November 2000.