Unreviewed Disposal Question Evaluation: Impact of New Information since 2008 PA on Current Low-Level Solid Waste Operations

G. P. Flach, F. G. Smith, L. L. Hamm, B. T. Butcher

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REVIEWS AND APPROVALS

G. P. Flach, Author, Radiological Performance Assessment Date

F. G. Smith, Author, Process Modeling & Computational Chemistry Date

L. L. Hamm, Author, Process Modeling & Computational Chemistry Date

B. T. Butcher, Author, Radiological Performance Assessment Date

R. F. Swingle, Design Check, Technical Execution Date

G. K. Humphries, Program Management & Integration Date

D. A. Crowley, Manager, Radiological Performance Assessment Date

R. S. Aylward, Manager, Environmental Restoration Technologies Date

M. G. Looper, Chief Engineer, Solid Waste and F Area Engineering Date

J. L. Mooneyhan, SWMF Facility Manager Date

EXECUTIVE SUMMARY

Solid low-level waste disposal operations are controlled in part by an E-Area Low-Level Waste Facility (ELLWF) Performance Assessment (PA) that was completed by the Savannah River National Laboratory (SRNL) in 2008 (WSRC 2008). Since this baseline analysis, new information pertinent to disposal operations has been identified as a natural outcome of ongoing PA maintenance activities and continuous improvement in model simulation techniques (Flach 2013). An Unreviewed Disposal Question (UDQ) Screening (Attachment 1) has been initiated regarding the continued ability of the ELLWF to meet Department of Energy (DOE) Order 435.1 performance objectives in light of new PA items and data identified since completion of the original UDQ Evaluation (UDQE). The present UDQE assesses the ability of Solid Waste (SW) to meet performance objectives by estimating the influence of new information items on a recent sum-of-fractions (SOF) snapshot for each currently active E-Area low-level waste disposal unit. A final SOF, as impacted by this new information, is projected based on the assumptions that the current disposal limits, Waste Information Tracking System (WITS) administrative controls, and waste stream composition remain unchanged through disposal unit operational closure (Year 2025).

Revision 1 of this UDQE addresses the following new PA items and data identified since completion of the original UDQE report in 2013:

- New K_d values for iodine, radium and uranium
- Elimination of cellulose degradation product (CDP) factors
- Updated radionuclide data
- Changes in transport behavior of mobile radionuclides
- Potential delay in interim closure beyond 2025
- Component-in-grout (CIG) plume interaction correction

Consideration of new information relative to the 2008 PA baseline generally indicates greater confidence that PA performance objectives will be met than indicated by current SOF metrics. For SLIT9, the previous prohibition of non-crushable containers in revision 0 of this UDQE has rendered the projected final SOF for SLIT9 less than the WITS Admin Limit.

With respect to future disposal unit operations in the East Slit Trench Group, consideration of new information for Slit Trench#14 (SLIT14) reduced the current SOF for the limiting All-Pathways 200-1000 year period (AP2) by an order of magnitude and by one quarter for the Beta-Gamma 12-100 year period (BG2) pathway. On the balance, updates to K_d values and dose factors and elimination of CDP factors (generally favorable) more than compensated for the detrimental impact of a more rigorous treatment of plume dispersion. These observations suggest that future operations in the East Slit Trench Group can be conducted with higher confidence using current inventory limits, and that limits could be increased if desired for future low-level waste disposal units. The same general conclusion applies to future ST's in the West Slit Trench Group based on the Impacted Final SOFs for existing ST's in that area.

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CDP	Cellulose Degradation Product
CIG	Components In Grout
DCF	Dose Conversion Factor
DOC	Dissolved Organic Carbon
DOE	Department of Energy
ELLWF	E-Area Low Level Waste Facility
EPA	Environmental Protection Agency
ET	Engineered Trench
GW	Groundwater
ICRP	International Commission on Radiological Protection
ILV	Intermediate Level Vault
LAWV	Low Activity Waste Vault
MCL	Maximum Contaminant Level
N/A	Not Applicable
NRCDA	Naval Reactor Component Disposal Area
ORWBG	Old Radioactive Waste Burial Ground
PA	Performance Assessment
PIF	Plume Interaction Factor
SA	Special Analysis
SOF	Sum of Fractions
SLIT	Slit Trench (when associated with a specific unit or group)
SRNL	Savannah River National Laboratory
ST	Slit Trench
SW	Solid Waste
UDQ	Unreviewed Disposal Question
UDQE	Unreviewed Disposal Question Evaluation
UQ	Unquantified
UVZ	Upper Vadose Zone
WITS	Waste Information Tracking System

Pathway Group Notation in Text and Tables

Notation	**Pathway Group – Time Interval**	**When Referring To:**
Alpha1	Gross Alpha 0-1000 year period	Slit and Engineered Trenches
Alpha2	Gross Alpha 1000-1120 year period	Slit and Engineered Trenches
Alpha3	Gross Alpha 1200-1130 year period	Slit and Engineered Trenches
AP1	All-Pathways 130-200 year period	Slit and Engineered Trenches
AP2	All-Pathways 200-1000 year period	Slit and Engineered Trenches
AP2	All-Pathways 125-1125 year period	CIG Trenches
BG	Beta-Gamma	LAWV, NRCDA's
BG1	Beta-Gamma 12-100 year period	Slit and Engineered Trenches
BG2	Beta-Gamma 12-100 year period	Slit and Engineered Trenches
BG2	Beta-Gamma 125-1125 year period	CIG Trenches
BG2	Beta-Gamma 200-1100 year period	ILV
BG3	Beta-Gamma 100-1130 year period	Slit and Engineered Trenches
Ra1	Radium 0-1000 year period	Slit and Engineered Trenches
Ra2	Radium 1000-1120 year period	Slit and Engineered Trenches
Ra3	Radium 1120-1130 year period	Slit and Engineered Trenches

1.0 INTRODUCTION

Solid low-level waste disposal operations, particularly inventory limits, are controlled in part based on an ELLWF Performance Assessment completed in 2008 (WSRC 2008) and subsequent Special Analyses (SA). Since these analyses were completed, new information having a bearing on disposal operations has been identified as a natural outcome of ongoing PA maintenance activities (e.g. $K_d$values updated by Kaplan (2010)) and continuous improvement in model simulation techniques. An Unreviewed Disposal Question Screening was completed regarding the continued ability of the ELLWF to meet DOE Order 435.1 (DOE 1999a, Radioactive Waste Management) performance objectives in light of this collective body of new information. New information may impact radiological disposal limits, other aspects of current operation, and facility closure design. The attached UDQ Screening document dated 10/24/2012 (see Attachment 1) provides additional context for this UDQE, and describes the specific items of new information under consideration, which are categorized as:

- Revised input parameters
- Revised facility design
- Evolving facility operations
- Design and operation assumptions
- Physical phenomena assumptions.

These new information items were identified by SRNL based on data and analyses published since the 2008 PA, and a survey of the PA modeling community on simulation advances and insights since 2008. The present UDQE assesses the ability of Solid Waste to continue to meet DOE 435.1 performance objectives by estimating the influence of new information items on a SOF snapshot for each active E-Area disposal unit. A final SOF is projected assuming the current disposal limits, WITS administrative controls, and waste stream composition remain unchanged through disposal unit operational closure. A projected closure SOF less than one indicates that DOE 435.1 performance objectives are still expected to be satisfied in light of new information since the 2008 PA; otherwise, measures should be considered to restore expected compliance with performance objectives.

2.0 APPROACH

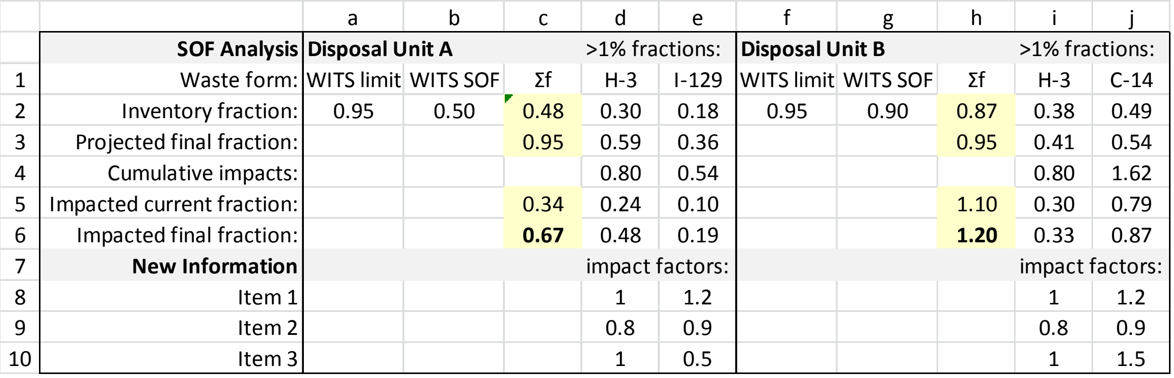
Low-level waste disposals in E-Area are controlled in part by a sum-of-fractions metric. When the inventory SOF is less than one, the low-level waste disposal unit is expected to meet DOE 435.1 performance objectives related to radiological dose. Each fraction is the ratio of buried activity to a disposal limit for a particular waste form. The disposal limit is derived from subsurface flow and transport modeling and dose calculations, which are based on various input information, analysis assumptions, and modeling techniques. The estimated impact of new information on facility performance is assessed in this UDQE by using a projected SOF at operational closure as the performance measure for each low-level waste disposal unit. The projected SOF accounts for the collective impact of new information relative to the current limits baseline.

The UDQE approach is conveniently described using an example calculation, such as the hypothetical set of parameters presented in Table 1. For each disposal unit, the WITS administrative limit, current WITS SOF, and individual fractions for waste forms contributing at least 1% to the SOF are shown (lines 1-2). The sum of the latter "key" radionuclide fractions (Σf; line 2; column c, h) is somewhat lower than the WITS SOF which includes contributions from all disposed radionuclide inventory (line 2; column b, g). Assuming that operations continue to facility closure under the current baseline, the maximum final fraction (line 3; columns c, h) will be the WITS administrative limit (line 2; columns a, f). Assuming that the closure waste composition is the same as the current key contributor composition, the projected final fractions for key wastes can be computed (line 3; columns d, e, i, j). Note, however, that inventories for special waste form radionuclides are held constant at their current inventory fractions if they are no longer being received by the facility.

The relative impacts of individual new information items are quantified as multipliers to the existing fractions (lines 8-10). Each factor is the reciprocal of the corresponding impact factor to disposal limits. The relative impact factor can thus be defined as the ratio of the current disposal limit to a hypothetical limit impacted by consideration of a new information item, all else being equal. The cumulative impact of new information items is the product of the individual factors (line 4; columns d, e, i, j). The current key fractions and projected final fractions multiplied by the cumulative impact factors are the 'impacted current' and 'impacted final' fractions, respectively (lines 5, 6). The projected final SOF (line 6; columns c, h), which considers new information but no change to current operations, is the sum of the impacted individual final fractions. In this example, consideration of new information improves confidence that Disposal Unit A will meet performance objectives, whereas an impacted final SOF > 0.95 for Disposal Unit B indicates decreased confidence relative to baseline knowledge.

The selected approach considers each new information item independently of other items, ignores potential changes in the timing of SOF contributions, and frequently relies on qualitative arguments and engineering judgment. Thus the SOF projections generated with this scoping analysis should be viewed more as an indication of trends than as rigorous quantitative predictions.

Table 1 - Hypothetical example illustrating UDQE approach



		a	b	c	d	e	f	g	h	i	j
	SOF Analysis	**Disposal Unit A**			>1% fractions:		**Disposal Unit B**			>1% fractions:	
1	Waste form:	WITS limit	WITS SOF	Σf	H-3	I-129	WITS limit	WITS SOF	Σf	H-3	C-14
2	Inventory fraction:	0.95	0.50	0.48	0.30	0.18	0.95	0.90	0.87	0.38	0.49
3	Projected final fraction:			0.95	0.59	0.36			0.95	0.41	0.54
4	Cumulative impacts:				0.80	0.54				0.80	1.62
5	Impacted current fraction:			0.34	0.24	0.10			1.10	0.30	0.79
6	Impacted final fraction:			**0.67**	0.48	0.19			**1.20**	0.33	0.87
7	**New Information**				impact factors:					impact factors:	
8	Item 1				1	1.2				1	1.2
9	Item 2				0.8	0.9				0.8	0.9
10	Item 3				1	0.5				1	1.5

3.0 ANALYSIS OF NEW INFORMATION

Information occurring after the basis document(s) for each current E-Area limit is considered "new". The basis documents for the current E-Area limits are the 2008 PA and subsequent Special Analyses (SA). The latter comprise the following reports:

1. Collard, L. B. and L. L. Hamm, *Special Analysis of Operational Stormwater Runoff Covers Over Slit Trenches*, SRNL-STI-2008-00397, December 2008

2. Swingle, R. F., *Special Analysis Disposal of Tritium-Containing IP-2 Boxes in the E-Area Low Level Waste Facility Intermediate Level Vault*, SRNL-STI-2008-00453, December 2008

3. Collard, L. B., L. L. Hamm and F. G. Smith, *Special Analysis of Tritium Disposal Limits for E-Area Slit Trench 4*, SRNL-STI-2010-00263, May 2010

4. Hamm, L. L. and F. G. Smith, *Special Analysis for Slit Trench Disposal of the Heavy Water Components Test Reactor*, SRNL-STI-2010-00574, October 2010

5. Hiergesell, R. A. and G. A. Taylor, *Special Analysis Air Pathway Modeling of E-Area Low-Level Waste Facility*, SRNL-STI-2011-00327, August 2011

6. Hamm, L. L., L. B. Collard, S. E. Aleman, M. B. Gorensek, and B. T. Butcher, *Special Analysis for Slit Trench Disposal of the Reactor Process Heat Exchangers*, SRNL-STI-2012-00321, June 2012

7. Swingle, R. F., *Special Analysis: Revised Groundwater Protection and All-Pathways Limits for E-Area Low-Level Waste Facility Trenches*, SRNL-STI-2012-00466, August 2012

The UDQ Screening (Attachment 1) contains a table of enumerated new information items identified for consideration. Appendix A contains a detailed analysis table to identify the new information items. New information items and new data for existing items identified in Revision 1 to this UDQE are identified below along with the section of the report where they are discussed:

- New K_d values for iodine, radium and uranium (Section 3.1)
- Elimination of CDP factors (Section 3.1.1)
- Updated radionuclide data (Sections 3.2 and 3.3)
- Changes in transport behavior of mobile radionuclides (Section 3.5.1)
- Potential delay in interim closure beyond 2025 (Section 3.5.2)
- CIG plume interaction correction (Section 3.15)

New items and data since Revision 0 are shown in red in the table in Appendix A. Each new information item is treated in one of three ways:

- determined to be not applicable (N/A) to the low-level waste disposal unit in question,
- chosen to be an unquantified (UQ) effect for one or more of various reasons, or
- quantified through a graded approach (numerical impact factor).

An item might remain unquantified because the impact has been determined to be beneficial, insignificant compared to other uncertainties, poorly-defined, and/or too difficult to quantify within the scoping level of effort undertaken in this UDQE. Unquantified beneficial impacts represent additional margin with respect to meeting performance objectives compared to the baseline.

To confine the analysis scope to impacts of practical importance, new information is considered in the context of a relatively small list of key parent nuclides and progeny. Key parents are those nuclides that currently have contributed a significant fraction to the SOF for the most limiting pathway group for any disposal unit. In selected cases impacts to the next most limiting pathway group are also evaluated depending on the significance of the secondary pathway (i.e., dissimilar pathway from the first, SOFs similar in magnitude, and SOF versus volume fraction). Appendix A includes parent nuclides for operating disposal units that contribute at least 1% to a recent SOF snapshot as of 6/16/2014 depending on disposal unit and pathway. The SOF snapshots obtained from Don Sink (Sink 2014a and 2014b) are provided in Appendix B. Appendix A shows the fractions from Appendix B. Before further discussing Appendix A, the techniques used to quantify the various impact factors or reasons for leaving factors unquantified are presented below in Sections 3.1 through 3.17.

3.1 Sorption coefficients (K_d)

New information items 1a through 1c (see Appendix A) pertain to sorption coefficients. Soil sorption coefficients (items 1a) and cementitious sorption coefficients (item 1b) are discussed below while elimination of CDP factors (item 1c) is treated separately in Section 3.1.1. Sorption coefficient (K_d, mL/g) is defined as the ratio of species concentration sorbed to the solid phase of a porous medium (C_{solid}, mol/g) to its equilibrium concentration dissolved in the liquid phase (C_{liquid}, mol/mL):

$$C_{solid} = K_d C_{liquid}. \tag{1}$$

Retardation factor (R, unitless) is defined as the ratio of total species mass (m) to the dissolved species mass (m_{liquid}) and related to sorption coefficient by:

$$R = \frac{m}{m_{liquid}} = 1 + \frac{\rho_b K_d}{\theta} \tag{2}$$

where ρ_b is bulk density (g/mL) and θ is water content (mL liquid / mL total volume). A change in sorption coefficient causes a redistribution of the species between the liquid and solid phases of a porous medium. The SOF impact factor is defined to be the ratio of liquid concentration with the new K_d to the liquid concentration using the baseline K_d:

$$F_{Kd} = \frac{C_{liquid,new\ Kd}}{C_{liquid,baseline\ Kd}} = \frac{m_{liquid,new\ Kd}}{m_{liquid,baseline\ Kd}} = \frac{R_{baseline\ Kd}}{R_{new\ Kd}}. \tag{3}$$

Generic values for soil density and saturated conditions are used to generate quantitative values, namely, $\theta = 0.40$ and ρ_b=1.56 g/mL. Similar values would be obtained for the vadose zone because water saturations tend to be high at the Savannah River Site (70-85%; Phifer and Dixon 2009). Retardation also impacts species travel time; specifically, the solute travel time is the retardation factor multiplied by the groundwater travel time. The factor defined by Equation (3) accounts for the change in peak concentration but not differences in peak arrival time. The impact factor expressed by Equation (3) above is a simple construct that provides a bounding effect (i.e., both as an impact or as a benefit) when all K_d values for a specific radionuclide either increase or decrease. For cases where some K_d values increase while others decrease, the transport aspects must be considered. Table 2 lists sorption coefficients, retardation factors, and travel times for key elements contributing to current SOFs for Sandy and Clayey materials. The selected impact factor is the maximum of the Sandy and Clayey values, e.g., 0.34 for carbon (C) in the bottom block of Table 2.

New in Revision 1 to this UDQE is the change in K_d for iodine (I) (Kaplan, et al., 2013), radium (Ra) (Powell et al., 2010) and uranium (U) (Seaman and Kaplan, 2010).

The impact of K_d values is beneficial or neutral in all cases except for neptunium (Np), for which the impact factor is 3.81. However, it was believed that the benefit of the increased sandy K_d value (0.6 → 3.0 mL/g) more than compensated for the loss due to the decreased clayey K_d value (35 → 9 mL/g). To verify this assertion, the 2008 PA transport analyses for Engineered Trench #2 was rerun using the new sand and clay K_d values for Np, with no other changes to the model, resulting in the following impacts.

Kd impact factor for Np-237										
Ratio of PA2008 limit / new limit										
	Beta-Gamma			**Alpha**			**Uranium**	**All-Pathways**		
Parent	**0-12**	**12-100**	**100-1130**	**0-1000**	**1000-1120**	**1120-1130**	**0-1130**	**130-200**	**200-1000**	**1000-1130**
Np-237	3.69E-10	7.74E-05	1.83	1.83	2.25	1.67	3.44	0.10	1.83	2.25

All impacts were less than the bounding impact factor of 3.81 calculated for Np using the methodology described by Equation (3). Due to the similarities in ST and Engineered

Trench (ET) construction, layout and waste composition this modeling result is considered to be applicable to all ST's and ET's, but not to units with cementitious barriers (CIG, LAWV and ILV). Therefore, these K_d impacts are used in place of the conservative impact factor of 3.81 for all ST's and ET's containing Np-237 as a key radionuclide (i.e., SLIT6, SLIT9, SLIT14 and ET#2).

The method of accounting for the impacts of K_d changes by comparing the ratio of 2008 PA to new retardation factors is known to be conservative. Due to adverse impacts from disposal of special waste form radium-226 (Ra-226) and thorium-230 (Th-230) in the SLIT6 gross alpha 1000-1120 year pathway (discussed in Section 3.1.1), special PORFLOW runs were made to accurately account for the increase in K_d for Ra-226. Both Ra-226 and Th-230 were run because Ra-226 is both a parent radionuclide and a daughter of Th-230. The following impact factors were calculated and used in place of those developed using the more conservative retardation ratio method (Table 2).

Kd impact factors for SLIT6 alpha 1,000-1,120 year pathway group

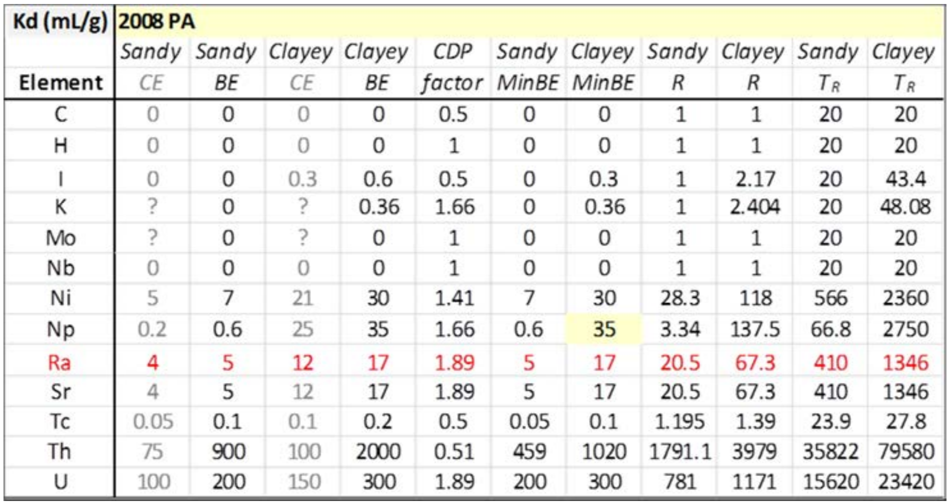
	PA2008	New	Impact Factor
Parent	**Alpha 1000-1120**	**Alpha 1000-1120**	**Ratio (PA2008/New)**
Ra-226T	1.16E+00	1.05E+13	**1.11E-13**
Th-230T	2.07E+00	2.89E+02	**7.16E-03**

Like Table 2, Table 3 defines K_d impact factors for oxidized cementitious materials, which are encountered in CIG trenches and Intermediate Level Vault (ILV) waste zones. The ILV also uses reduced concrete, but the initial waste concentration is controlled by oxidized grout surrounding the waste, so oxidized K_d values are used to estimate impact factors. For these cementitious materials, $\theta = 0.20$ and $\rho_b = 2.08$ g/mL are assumed in computing the retardation factors. The selected impact factor is the maximum of the Young, Moderate, and Aged material values. The impact of new K_d values is beneficial for several elements, often strongly so. However, the impact of new sorption information is negative for I, Ni, and U.

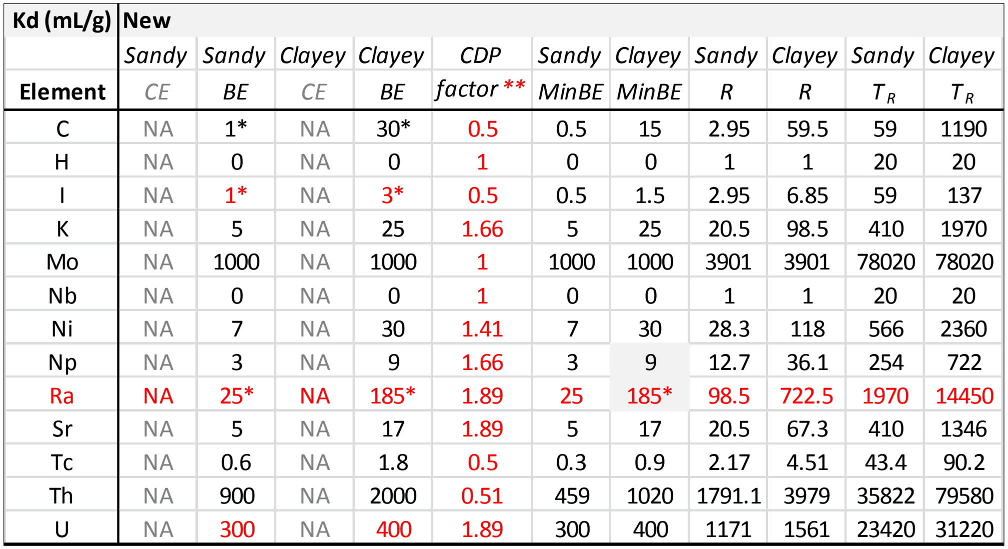
Reduced concrete is used in the Low Activity Waste Vault (LAWV), for which C-14 and I-129 are the key contributors. Reduced K_d values for C-14 are the same as the oxidized values so the impact factors are the same. For I-129, the reduced K_d values are either the same (Aged = 4 mL/g) or lower (Young = 5 mL/g and Moderate = 9 mL/g) than the corresponding oxidized values, resulting in a larger impact factor, 2.21 for reduced conditions versus 1.33 for oxidized conditions.

The sources of the updated K_d values and those used in the 2008 PA are identified in the notes to Table 2 and Table 3. The new entries for three elements (I, Ra, and U) in revision 1 are shown in red type. The radionuclides Mo-93, Nb-93m, Th-229 and U-233 shown in the two K_d tables are daughters of either Nb-94 or Np-237 (key PA radionuclides) and are therefore not included in the summary table in Appendix A.

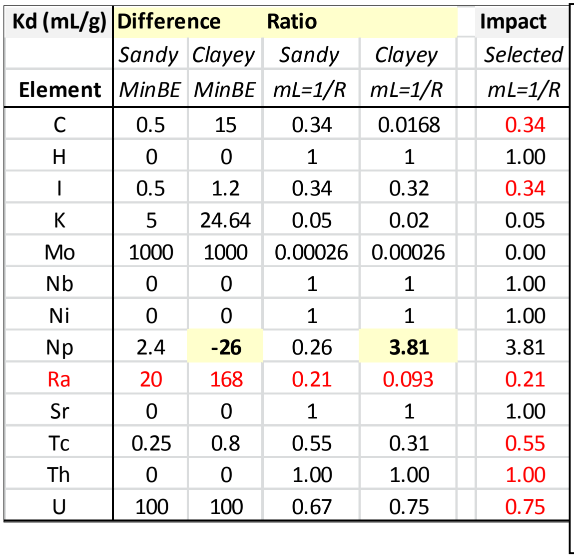
Table 2 - Sorption coefficients and impact factors for soils.



Kd (mL/g)	2008 PA										
	Sandy	Sandy	Clayey	Clayey	CDP	Sandy	Clayey	Sandy	Clayey	Sandy	Clayey
Element	CE	BE	CE	BE	factor	MinBE	MinBE	R	R	T_R	T_R
C	0	0	0	0	0.5	0	0	1	1	20	20
H	0	0	0	0	1	0	0	1	1	20	20
I	0	0	0.3	0.6	0.5	0	0.3	1	2.17	20	43.4
K	?	0	?	0.36	1.66	0	0.36	1	2.404	20	48.08
Mo	?	0	?	0	1	0	0	1	1	20	20
Nb	0	0	0	0	1	0	0	1	1	20	20
Ni	5	7	21	30	1.41	7	30	28.3	118	566	2360
Np	0.2	0.6	25	35	1.66	0.6	35	3.34	137.5	66.8	2750
Ra	4	5	12	17	1.89	5	17	20.5	67.3	410	1346
Sr	4	5	12	17	1.89	5	17	20.5	67.3	410	1346
Tc	0.05	0.1	0.1	0.2	0.5	0.05	0.1	1.195	1.39	23.9	27.8
Th	75	900	100	2000	0.51	459	1020	1791.1	3979	35822	79580
U	100	200	150	300	1.89	200	300	781	1171	15620	23420



Kd (mL/g)	New										
	Sandy	Sandy	Clayey	Clayey	CDP	Sandy	Clayey	Sandy	Clayey	Sandy	Clayey
Element	CE	BE	CE	BE	factor **	MinBE	MinBE	R	R	T_R	T_R
C	NA	1*	NA	30*	0.5	0.5	15	2.95	59.5	59	1190
H	NA	0	NA	0	1	0	0	1	1	20	20
I	NA	1*	NA	3*	0.5	0.5	1.5	2.95	6.85	59	137
K	NA	5	NA	25	1.66	5	25	20.5	98.5	410	1970
Mo	NA	1000	NA	1000	1	1000	1000	3901	3901	78020	78020
Nb	NA	0	NA	0	1	0	0	1	1	20	20
Ni	NA	7	NA	30	1.41	7	30	28.3	118	566	2360
Np	NA	3	NA	9	1.66	3	9	12.7	36.1	254	722
Ra	NA	25*	NA	185*	1.89	25	185*	98.5	722.5	1970	14450
Sr	NA	5	NA	17	1.89	5	17	20.5	67.3	410	1346
Tc	NA	0.6	NA	1.8	0.5	0.3	0.9	2.17	4.51	43.4	90.2
Th	NA	900	NA	2000	0.51	459	1020	1791.1	3979	35822	79580
U	NA	300	NA	400	1.89	300	400	1171	1561	23420	31220



Kd (mL/g)	Difference		Ratio		Impact
	Sandy	Clayey	Sandy	Clayey	Selected
Element	MinBE	MinBE	mL=1/R	mL=1/R	mL=1/R
C	0.5	15	0.34	0.0168	0.34
H	0	0	1	1	1.00
I	0.5	1.2	0.34	0.32	0.34
K	5	24.64	0.05	0.02	0.05
Mo	1000	1000	0.00026	0.00026	0.00
Nb	0	0	1	1	1.00
Ni	0	0	1	1	1.00
Np	2.4	**-26**	0.26	**3.81**	3.81
Ra	20	168	0.21	0.093	0.21
Sr	0	0	1	1	1.00
Tc	0.25	0.8	0.55	0.31	0.55
Th	0	0	1.00	1.00	1.00
U	100	100	0.67	0.75	0.75

Notes:

2008 PA = Kaplan (2006), WSRC-TR-2006-00004, Rev. 0

New = Kaplan (2010), SRNL-STI-2009-00473, Rev. 0

*New C-14 = Roberts & Kaplan (2013), SRNS-STI-2008-00445, Rev. 1

*New I-129 = Kaplan et al. (2013), SRNL-STI-2012-00518, Rev. 0

New Ra-226 = Powell et al. (2010), SRNL-STI-2010-00527, Rev. 0

New U-233 = Seaman & Kaplan (2010), SRNL-STI-2010-00493, Rev. 0

**CDP treated separately in section 3.1.1; reverted back to CDP factors used in 2008 PA

BE = Best Estimate; CE = Conservative Estimate; Columns containing “CE” or “BE” in title represent K_d (mL/g)

CDP factor = Cellulose degradation product factor (unitless)

R = Retardation factor (unitless)

T_R denotes retarded solute travel time for a 20 year reference groundwater travel time

Table 3 - Sorption coefficients and impact factors for cementitious materials.

Kd (mL/g)	2008 PA								
Oxidized	Young	Young	Mod.	Mod.	Aged	Aged	Young	Mod.	Aged
Element	CE	BE	CE	BE	CE	BE	R	R	R
C	14	20	7	10	0	0	209	105	1
H	0	0	0	0	0	0	1	1	1
I	6	8	14	20	0	0	84.2	209	1
K							1	1	1
Mo							1	1	1
Nb	500	1000	500	1000	360	500	10401	10401	5201
Ni	500	1000	500	1000	360	500	10401	10401	5201
Np	1000	2000	1000	2000	140	200	20801	20801	2081
Sr	0.2	1	0.5	1	0.2	0.8	11.4	11.4	9.32
Tc	0	0	0	0	0	0	1	1	1
Th	1000	5000	1000	5000	250	500	52001	52001	5201
U	500	1000	500	1000	50	70	10401	10401	729

Kd (mL/g)	New								
Oxidized	Young	Young	Mod.	Mod.	Aged	Aged	Young	Mod.	Aged
Element	CE	BE	CE	BE	CE	BE	R	R	R
C	NA	3000	NA	3000	NA	300	31201	31201	3121
H	NA	0	NA	0	NA	0	1	1	1
I	NA	8	NA	15	NA	4	84.2	157	42.6
K	NA	2	NA	20	NA	10	21.8	209	105
Mo	NA	300	NA	300	NA	150	3121	3121	1561
Nb	NA	1000	NA	1000	NA	500	10401	10401	5201
Ni	NA	4000	NA	4000	NA	400	41601	41601	4161
Np	NA	10000	NA	10000	NA	5000	104001	104001	52001
Sr	NA	15	NA	15	NA	5	157	157	53
Tc	NA	0.8	NA	0.8	NA	0.5	9.32	9.32	6.2
Th	NA	10000	NA	10000	NA	2000	104001	104001	20801
U	NA	1000*	NA	1000*	NA	100*	10401	10401	1041

Kd (mL/g)	Difference			Ratio			Impact
Oxidized	Young	Mod.	Aged	Young	Mod.	Aged	Selected
Element	Kd	Kd	Kd	mL=1/R	mL=1/R	mL=1/R	mL=1/R
C	2980	2990	300	6.7E-03	3.4E-03	3.2E-04	0.0067
H	0	0	0	1.0E+00	1.0E+00	1.0E+00	1.00
I	0	**-5**	4	1.0E+00	**1.3E+00**	2.3E-02	1.33
K	2	20	10	4.6E-02	4.8E-03	9.5E-03	0.05
Mo	300	300	150	3.2E-04	3.2E-04	6.4E-04	0.00064
Nb	0	0	0	1.0E+00	1.0E+00	1.0E+00	1.00
Ni	3000	3000	**-100**	2.5E-01	2.5E-01	**1.2E+00**	1.25
Np	8000	8000	4800	2.0E-01	2.0E-01	4.0E-02	0.20
Sr	14	14	4.2	7.3E-02	7.3E-02	1.8E-01	0.18
Tc	0.8	0.8	0.5	1.1E-01	1.1E-01	1.6E-01	0.16
Th	5000	5000	1500	5.0E-01	5.0E-01	2.5E-01	0.50
U	0	0	30	1.0E+00	1.0E+00	7.0E-01	1.00

Notes: 2008 PA = Kaplan (2006), WSRC-TR-2006-00004, Rev. 0
New = Kaplan (2010), SRNL-STI-2009-00473, Rev. 0
* New U-233 = Seaman & Kaplan (2010), SRNL-STI-2010-00493, Rev. 0

3.1.1 Elimination of CDP factors

Many low-level waste streams disposed in E-Area contain wood, cardboard, paper and other cellulosic materials. As these buried celluosic materials degrade over time, complex soluble organic compounds known as Cellulose Degradation Products (CDPs) are formed that influence the tendency of radionuclides to sorb to sediments thus affecting their transport behavior. The CDP-correction factor, f_{CDP}, has been used to calculate a CDP-corrected K_d value, Kd_{CDP}

$$Kd_{CDP} = f_{\mathrm{CDP}} \mathrm{~x~} K_d \tag{4}$$

The f_{CDP} factor varies with cation and is a function of sediment type, pH and dissolved organic carbon (DOC) concentration in the pore water. The concentration of CDPs (as measured by DOC concentration) in pore water is a function of the rate of formation of CDPs from the decomposition of the waste. Experimental data has shown that CDP generally decreases K_d values of cations (most radionuclides) at high concentrations [>20 mg/L as Carbon (C)]. Conversely, at low concentrations, CDP generally increases K_d values of cations. Presumably, at low concentrations CDP sorbs to the sediment and provides more exchange sites for cations to sorb to, thereby increasing K_d values, whereas at elevated CDP concentration sediment exchange sites became swamped and the CDP remains in the aqueous phase, where it will complex the radionuclides and not permit them to adsorb to the sediment surfaces. In the 2008 PA it was conservatively assumed that CDP would leach from the cellulosic source terms at a rate producing 95 mg/L C. This concentration was selected to produce the generally lowest set of $K_d$values.

A subsequent review of DOC data obtained from the 643-G Old Radioactive Waste Burial Ground (ORWBG) was performed as part of the 2010 update of SRNL's Geochemistry Data Package (Kaplan 2010). The ORWBG, operated between 1954 and 1971, received cellulosic waste similar in composition to that in the nearby ELLWF. The ORWBG contains a system of shallow monitoring wells installed in a grid pattern across the entire footprint of the burial facility. An extensive DOC sampling campaign of these grid wells was conducted between 1982 and 1985 (McIntyre and Wilhite, 1987) resulting in over 230 measurements of DOC (referred to as total organic carbon, TOC). The average DOC concentration from this dataset was 5.2 mg/L.

Thus, at present the best estimate of CDP concentrations in ELLWF pore water is ~5 mg/L. Experimental data suggests that a majority of Kd_{CDP} values in the presence of this concentration of CDP are in fact greater than baseline $K_d$values. It was elected not to recommend increasing these values to be conservative in future PA calculations (Kaplan, 2012). Therefore, the following condition is assumed,

$$Kd_{CDP} = K_d \tag{4}$$

For the 2008 PA, CDP impacts were considered differently depending on the type of disposal unit being evaluated:

- ET's and ST's: For trench simulations, two geochemical cases were thought to be plausible and therefore evaluated separately. These two cases are: 1) the no cellulose case, in which baseline K_d values are assigned for each radionuclide simulated, and 2) the CDP case in which Kd_{CDP} values were assigned at the assumed CDP concentration of 95 mg/L C. The development of facility limits considered the results of both scenarios (in combination with and without non-crushable containers) and selected the most restrictive scenario (highest groundwater concentration over the PA period of interest) to set the limits.
- CIG Trenches and LAWV: CDPs, at a concentration level of 95 mg/L C, were assumed to be present as the baseline scenario to set limits. Sensitivity cases assuming CDP's to be absent were also run to assess the importance of the CDP correction factor to results.
- ILV and NRCDA: CDP's were assumed to be absent in setting the limits based on process knowledge that the waste streams received by these two facilities contain negligible amounts of cellulose.

Engineered Trenches and Slit Trenches

For ET's and ST's the act of selecting the most restrictive scenario (highest groundwater concentration over the PA period of interest) from either the CDP present or absent condition (in combination with and without non-crushable containers) ensures that reducing the analysis to the baseline K_d case can result in only one of two outcomes; either no change or an increase in the disposal limit. The ratios of the final PA limit to the minimum limit for the CDP absent condition are shown in Table 4 for the key radionuclides associated with each ST and ET. Except as noted below for SLIT6, treatment of generic and special waste form radionuclides followed this methodology and outcome. The ratios in Table 4 are included as impact factors in item 1c in Appendix A.

Slit Trench #6. With one exception, eliminating CDP factors would have either no effect on the limits or would be beneficial. The one exception is the disposal of waste from demolition of the 285-F cooling tower containing Ra-226 and Th-230 in SLIT6 (designated Ra-226T and Th-230T in following two tables). This waste stream consisted of 135 roll off pans of waste and was disposed in the year 2006. For this particular disposal the lowest limit was not selected. Rather, selection of the higher CDP-impacted Ra-226 limit was necessary because of the amount of curies of Ra-226 estimated to be present in the tower. The justification for this decision is that the cooling tower was constructed with wood baffles thereby creating a largely wood-based (cellulose) waste form. Nevertheless, based on the historical DOC measurement data discussed above, the impact of assuming a CDP absent condition was evaluated in Table 5. Table 5 shows the development of new non-CDP impacted Ra-226 and Th-230 limits for SLIT6 and resulting SOF adjustments. If implemented in WITS, either the gross alpha 1000-1120 year period (Alpha2) or gross alpha 1120-1130 year period (Alpha3) would replace Beta-Gamma2 to become the new limiting pathway with a SOF of 1.47 for SLIT6. Alpha2 was selected as the limiting pathway for calculating impacts in Appendix A.

As discussed earlier in Section 3.1 and shown in the detailed analysis spreadsheet in Appendix A, a new larger K_d has been developed for radium (Powell et al. 2010) that offsets this negative impact to produce an acceptable SOF for SLIT6.

Component-in-Grout Trenches and Low Activity Waste Vault

For CIG Trenches and the LAWV, the CDP absent condition was evaluated in sensitivity runs to assess the importance of the CDP correction factors to results.

CIG Trenches. The key generic CIG radionuclides H-3, C-14, I-129, and Tc-99 collectively contribute 40% to the SOF in the limiting Beta-Gamma2 pathway (125-1,125 years). For these isotopes, the baseline (CDP present) limits were all lower than the sensitivity run (CDP absent) limits as shown in Table 4. In contrast, the two special wasteform isotopes, C-14K and I-129K, produce more restrictive limits for the CDP absent condition. However, C-14K and I-129K contribute only 3% to the SOF and are therefore more than offset by the less restrictive limits for the key generic radionuclides. All other radionuclides contribute less than 1% to the SOF for this pathway and time interval. Thus, changing to the CDP absent condition marginally improves the projected final SOF for CIG-1. The ratio of the CDP present limits to the CDP absent limits in Table 4 are included as impact factors in item 1c in the detailed analysis spreadsheet in Appendix A.

LAWV. C-14 and I-129 are key isotopes for the LAWV contributing 14% to the SOF to the limiting BG pathway. The baseline (CDP present) limits for these two isotopes were both lower than the sensitivity run (CDP absent) limits as shown in Table 4. All other radionuclides contribute less than 1% to the SOF for this pathway. Thus, changing to the CDP absent condition marginally improves limits. The ratio of the CDP present limits to the CDP absent limits in Table 4 are included as impact factors in item 1c in the detailed analysis spreadsheet in Appendix A.

Intermediate Level Vault and Naval Reactor Component Disposal Areas

For ILV and Naval Reactor Component Disposal Areas (NRCDA's) there is no effect of this change because CDP's were assumed to be absent in the base case. Therefore, the impact factor for this change in these disposal units is one.

Table 4 -Impact of eliminating CDP factors

Disposal Unit	1st or 2nd Limiting Pathway	Key Radionuclide	Limit CDP Absent	Limit Current PA Baseline	Impact Factor[1]
SLIT6	BG2	C-14	2.5E-01	2.5E-01	1.00
		H-3	4.8E+00	4.8E+00	1.00
		I-129	1.6E-04	1.4E-04	0.86
		Tc-99	1.5E-01	1.3E-01	0.85
SLIT6	Alpha2	Np-237	6.5E-01	1.5E-01	0.23
		Ra226T	3.8E-02	9.7E-01	25.1
		Th230T	1.1E-01	1.8E+00	17.2
SLIT7	BG2	C-14	2.8E-01	2.8E-01	1.00
		H-3	5.3E+00	5.3E+00	1.00
		I-129	1.8E-04	1.6E-04	0.91
		Tc-99	1.7E-01	1.4E-01	0.79
SLIT8	BG1	C-14	1.5E-01	1.5E-01	1.00
		H-3	2.8E+00	2.8E+00	1.00
		I-129	2.0E-04	1.6E-04	0.78
		Tc-99	1.6E-01	9.4E-02	0.58
SLIT9[2]	BG3	C-14X	2.7E+00	2.7E+00	1.00
		Sr-90	2.3E+06	2.5E+01	1.1E-05
SLIT9[2]	AP1	C-14X	2.7E+00	2.7E+00	1.00
		Np-237	6.6E-01	1.7E-02	0.03
		Sr-90	8.7E+07	9.2E+02	1.1E-05
SLIT14	AP2	C-14N	1.4E+00	1.4E+00	1.00
		Np-237	1.4E-02	1.4E-02	1.00
SLIT14	BG2	C-14	1.9E-01	1.9E-01	1.00
		H-3	4.2E+00	4.2E+00	1.00
		I-129	1.1E-04	1.0E-04	0.92
		Tc-99	1.2E-01	1.0E-01	0.85
ET#1	BG2	C-14	5.0E-01	5.0E-01	1.00
		H-3	1.2E+01	1.2E+01	1.00
		I-129	3.7E-04	3.0E-04	0.81
		Nb-94	1.9E-01	1.9E-01	1.00
		Tc-99	3.2E-01	2.7E-01	0.85
ET#2	AP2	Np-237	6.0E-02	6.0E-02	1.00
ET#2	BG2	C-14	5.6E-01	5.6E-01	1.00
		H-3	1.3E+01	1.3E+01	1.00
		I-129	4.1E-04	3.3E-04	0.81
		Tc-99	3.6E-01	3.0E-01	0.85

Table 4 – Impact of eliminating CDP factors (continued)

Disposal Unit	1st or 2nd Limiting Pathway	Key Radionuclide	Limit CDP Absent	Limit Current PA Baseline	Impact Factor[1]
CIG1	BG2	C-14	3.7E-01	3.2E-01	0.88
		C-14K	2.7E+00	3.0E+00	1.14
		H-3	9.3E+04	9.3E+04	1.00
		I-129	1.3E-04	9.2E-05	0.69
		I-129K	2.5E-02	3.3E-02	1.30
		Tc-99	3.2E-01	2.8E-01	0.89
CIG1	AP2	C-14	3.9E-01	3.5E-01	0.89
		C-14K	2.8E+00	3.2E+00	1.14
		Np-237	1.3E-02	2.2E-02	1.66
		Tc-99	4.8E-01	4.3E-01	0.89
LAWV	BG	C-14	5.8E+00	4.2E+00	0.72
		I-129	3.0E-03	2.2E-03	0.73
ILV	BG2	I-129	1.1E-02	1.1E-02	1.00
		I-129C	3.9E-01	3.9E-01	1.00
NR (643-26E)	BG	Ni-59	9.7E+04	9.7E+04	1.00

[1] The SOF Impact Factor is used in the detailed analysis spreadsheet in Appendix A. It is the ratio of the current baseline limit to the limit for the CDP-absent condition. Values in red type negatively impact the SOF.

[2] C-14X is a special waste form isotope from burial of reactor process HX's in SLIT9. The waste form is entirely metal, so the CDP case was not evaluated. The projected Sr-90 limits absent CDP are based on the 0% non-crushable case because of the prohibition on non-crushable containers in SLIT9 (see Key Inputs & Assumptions).

Notes: Unless noted otherwise in the text or tables impact factors for the generic and special waste forms of a radionuclide (ex. C-14 and C-14N) are calculated in the same manner.

The following pathway group notation is used in Table 4, Table 5 and Table 10.

Notation	Pathway Group – Time Interval	When Referring To:
Alpha1	Gross Alpha 0-1000 year period	Slit and Engineered Trenches
Alpha2	Gross Alpha 1000-1120 year period	Slit and Engineered Trenches
Alpha3	Gross Alpha 1200-1130 year period	Slit and Engineered Trenches
AP1	All-Pathways 130-200 year period	Slit and Engineered Trenches
AP2	All-Pathways 200-1000 year period	Slit and Engineered Trenches
AP2	All-Pathways 125-1125 year period	CIG Trenches
BG	Beta-Gamma	LAWV, NRCDA's
BG1	Beta-Gamma 12-100 year period	Slit and Engineered Trenches
BG2	Beta-Gamma 12-100 year period	Slit and Engineered Trenches
BG2	Beta-Gamma 125-1125 year period	CIG Trenches
BG2	Beta-Gamma 200-1100 year period	ILV
BG3	Beta-Gamma 100-1130 year period	Slit and Engineered Trenches
Ra1	Radium 0-1000 year period	Slit and Engineered Trenches
Ra2	Radium 1000-1120 year period	Slit and Engineered Trenches
Ra3	Radium 1120-1130 year period	Slit and Engineered Trenches

Table 5 -Non-CDP impacted Ra-226 and Th-230 limits for SLIT6 and resulting SOF adjustments

						PATHWAYS						
LIMITS AND SOF ADJUSTMENTS	**Alpha1**	**Alpha2**	**Alpha3**	**Ra1**	**Ra2**	**Ra3**	**AP1**	**AP2**	**AP3**	**BG1**	**BG2**	**BG3**
Current Ra-226T & Th-230T Limits for ST6 (Curies)												
Ra-226T Limit (from PA Limits Database)	2.3E-01	9.7E-01	8.2E-01	2.3E-01	9.8E-01	8.2E-01	9.9E+03	6.5E-01	2.4E+00	---	1.2E+12	1.4E+01
Th-230T Limit (from PA Limits Database)	1.9E+00	1.8E+00	1.7E+00	1.9E+00	1.8E+00	1.7E+00	4.9E+05	5.5E+00	4.9E+00	---	9.9E+14	1.1E+02
Non-CDP Impacted Limits (Curies)*												
Ra-226T												
No Non-crushable - CDP off preliminary limit	7.5E-02	4.6E-02	4.6E-02	7.5E-02	4.6E-02	4.6E-02	5.9E+05	2.2E-01	1.3E-01	2.7E+17	3.0E+07	3.5E+00
Final Limit (with adjustments)	6.3E-02	3.8E-02	3.9E-02	6.3E-02	3.8E-02	3.9E-02	5.0E+05	1.8E-01	1.1E-01	2.3E+17	2.5E+07	2.9E+00
10% Non-crushable - CDP off preliminary limit	8.3E-02	5.1E-02	5.1E-02	8.3E-02	5.1E-02	5.1E-02	6.2E+00	2.4E-01	1.5E-01	2.7E+17	3.0E+07	3.9E+00
Final Limit (with adjustments)	7.0E-02	4.3E-02	4.3E-02	7.0E-02	4.3E-02	4.3E-02	5.2E+00	2.0E-01	1.3E-01	2.3E+17	2.5E+07	3.3E+00
Th-230T												
No Non-crushable - CDP off preliminary limit	3.9E-01	1.3E-01	1.2E-01	3.9E-01	1.3E-01	1.2E-01	4.4E+08	1.1E+00	3.6E-01	---	2.4E+10	1.0E+01
Final Limit (with adjustments)	3.3E-01	1.1E-01	1.0E-01	3.3E-01	1.1E-01	1.0E-01	3.7E+08	9.6E-01	3.0E-01	---	2.0E+10	8.8E+00
10% Non-crushable - CDP off preliminary limit	3.7E-01	1.3E-01	1.3E-01	3.7E-01	1.3E-01	1.3E-01	1.7E+02	1.1E+00	3.8E-01	---	2.4E+10	1.1E+01
Final Limit (with adjustments)	3.1E-01	1.1E-01	1.1E-01	3.1E-01	1.1E-01	1.1E-01	1.4E+02	9.1E-01	3.2E-01	---	2.0E+10	9.2E+00
Adjustments												
SLITc Plume Interaction Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
ST6 Size Adjustment	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Minimum Limit (Curies)												
Ra-226T	6.3E-02	3.8E-02	3.9E-02	6.3E-02	3.8E-02	3.9E-02	5.2E+00	1.8E-01	1.1E-01	2.3E+17	2.5E+07	2.9E+00
Th-230T	3.1E-01	1.1E-01	1.0E-01	3.1E-01	1.1E-01	1.0E-01	1.4E+02	9.1E-01	3.0E-01	---	2.0E+10	8.8E+00
SOF Adjustments												
Ra-226T Inventory (from WITS)	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02
Th-230T Inventory (From WITS)	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02	3.99E-02
SOF as of 10/31/14 (per Sink Spreadsheet)	2.65E-01	1.21E-01	1.16E-01	2.01E-01	7.47E-02	8.46E-02	1.84E-01	3.26E-01	2.00E-01	7.90E-01	8.22E-01	4.69E-01
(Contrib to SOF from Ra-226T)	1.73E-01	4.11E-02	4.87E-02	1.73E-01	4.07E-02	4.87E-02	4.03E-06	6.14E-02	1.66E-02	0.00E+00	3.33E-14	2.85E-03
(Contrib to SOF from Th-230T)	2.10E-02	2.22E-02	2.35E-02	2.10E-02	2.22E-02	2.35E-02	8.14E-08	7.25E-03	8.14E-03	0.00E+00	4.03E-17	3.63E-04
= SOF excluding Ra-226T and Th-230T contribution	7.05E-02	5.77E-02	4.39E-02	6.52E-03	1.18E-02	1.25E-02	1.84E-01	2.57E-01	1.75E-01	7.90E-01	8.22E-01	4.66E-01
+ Ra-226T fraction calc. from minimum limit	6.35E-01	1.04E+00	1.04E+00	6.34E-01	1.04E+00	1.04E+00	7.70E-03	2.17E-01	3.54E-01	1.74E-19	1.59E-09	1.36E-02
+ Th-230T fraction calc. from minimum limit	1.29E-01	3.73E-01	3.89E-01	1.29E-01	3.73E-01	3.89E-01	2.81E-04	4.39E-02	1.33E-01	0.00E+00	2.00E-12	4.56E-03
= SOF adjusted with maximum Ra/Th fractions	8.34E-01	1.47E+00	1.47E+00	7.69E-01	1.42E+00	1.44E+00	1.92E-01	5.18E-01	6.62E-01	7.90E-01	8.22E-01	4.84E-01
Current Limiting Pathway and SOF											8.22E-01	
New Limiting Pathway and SOF		1.47E+00	1.47E+00									

*CDP-off preliminary limits for Ra-226T and Th-230T were taken from the generic values for Ra-226 and Th-230 because no CDP-off limits were calculated.

3.2 Dose calculations

The PA defines performance objectives for solid low-level waste disposal in E-Area (WSRC 2008, Section 2.3). The most limiting objectives are: a) compliance with U. S. Environmental Protection Agency (EPA) drinking water standards with respect to beta-gamma dose (4 mrem/yr) and b) the U. S. Department of Energy 25 mrem/yr All Pathways dose. These two controlling pathways are discussed in turn.

Groundwater Resource Protection

As noted in the PA, the guide (DOE 1999b) for DOE 435.1 (DOE 1999a) states:

> "DOE M 435.1-1 does not specify the level of protection for water resources that should be used in a performance assessment for a specific low-level waste disposal facility. Rather, a site-specific approach, in accordance with a hierarchical set of criteria should be followed."

For the 2008 PA, the appropriate measure for protection of water resources was determined to be the Safe Drinking Water Act Maximum Contaminant Levels (MCLs). At the Savannah River Site, compliance with EPA drinking water standards is accomplished through adherence to the protocol defined by technical memorandum ERTEC-2001-0002 (Gaughan 2001) which is based on direction from EPA Region IV. With respect to beta-gamma dose, the protocol specifies use of derived concentrations published in a January 1981 EPA document: *Radioactivity in Drinking Water*, *Appendix III*, pages 72-74. Because this document and the site-specific protocol pre-date the 2008 PA, the beta-gamma pathway is unaffected by new information (item 2a) for the key (>1%) SOF nuclides with the single exception of Nb-94. For beta-gamma emitting radionuclides not included in the EPA standard, the 2008 PA applies derived MCL's based on the drinking water concentration that would give a dose of 4 mrem/yr. The radionuclide Nb-94, identified as a key radionuclide for Engineered Trench #1 (ET#1), falls into this category. An impact factor of 1.16 was estimated for the beta-gamma dose from Nb-94 by taking the ratio of the current derived MCL to the derived MCL calculated using new dose parameters that would be applied in future calculations.

All-Pathways

Since the 2008 PA, the DOE has published a new technical standard for derived radiological concentrations and dose coefficients, DOE-STD-1196-2011 (DOE 2011), which represents new information with respect to the 25 mrem/yr All Pathways dose calculation (item 2b). In particular, the water ingestion dose factors (Sv/Bq) for various nuclides differ from the EPA Federal Guidance Report No. 11 (EPA 1988) values used in the 2008 PA. The All Pathways dose includes contributions from water ingestion, and vegetable, milk, and meat consumption. DOE considers the dose impact from the ingestion pathway to be the same regardless of the form in which the radionuclide is consumed. The dose conversion factors (DCFs) for each of these components include the water ingestion dose factor (Sv/Bq) as a multiplicative factor. Therefore, the All Pathways DCFs accumulating these dose contributors (i.e., the sum of the water ingestion, and vegetable, milk, and meat consumption DCFs) can to a first approximation be updated by multiplying by the ratio of the water ingestion dose factors used in the 2008 PA and found in DOE-STD-1196-2011 (Lawrence 2013).

However, other factors also impact the all-pathways dose. Human consumption rates for water, vegetables, meat and milk specific to SRS have recently been updated by Stone and Jannik (2013). From this study, the consumption of water by an average person was reduced from 511 L/yr used in the 2008 PA to 300 L/yr. This change, considered alone, would give a favorable impact factor on all-pathways dose of 0.59. Similarly, bio-transfer factors representing the transfer of radionuclides from the soil to plants, feed to meat, and feed to milk have been updated since the 2008 PA by Jannik et al. (2010). The most significant change to these parameters was an increase in the soil to plant transfer factor for Tc-99 from 0.25 to 17.9 which, considered alone, would give an adverse impact factor on all-pathways dose of 71.6.

Neither factor described above can be considered alone; therefore, to evaluate the impact from changes to all-pathways dose calculations, a spreadsheet calculation was performed. The spreadsheet calculation was validated by first reproducing preliminary 2008 PA limits. The calculation was then run a second time using revised dose parameters and the impact factor calculated as the ratio of the preliminary PA disposal limits to the revised values. Initial calculations using the 2008 PA dose models indicated that Tc-99 would be problematic because of an increased dose resulting from vegetable ingestion which is directly related to the soil to plant bio-transfer factor. Therefore, the dose model was modified along the lines of the model being used by SRR (2012) to include radionuclide removal from garden soil through water infiltration. Because Tc-99 has a low K_d, including this term in the calculation of dose from vegetable consumption reduced, but did not entirely eliminate, the impact from the large change in bio-transfer factor. Table 6 lists the impact factors for key radionuclides resulting from the analysis described above. The beta-gamma factor for Nb-94 is included for completeness. It should be noted that the most restrictive limit for Np-237 shifted from all-pathways to alpha dose in the revised calculations. These impact factors are included as item 2b in Appendix A. All other isotopes, disposal units and pathways are not applicable for this item.

Table 6 - Impact factors for key radionuclides from revised dose calculations.

Disposal Unit	Nuclide	Dose Pathway	Impact Factor
SLIT9	C-14	All-Pathways	0.14
	Np-237	All-Pathways	0.04
	Sr-90	All-Pathways	0.43
SLIT14	C-14	All-Pathways	0.14
	Np-237	All-Pathways	0.04
ET#1	Nb-94	Beta-Gamma	1.16
ET#2	Np-237	All-Pathways	0.04
CIG1	C-14	All-Pathways	0.14
	Np-237	All-Pathways	0.04
	Tc-99	All-Pathways	2.74

Note: Dose impacts apply to the radionuclide irrespective of whether it is generic or special waste form. Only the generic form of the nuclide is listed.

3.3 Radioactive decay data

DOE Technical Standard DOE-STD-1196-2011 (DOE 2011) is based on radionuclide decay data from the International Commission on Radiological Protection (ICRP) publication 107 (ICRP 2008). For consistency with the new All Pathways DCFs presented in Section 3.2, the underlying radionuclide decay are considered new information (item 3) relative to the 2008 PA, which used 2005 Nuclear Wallet Cards data (www.nndc.bnl.gov/wallet). Half-life data for key nuclides from the 2008 PA and ICRP 107 are presented in Table 7. Not surprisingly little difference is observed in general, however, Ni-59 is the exception. Ni-59 is a key contributor only to the Naval Reactor Component Disposal Area (643-26E), which has a very low SOF, currently 0.026, with Ni-59 contributing a SOF impact of 0.015. With this consideration, effort to quantify the impact of a longer Ni-59 half-life was judged to be unwarranted.

Table 7 - Half-life data for key nuclides

2008 PA			**New**		**Ratio**
Nuclide	Half-life	Units	Half-life	Units	-
C-14	5.73E+03	yr	5.70E+03	yr	0.99
H-3	1.23E+01	yr	1.23E+01	yr	1.00
I-129	1.57E+07	yr	1.57E+07	yr	1.00
K-40	1.25E+09	yr	1.25E+09	yr	1.00
Mo-93	4.00E+03	yr	4.00E+03	yr	1.00
Nb-93m	1.61E+01	yr	1.61E+01	yr	1.00
Nb-94	2.03E+04	yr	2.03E+04	yr	1.00
Ni-59	7.61E+04	yr	1.01E+05	yr	**1.33**
Np-237	2.15E+06	yr	2.14E+06	yr	1.00
Sr-90	2.89E+01	yr	2.88E+01	yr	1.00
Tc-99	2.11E+05	yr	2.11E+05	yr	1.00
Th-229	7.36E+03	yr	7.34E+03	yr	1.00
U-233	1.59E+05	yr	1.59E+05	yr	1.00

3.4 Final cover system design

The final cover design assumed in the 2008 PA is described in the conceptual closure plan for E-Area (WSRC 2004, Phifer et al. 2009). The cover design now anticipated at facility closure is identified as an “Alternative Closure System Concept” in the closure plan and “adds a geotextile fabric and a 60 mil high density polyethylene geomembrane directly above the geosynthetic clay liner and a blended soil-bentonite mixture to the upper one-foot (0.3 m) lift of the lower controlled compacted backfill layer-foundation layer” (Phifer et al. 2009, Section 4.4.2), which improves infiltration performance. Table 8 and Figure 1 compare the trench infiltration rates for the 2008 PA (McDowell-Boyer et al. 2011) and new (Phifer et al. 2007) cover designs (the latter has been adopted for F-Tank Farm closure plan). Also shown is infiltration prior to final cover placement, a period of 130 years (30 yr operation + 100 yr institutional control), after which the covers reduce infiltration. The new design generally represents a beneficial impact toward meeting performance objectives under unsubsided conditions. Because the benefit is difficult to quantify without resorting to model simulations, new information item 4a (unsubsided infiltration) is treated as an unquantified factor.

Similarly, new information item 4b (subsided infiltration) is also considered an unquantified factor, because the new cover configuration has not yet been quantitatively analyzed in detail. However, the following qualitative influences are observed. Table 8 provides both the infiltration and the combined lateral drainage and runoff for the 2008 PA and new cover designs. The unsubsided infiltration associated with the new cover design is lower than that of the 2008 PA cover design over time. However the combined lateral drainage and runoff associated with the new cover design is larger than that of the 2008 PA cover design over time. Infiltration in subsided areas of the closure cap (maximum 10% of the disposal area for Slit Trenches) is a direct function of the combined lateral drainage and runoff. Based upon this observation, contaminant transport out of unsubsided areas would be slower with the new cover design, but faster out of subsided areas. This would tend to separate the peaks associated with unsubsided and subsided areas of the new cover design relative to that of the 2008 PA cover design, which would make any combined peaks lower with the new cover design. On the other hand, inventory limits are frequently controlled by peak releases from subsided trenches, which would be higher with the new cover design. New information item 4b is considered an unquantified factor because the net impact of these influences is not clear.

Table 8 - Comparison of 2008 PA and new infiltration rates and combined lateral drainage and runoff.

Time (yr)	PA Unsubsided Infiltration (in/yr)	PA Lateral Drainage plus Runoff (in/yr)	New Unsubsided Infiltration (in/yr)	New Lateral Drainage plus Runoff (in/yr)
-130	15.748	-	-	-
-100	15.748	-	-	-
-100	0.36	-	-	-
0	0.36	-	-	-
0	0.098	14.172	0.00088	16.5
100	0.107	14.162	0.01	16.48
180	-	-	0.17	16.32
290	-	-	0.37	16.12
300	1.27	13.011	0.5	15.99
340	-	-	1	15.5
380	-	-	1.46	15.04
550	3.12	11.151	-	-
560	-	-	3.23	13.25
1000	7.28	6.991	7.01	9.36
1800	12.26	2.011	10.65	5.43
2623	-	-	11.47	4.45
2740	13.43	0.845	-	-
2805	13.44	0.83	-	-
3200	-	-	11.53	4.4
3400	13.56	0.72	-	-
5600	13.77	0.516	11.63	4.34
7000	13.83	0.451	-	-
10000	-	-	11.67	4.37

“ - “ indicates a value was not computed at the indicated time

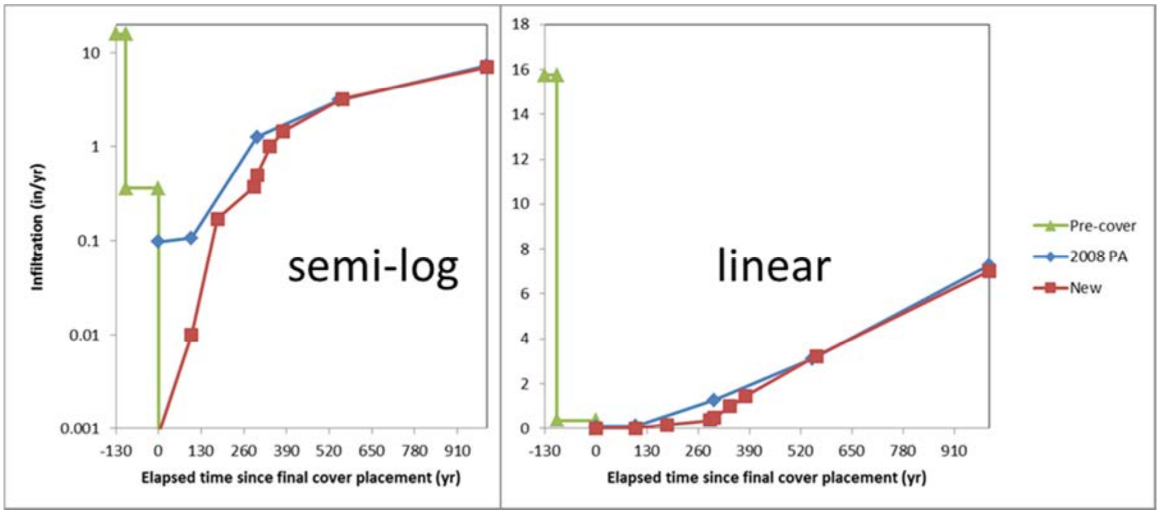


Figure 1 - Comparison of 2008 PA and new infiltration rates.

3.5 Duration of operations / operational cover timing

Most E-Area disposal units will not remain uncovered for the duration of active disposal operations assumed in the 2008 PA, (e.g., 30 years in the case of Slit and Engineered Trenches). Since the 2008 PA, DOE has entered into an agreement with the regulators to install flexible membrane liner covers to promote runoff and limit water infiltration over individual Slit Trench Units that have been operationally closed. Earlier placement of operational covers prior to the planned area-wide interim closure at the end of E-Area operations is generally beneficial (Collard and Hamm 2008). This is especially true for the early period limits for the beta-gamma pathway, because release of mobile nuclides is substantially retarded. The same benefit is derived for those trenches with a later operational startup than that assumed by the PA (i.e., without significant operational history it is conservatively assumed in the PA that all trenches were simultaneously opened and filled on day one of E-Area trench operations). The beneficial impact of early operational cover placement / late operational startup is treated as an unquantified conservatism (item 5a).

3.5.1 Changes in transport behavior of mobile radionuclides

As described above, peak concentrations for the highly mobile species have been shifted from very early times to much later times because of changes made since the 2008 PA. This is due to increases in K_d for key radionuclides in combination with the assumed placement of impermeable runoff covers over trenches much sooner after burial. The following case study is provided as evidence that such changes in transport behavior can be treated as either conservative-tending or mildly non-conservative. From an overall sum-of-fractions perspective, a net benefit is realized when inventory compositions consistent with historical patterns are considered.

Engineered Trench #3 Case Study

Because ET#3 has been placed in the location previously designated for SLIT12, Solid Waste requested that SRNL determine if the SLIT12 limits could be employed as surrogate disposal limits for ET#3 operations (Hamm et al. 2013).

Based on current disposal limit methodology, SRNL determined that the SLIT12 disposal limits could be used as "conservative" surrogates for ET#3 operations provided that each SLIT12 disposal limit be less than or equal to corresponding ET#3 disposal limits for: (1) every "parent" nuclide to be disposed of in ET#3, (2) for every groundwater (GW) and non-GW pathway; and (3) for every time window within each pathway.

However, increases in sorption (K_d) for key radionuclides in combination with the assumed placement of an interim closure runoff cover over the ET#3 waste much sooner after burial (i.e., 12 years uncovered for ET#3 versus 30 years uncovered for ET#1 before interim closure), shifted peak concentrations for the highly mobile species (e.g., Mo-93, Tc-99, C-14 and I-129) to much later times. This meant that direct comparison of SLIT12 limits and new ET#3 limits was not possible because of the lack of plume super-positioning between the 2008 PA and new ET#3 model. For example, the peak GW concentration for Tc-99 shifted from about 14 years in the 2008 PA to almost 700 years in the revised analysis. The disposal limit for Tc-99 changed from being GW beta-gamma MCL limited to being GW ingestion dose (All-Pathways) limited.

To deal with these changes in transport behavior and other factors, SRNL utilized a stochastic approach in the evaluation to compare the impact of expected radionuclide inventory compositions on DOE 435.1 performance measures when controlling to SLIT12 limits versus new estimated ET#3 limits. This stochastic analysis relied on the overall performance of ET#3 rather than deterministically evaluating the behavior of individual radionuclides. This approach was deemed possible because of the existence of 18 years of historical Slit and Engineered Trench disposal inventories supporting the expectation that the final ET#3 inventory distribution will not be significantly different from historical Slit and Engineered Trench disposal compositions. Based on this operational history, it is believed that the increased risk associated with this proposed approach would be small. The stochastic approach taken accounts for a modest range of compositional variability and only under extremely unlikely conditions would inventory composition be skewed beyond values tested.

Seven key GW radionuclides were chosen for full modeling of vadose and aquifer transport from ET#3 to the point of assessment. Vadose zone transport calculations produced contaminant fluxes to the water table which were used as input to the PORFLOW aquifer transport model. Results from the PORFLOW aquifer transport analysis produced concentrations at the point of assessment in terms of pCi/L/(Ci of parent buried). For each applicable GW pathway, doses were calculated and new estimated ET#3 inventory limits were produced using the peak groundwater concentrations in each time window for each parent nuclide (including its progeny where applicable). For assessing/comparing inventory limits between the current SLIT12 and the new ET#3, updated plume interaction factors (PIFs) were calculated.

<u>Results</u>. The above analyses produced a set of expected GW limits for the new ET#3 which were then used in the stochastic analysis that lead to the conclusion that there is less than a 0.05% chance that waste disposal in ET#3 would result in an SOF greater than one. The average max SOF during this simulation was 26.5%. This can be interpreted to mean that operating ET#3 to a SOF of 1.0 using SLIT12 limits will result in a “true” SOF of 0.265 for the average radionuclide compositions based on historical trench inventories (Sink, 2012).

<u>Conclusions</u>. SRNL concluded that use of SLIT12 disposal limits as surrogates for the new ET#3 disposal unit provides reasonable assurance that DOE Order 435.1 performance objectives and measures will be protected with a high degree of confidence. Thus, larger K_d values for key radionuclides in combination with the assumed placement of impermeable runoff covers over trenches much sooner after burial result in a reduction of impacts in this example. This case study serves as evidence that such changes in transport behavior (item 5b) can be treated as either conservative-tending or mildly non-conservative (unquantified conservatism).

3.5.2 Potential delay in interim closure beyond 2025

SW has projected that a number of ST’s and ET’s, CIG-1, the ILV and LAWV, and the 643-26E NRCDA will remain in operation past the year 2025 (Sink, 2014c), the date when the PA assumes that interim closure occurs (i.e., all E-Area disposal units are full and operations have ceased). Based on this projection, SRNL assessed the impact of a delay in interim closure of the ELLWF beyond 2025 on PA results and conclusions.

2008 PA timeline

The 2008 PA established a timeline for modeling purposes that assumed the following operational periods:

25 years – CIG, LAWV, ILV, NRCDA
30 years – ST, ET

A standard 25-year operational period was originally assumed for all disposal units based on the expected life and operational capacity of the 100 acre ELLWF site. Later, a 30-year operational period was selected for modeling ST’s and ET’s even though most of these footprints were still future units not yet opened in 2008. The first ST unit was opened in December 1995, a full five years before the first CIG unit. Making the assumption that all ST’s and ET’s were opened simultaneously with the very first ST unit simplified the modeling and was generally considered to be conservative with respect to setting disposal limits. The start of operations for the three trench categories (ST, ET, CIG) was also assumed to be the date when all trenches were instantaneously filled to capacity and operationally closed. Practically speaking, this meant that all ST and ET disposal units were modeled for a full 30-year operational period irrespective of the actual sequencing of operations (i.e., receipt of first waste package to operational closure) for individual trench units. This assumption was considered to be generally conservative as it resulted in waste being in the ground for the longest amount of time prior to any placement of an infiltration reduction cover. However, it ignored the effects of runoff covers on the behavior of mobile radionuclides as described in Section 3.5.1 above. Finally, a standard 100-year Institutional Control period and 1,000-year Post-Closure period were assumed for all disposal facilities following the end of operations.

Current interim closure strategy

The proposed ELLWF closure approach includes three phases: operational closure, interim closure, and final closure. Interim closure is implemented differently depending on the type of disposal facility being closed:

- ET's, ST's and CIG Trenches: At the end of the operational period, interim runoff covers will be installed over all ST's, ET's and CIG footprints. The pre-existing operational stormwater runoff covers over the ST's and CIG footprints may transition into the interim runoff covers if the cover material is deemed serviceable for continued sustained performance after technical evaluation. If these operational stormwater runoff covers are not serviceable, they will be removed prior to installation of the replacement interim runoff covers.
- ILV and LAWV: No additional interim closure actions are anticipated beyond that of operational closure for the LAWV and ILV during the 100-year institutional control period. Operational closure of the LAWV consists of filling the interior collection trench and exterior sump with grout and sealing exterior vault openings. Operational closure of the ILV consists of grouting each cell to the top of the interior vault wall and installing the permanent reinforced concrete roof slab and overlying waterproof membrane roofing.
- NRCDAs: No operational closure or interim closure actions are being considered for the NRCDAs beyond placing casks on the pad due to the water and air-tight nature of the casks. However, if radiation shielding is required for personnel protection during the operational or institutional control period, the casks may be surrounded with a structurally suitable material.

Impact of an extended operational period

The 2008 PA plume interaction study was performed as an aquifer analysis only (i.e., no vadose zone analysis) assuming waste (radionuclide) inventory was placed simultaneously and instantaneously into the aquifer cells beneath each disposal unit footprint without considering the impacts of impermeable covers or other barriers (e.g., concrete vaults or CIG grout trenches). The following evaluation and conclusions assume that plume interaction factors calculated in the 2008 PA adequately account for plume overlap among disposal units under as-built conditions considering the uncertainty in sequencing of individual trench unit operations, and timing of operational covers.

- ILV, LAWV and NRCDAs. Because no additional interim closure actions are planned for the ILV, LAWV and NRCDAs there is no impact of delaying the end of E-Area operations beyond the year 2025 relative to the 2008 PA. Therefore, this has an impact of one for item 5c.
- CIG Trenches. High-density plastic runoff covers have been emplaced over all existing eight trench segments containing components-in-grout. Similar covers are required for all future segments within three months of creation. Runoff is required to be entirely removed from the CIG region through grading and associated drainage system. As a result of these measures a delay in the emplacement of an area-wide interim runoff cover beyond 2025 will not have a negative impact on the current or projected CIG performance relative to the 2008 PA. Therefore, an extended operational period beyond 2025 has an impact of one for item 5c.
- Center ST Units. The 2008 SA provided an evaluation of the impact of placing stormwater runoff covers over the Center ST units at either year 5, 10 or 15 of the 30-year operational period (Collard and Hamm 2008). Because the time of actual placement of covers was unknown, this SA did not consider limit increases, only limit decreases. Thus, each disposal limit is the minimum of the PA final limit (i.e., limit assuming interim cover at 30 years and no operational runoff covers) and the limit calculated for operational covers placed at 5, 10 or 15 years. Thus, a delay in the installation of an area-wide interim runoff cover beyond 2025 will not have a negative impact on the current or projected performance of the individual trench units relative to the 2008 SA as long as the following three conditions are met:

  1. Operational closure (i.e., installation of a stormwater runoff cover) occurs within 30 years of opening an individual ST unit.
  2. Runoff from these operational covers is effectively carried away from the trenches by the associated drainage structures.
  3. Operational covers are adequately maintained during the extended E-Area operational period.

  Under these conditions this has an impact of one for item 5c.

- East and West ST Units. An analysis similar to the one done for the Center ST's by Collard and Hamm (2008) is needed for the East and West ST units to ensure minimum disposal limits are established assuming the requirement for installation of operational stormwater runoff covers. Collard and Hamm (2008) demonstrated that earlier placement of operational covers prior to the planned area-wide interim closure at the end of E-Area operations is generally beneficial. This is especially true for the early period limits for the beta-gamma pathway, because release of mobile nuclides is substantially retarded. The same benefit is derived for those trenches with a later operational startup than assumed by the PA. Because the first West Slit Trench unit (SLIT8) was opened in 2007 (12 years after first Center ST) and first East Slit Trench unit (SLIT14) in 2011 (16 years after first Center ST), it is likely to offset negative effects of extending the end of E-Area operations past 2025 as long as operational stormwater runoff covers are installed over individual ST units within a 30-year operating window subject to the conditions described above for the Center ST's. Under the assumption that a 30-year operational closure date is not exceeded for individual ST units, this change should be considered an unquantified conservatism for item 5c.

- Engineered Trenches. Unlike ST units, ET's do not require the installation of a high-density plastic cover as part of their operational closure because they do not receive CERCLA waste. A delay in the interim closure past 2025 would potentially have an impact on performance if it results in an operational period greater than 30 years. ET operational closure consists of overlaying the waste with a minimum 4-feet-thick clean soil layer (i.e., operational soil cover), grading it to provide positive drainage off the trench area and establishing a vegetative cover of shallow rooted grass. The 2008 PA assumes this period of higher infiltration through the trench to be limited to 30 years in setting limits for the facility. Thus, in order to protect the current disposal limits, any delay in interim closure as described earlier would need to be less than the 30-year operational window for each ET. The delays shown below would be acceptable under the current ET disposal limits. Under the assumption that a 30-year interim closure date is not exceeded for individual ET units this change should be considered an unquantified conservatism for item 5c.

Engineered Trench	Date Trench Opened	30-Year Operating Window	Extension beyond 12/2025
ET#1	Feb-2001	Feb-2031	5.2 years
ET#2	Jun-2004	Jun-2034	8.5 years
ET#3	Sep-2013	Sep-2043	17.75 years

3.6 Vadose zone geology

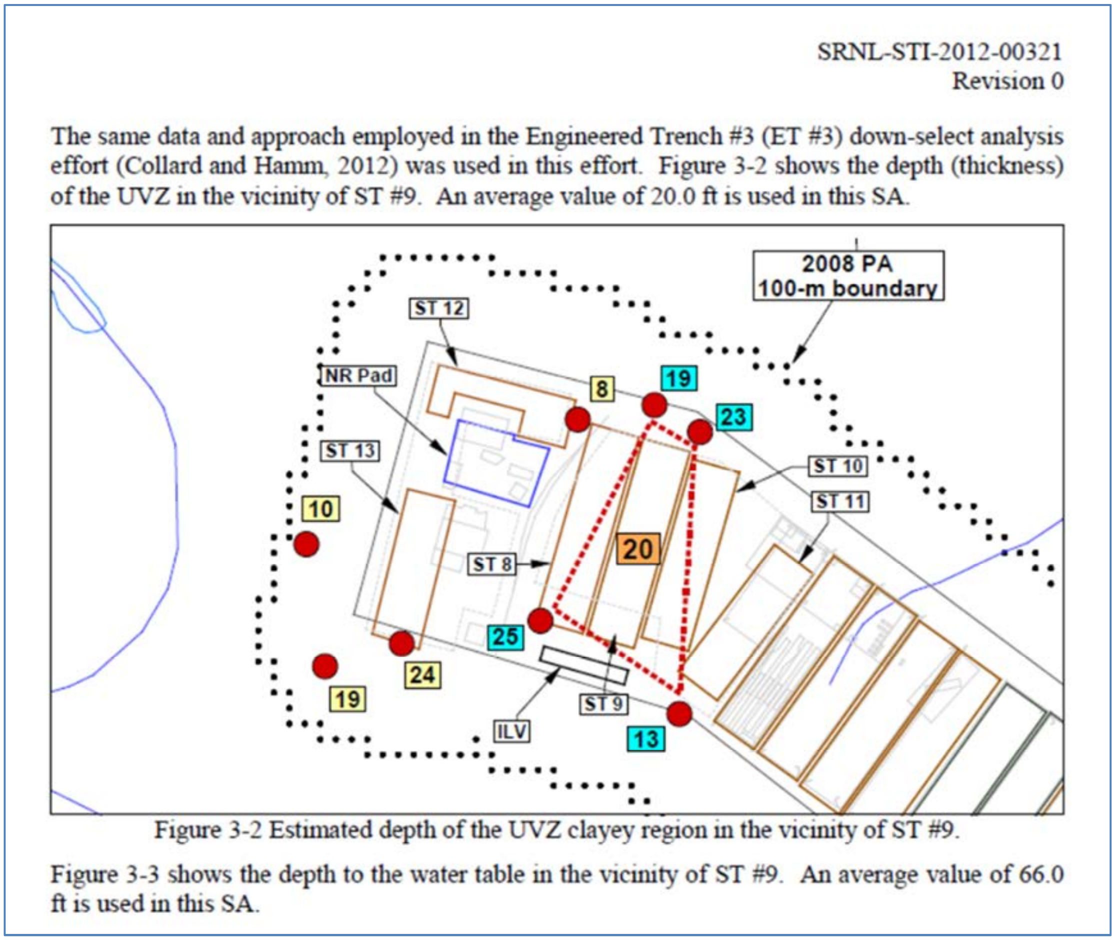
New information items 6a and 6b refer to the overall thickness of the unsaturated zone and the thickness of the clayey Upper Vadoze Zone (UVZ) sediment layer.

Depth to Water Table

For trench disposal the 2008 PA assumed a minimum depth to the water table of 35 ft from trench bottom. For some trench locations the actual depth is larger. For example, Figure 2 is an excerpt from SRNL-STI-2012-00321 (Hamm et al. 2012) describing some characteristics of the vadose zone beneath western E-Area. In this area the average distance from ground surface to the water table is 66 ft, which exceeds the 55 ft dimension assumed for trenches in the PA (20 ft trench depth + 35 ft). The greater depth in western E-Area lowers peak concentration because of additional plume dispersion and radioactive decay. No credit is taken for greater depth in this UDQE and new information item 6a is classified as an unquantified factor.

Thickness of the UVZ

The thickness of the UVZ affects solute transport through sorption coefficient (K_d). For older E-Area disposal units, the UVZ was observed to be 20 ft thick or more and Clayey K_d values were assigned to the trench zone in the 2008 PA. While the UVZ thickness has been determined to be at least 20 ft thick in the central and east trench areas, excavations and characterization in western E-Area indicated a general tendency for a smaller UVZ sediment layer which could lead to sandier sediments in direct contact with trench waste. Sandy K_d values are generally lower than Clayey values, which increase peak concentration. Figure 2, however, indicates that the UVZ is nominally 20 ft thick in the vicinity of SLIT8 - SLIT11, the same as the 2008 PA assumption. Therefore, the impact factor is one for new information item 6b.



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The same data and approach employed in the Engineered Trench #3 (ET #3) down-select analysis effort (Collard and Hamm, 2012) was used in this effort. Figure 3-2 shows the depth (thickness) of the UVZ in the vicinity of ST #9. An average value of 20.0 ft is used in this SA.

Figure 3-2 Estimated depth of the UVZ clayey region in the vicinity of ST #9.

Figure 3-3 shows the depth to the water table in the vicinity of ST #9. An average value of 66.0 ft is used in this SA.

Figure 2 - Characteristics of the vadose zone for western E-Area.

3.7 Waste characteristics

New information items 7a, 7b, and 7c pertain to various characteristics of the waste zone in trench disposals. These factors are considered separately for containerized and bulk (un-containerized) waste forms. Bulk waste in this UDQE refers to waste that is buried in loose form, analogous to a sanitary landfill, such that void spaces around the waste at initial placement are subsequently filled by backfilled soil. Containerized waste refers to waste in a container with significant internal void space, principally waste in B-25 boxes and Sea-Land containers.

Bulk Waste

For bulk waste, the PA model assumption that the waste zone takes on soil properties is considered a reasonable approximation with respect to initial density and porosity (item 7a). The compacted thickness (item 7b) in the PA is based on containerized waste, which has larger void space than bulk waste prior to compaction. The PA assumption thus tends to be conservative, but has not been quantified in this UDQE. Delay in nuclide release due to waste form containment (item 7c) is not applicable to bulk waste. The bulk waste impact factors for items 7a, 7b, and 7c are taken as one, “UQ” (effectively one), and one, respectively.

Containerized Waste

For containerized waste, the initial waste density and porosity (item 7a) are lower than assumed in the PA (non-conservative), while no credit is taken for waste containment (item 7c; conservative). The PA assumption for compacted thickness (item 7b) is appropriate for containerized waste. The containerized waste impact factors for items 7a, 7b, and 7c are taken as “UQ”, one, and “UQ”, respectively. Non-conservative item 7a and conservative item 7c are assumed to roughly negate each other.

Rollup

With respect to evaluating impacted SOFs, a “UQ” designation is functionally equivalent to an explicit factor of “one”. The analysis table in Appendix A does not breakout items 7a, 7b, and 7c into separate Bulk and Containerized waste sub-categories; rather “UQ” is indicated for brevity to capture the bottom-line impact of either an underlying “UQ” or “one” factor depending on waste form.

3.8 Distribution of non-crushable container failures

The 2008 PA assumes instantaneous failure of non-crushable containers immediately after final cover placement. This assumption is recognized now as a significant conservatism, but item 8 is not quantified in this UDQE.

3.9 Volume- vs. area-based source distribution

A recent Interim Measures Assessment (Butcher and Hiergesell, 2012) identified a PA modeling oversight involving conflicting assumptions on water table flux distribution within and between disposal units. Model simulations distributed the aquifer source to the cells associated with the water table by computational cell volume, whereas limits calculations assumed the overall source was distributed by cell area. Subsequent to

Revision 0 of this UDQE (Flach, 2013), the PA Disposal Limits Database was revised, Revision 2013-1 (Butcher, 2013), and limits in WITS updated based on a Special Analysis (Swingle, 2012) implementing this change. The current SOF snapshots provided by Solid Waste have been updated in Appendix A to reflect the revised limits (Sink, 2014a, 2014b). Impact factors for ST and ET units are thus no longer needed in Revision 1 of the UDQE because the current fractions reflect consideration of new information (9b). The impact of volume- versus area-weighted source distribution within a disposal unit (item 9a) is expected to be minimal and designated as “UQ”.

3.10 Non-crushable waste infiltration for ET’s

When non-crushable containers subside immediately after final cover placement, infiltration through the waste zone increases in model simulations. The infiltration rate under these subsided conditions has been explicitly analyzed for ST’s, but not ET’s. Instead ST’s are used as a surrogate for ET’s, based on the assertion that the pattern of subsided versus unsubsided areas will be similar for both trench types. The impact of this assumption for ET’s (item 10) is expected to be minimal and is unquantified in this UDQE.

3.11 Influence of adjoining trench segments

The 2008 PA model simulations consider a single 20 ft by 20 ft trench segment in isolation to other trench segments. Undisturbed soil adjoining a trench segment has a lower conductivity than backfilled soil and moisture migrates laterally to the trench, increasing flow through the waste zone. The PA model includes 20 ft of undisturbed soil on each side of the waste zone. In reality the width of undisturbed soil is much lower, so the PA model modestly over-predicts flow through the waste zone, a conservatism. The impact of new information item 11 is not quantified in this UDQE.

3.12 Waste distribution in space and time

The 2008 PA assumes uniform distribution of generic waste burials in space and instantaneous burial at the start of operations. The former assumption (item 12a) may be conservative or non-conservative, while the latter (item 12b) tends to be a significant conservatism. Item 12a could be non-conservative for specific disposal units because actual burials are distributed non-uniformly. Example non-conservative configurations relative to the PA assumption include “hot spots” and burials biased toward the down-gradient end of the disposal unit footprint. Other non-uniform configurations are favorable such as burials biased toward the up-gradient end.

Solid Waste has requested that SRNL assume uniform distribution of generic waste throughout the trench and has accepted responsibility to defend that the results of their operational methodology meet the uniform distribution assumption. SW has implemented protective measures including one that states that no single package shall contain >5% of the SOF. SW believes that this and other improvements made to their operational methodology based on lessons learned from 2010 study, *Dose Assessment of Final Inventories in Center Slit Trenches One through Five* , SRNL-STI-2010-00760, (Collard, et al., 2011) ensures that the assumption of the uniform distribution of waste is being adequately protected for both Slit and Engineered Trenches. This 2010 study, which used the latest available information and data from the first 15 years of Slit Trench operations (i.e., actual disposal locations and timing) demonstrated that the current PA limits in combination with the specific inventory distribution and timing were bounding. The impact of new information is not quantified in this UDQE.

3.13 Half-life cutoff and secular equilibrium assumptions

The 2008 PA modeling explicitly simulated transport of nuclides with a half-life greater than five years (item 13c), and progeny with shorter half-lives were assumed to be part of an isolated system in secular equilibrium with their long-lived ancestors. *Secular equilibrium* implies that the activity (pCi/L) of the progeny is the same as the closest long-lived ancestor. The assumption of instantaneous secular equilibrium ignores the time required to achieve quasi-steady decay (item 13a), a conservatism. Secular equilibrium is an accurate assumption when the half-life of the ancestor is much longer than that of the progeny, say two orders of magnitude. Otherwise, *transient equilibrium* is a more accurate assumption (item 13b). The activity of the progeny is higher under transient equilibrium than secular equilibrium.

These assumptions have practically no impact on the SOF calculation because the key (>1%) contributors to date have no progeny, with the exception of Np-237, Sr-90, Th-230 and Ra-226, and secular equilibrium is quite accurate for all of them because the progeny omitted from explicit simulation are very short-lived. New information item 13a is conservative and unquantified for this same group, and not applicable to non-chain parents. Item 13b is not applicable except for parents with decay chains, for which the impact factor is essentially one. Item 13c is closely related to items 13a and 13b and considered a UQ impact for this group following item 13a.

3.14 Plume spreading

New information items 14a-14c affect plume spreading in aquifer transport simulations. Item 14a refers to the choice of dispersion model. The 2008 PA assumed a traditional, two-parameter, dispersion model attributed to Scheidegger (1961), which was the only option available in the PORFLOW code at the time (Flach 2009, Aleman and Flach 2010). The two-parameters are a longitudinal dispersivity and a transverse dispersivity. Because the model incorporates a single transverse dispersivity, plume dispersion occurs equally in the transverse horizontal and transverse vertical directions. Conventional practice is to set the longitudinal dispersivity (α_L) to 10% of the plume travel distance, and transverse dispersivity (α_T) to 1% of plume travel distance (e.g. Fetter 1993, Section 2.11; Zheng and Bennett 2002, Section 11.3.2). The 2008 PA adopted this rule of thumb and a conservative plume travel distance of 100 meters for trench analyses:

$$\alpha_L = 10\%L = 10\%(100\ m) = 10\ m \tag{4a}$$

$$\alpha_T = 1\%L = 1\%(100\ m) = 1\ m. \tag{4b}$$

At the Savannah River Site, the transverse vertical plume dispersion is expected to be significantly lower than transverse horizontal dispersion because stratified lower and higher permeability (sand and clay) sediments limit vertical movement across strata. Current versions of PORFLOW (e.g., version 6.30.2) offer a four-parameter dispersion model (Aleman and Flach 2010) that enables separate specification of transverse vertical and transverse horizontal dispersivities in a manner more consistent with SRS geology. Following guidance from Zheng and Bennett (2002, Section 11.3.2) and using an average plume travel length for E-Area disposal units of 200 meters, best-estimate parameter settings for the four-parameter model are

$$\alpha_L = 10\%L = 10\%(200\ m) = 20\ m \tag{5a}$$

$$\alpha_{TH} = 1\%L = 1\%(200\ m) = 2\ m \tag{5b}$$

$$\alpha_{TV} = 0.1\%L = 0.1\%(200\ m) = 0.2\ m \tag{5c}$$

$$\alpha_{LV} = 1\%L = 1\%(200\ m) = 2\ m \tag{5d}$$

where α_L = longitudinal-horizontal dispersivity, α_{TH} = transverse-horizontal dispersivity, α_{TV} = transverse-vertical dispersivity, and α_{LV} = longitudinal-vertical dispersivity. Figure 3 and Figure 4 illustrate the 50 ft by 50 ft computational grids used in the 2008 PA to simulate plume migration from E-Area disposal units. Tracer simulations were performed on these grids to assess the relative impact of the PA (Equations 4) and new (Equations 5) dispersion representations on plume spreading, along with two additional scenarios for reference. In one reference run, the dispersivities were set to zero to maximize peak plume concentration. In the other simulation, a plume travel distance of 100 meters was used in Equations (5) instead of 200 meters. Two release scenarios were considered: a) a constant (non-depleting) source equal to 1 mol/yr, and b) a pulse (slug release) equal to 1 mol. Figure 5 and Figure 6 illustrate the results for central and western ST's. Figure 7 shows the outcome for ET's. The curve labels identify the following cases:

PA = 2008 PA; Equations (4)
200m = New best-estimate dispersion model; Equations (5)
lowerAlphaTV = Equations (5) with L = 100 meters
noDisp = all dispersivities set to zero.

The ratio of the "200m" to "PA" peak is shown for each case and averaged between the constant and pulse sources to approximate the behavior of actual waste releases, which are bracketed by these end-members. This average is taken as the new information impact factor for item 14a in Table 9. The ET value is used for nearby eastern ST's to avoid creation of an additional model. Aquifer transport simulations for the other disposal units in the 2008 PA conservatively neglected explicit consideration of dispersion. Thus the impact factor for these disposal units is one.

Table 9 - Impact factors for plume dispersion model.

Disposal unit group	Plume dispersion Impact factor
SLITc	1.42
SLITw	1.18
ET	1.42
SLITe	1.42 (ET)

New information item 14b refers to the resolution of the computational grid. Current computing resources and the new dispersion model defined by Equations (5) warrant use of a refined computation grid to avoid excessive numerical dispersion. A parametric study using different grid resolutions in support of the F-Tank Farm PA (SRR 2011, RAI-FF-3) suggests that a refined grid compared to the 2008 E-Area PA would increase peak simulated plume concentrations by approximately 10% when the grid size is halved in all directions. An impact factor of 1.1 is adopted for item 14b.

A final issue affecting plume spreading is placement of the water table flux on the aquifer transport grid. To avoid potential smearing of a source due to spreading the aquifer source term across multiple grid layers, current practice is to confine the source to the single grid layer that best aligns with the water table. This practice is expected have a minor impact on plume spreading and quantification was not attempted. This factor was therefore considered a UQ impact for item 14c. GoldSim was used to produce limits for NRCDA (643-26E), thus item 14c is not applicable to that disposal unit.

Plume spreading also impacts the plume interaction factors used to adjust the 2008 PA preliminary limits downward to account for co-mingled plumes from nearby disposal units. Reduced plume spreading with the new dispersion model and mesh refinements would likely lead to the same or lower plume interaction (depending of the specific disposal units). This influence has not been quantified but is expected to generally be conservative.

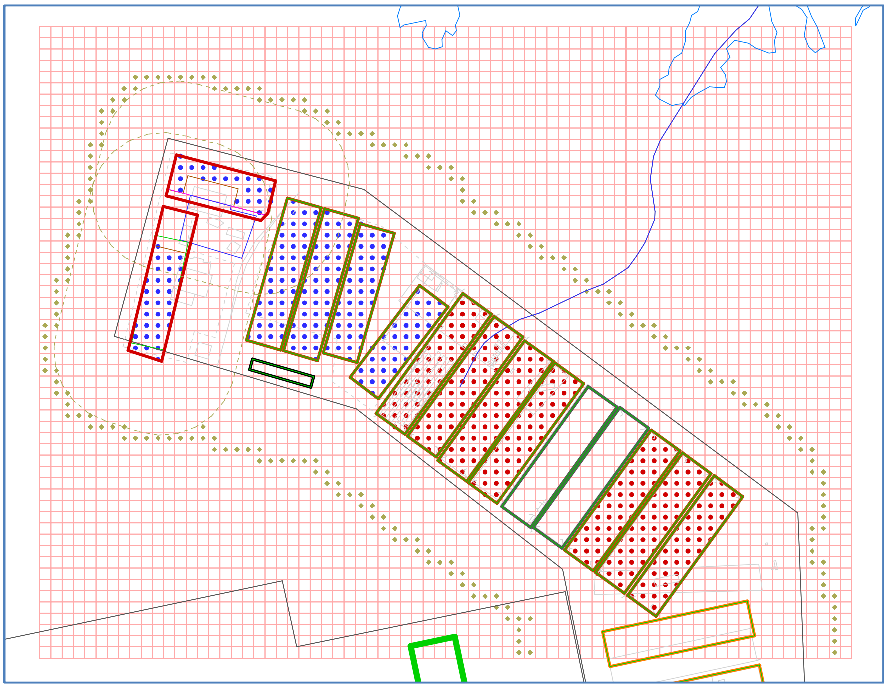


Figure 3 - Computational grid for central and western Slit Trench tracer plume simulations.

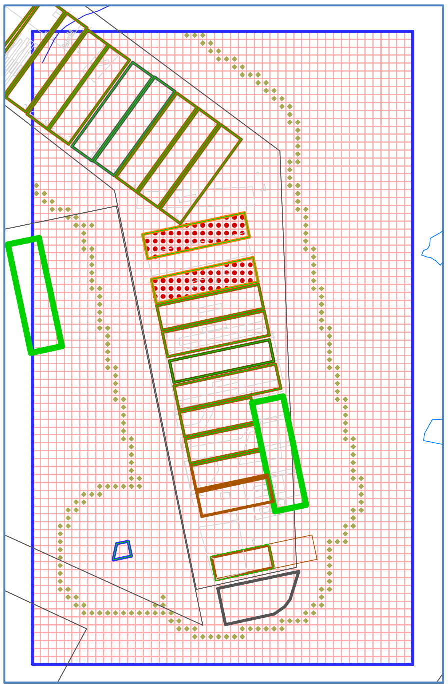
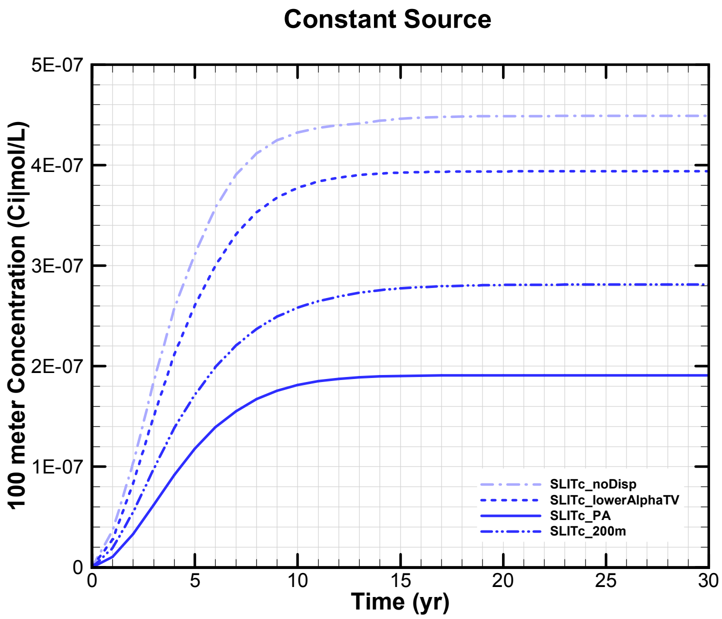


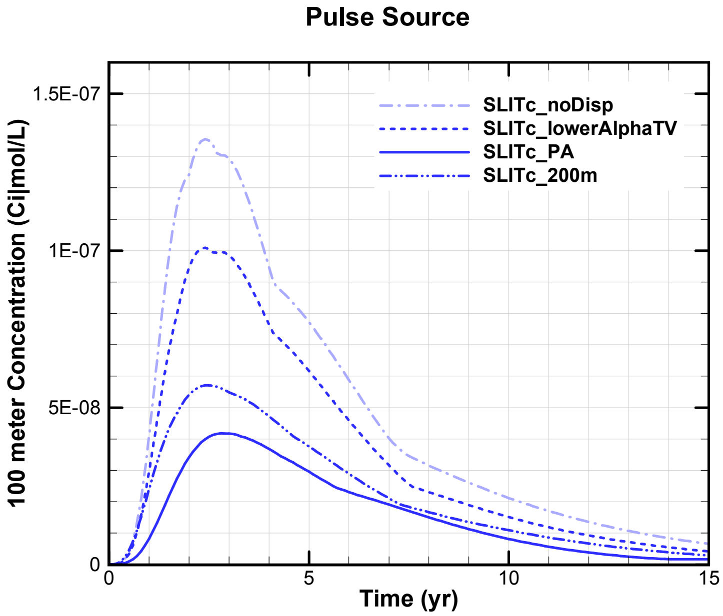
Figure 4 - Computational grid for Engineered Trench and eastern Slit Trench tracer plume simulations.

SLITc



Constant Source

L=200m STRAtified vs. PA: 1.47



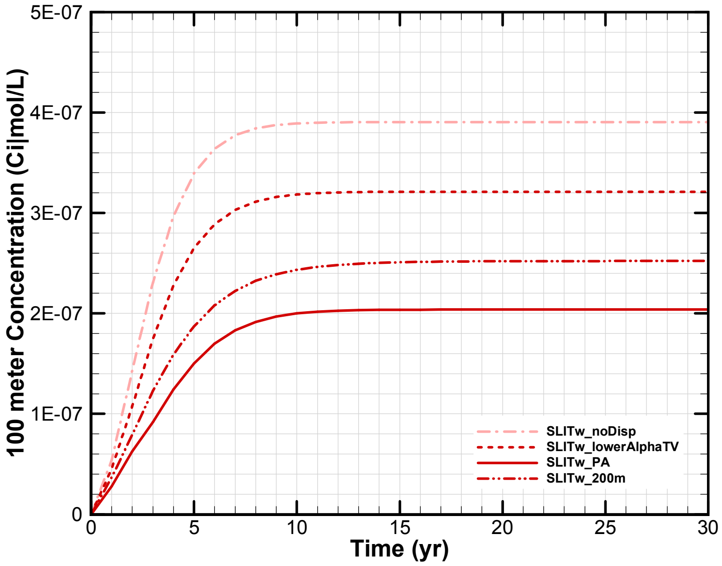
Pulse Source

L=200m STRAtified vs. PA: 1.37

SLITc average: 1.42

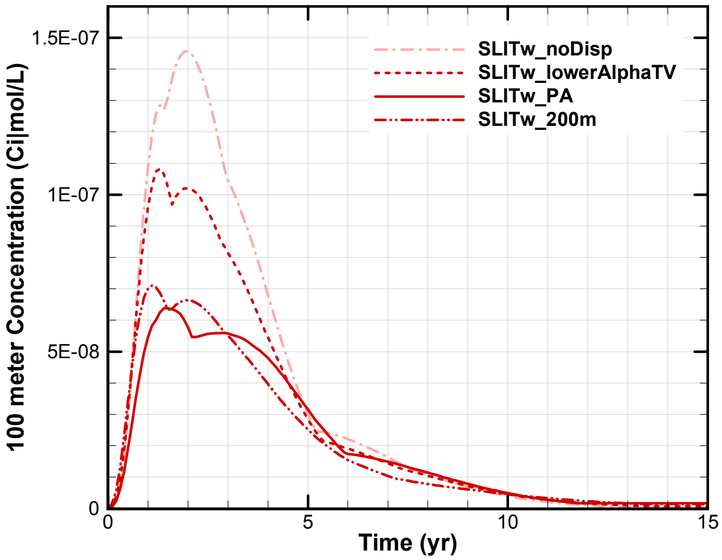
Figure 5 - Tracer plume concentrations at 100 meters for constant and pulsed releases from central Slit Trenches.

SLITw



Constant Source

L=200m STRAtified vs. PA: 1.24



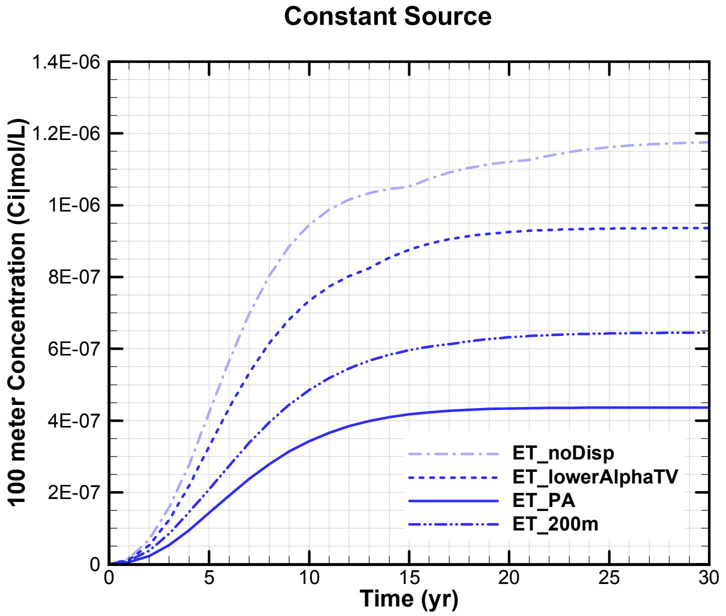
Pulse Source

L=200m STRAtified vs. PA: 1.12

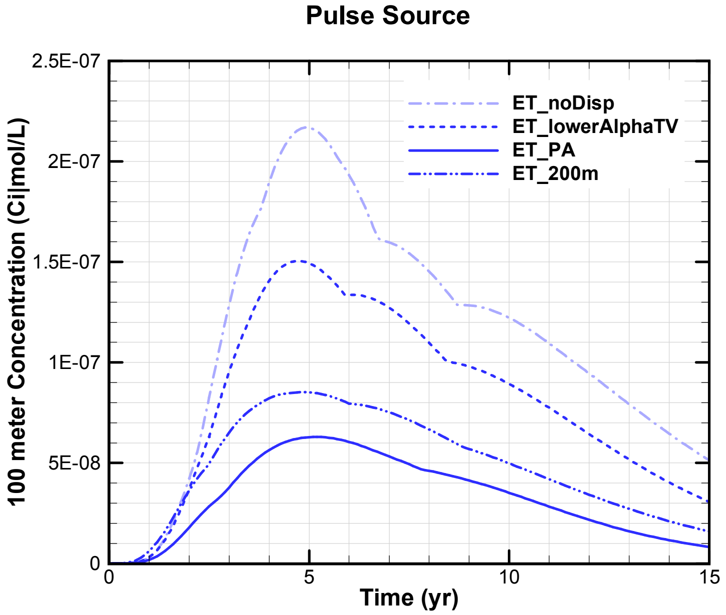
SLITw average: 1.18

Figure 6 - Tracer plume concentrations at 100 meters for constant and pulsed releases from western Slit Trenches.

ET



L=200m STRAtified vs. PA: 1.48



L=200m STRAtified vs. PA: 1.36

ET average: 1.42

Figure 7 - Tracer plume concentrations at 100 meters for constant and pulsed releases from Engineered Trenches.

3.15 CIG plume interaction correction

The 2008 PA inventory limits for the two CIG disposal units are being revisited to determine the impact associated with an incorrect application of the plume interaction factor during the calculation of individual disposal unit limits from the "combined" future inventory limits. In the 2008 PA, each disposal unit or group of units (e.g., CIG-1 and CIG-2 pair) was analyzed in isolation without considering the effect of adjacent disposal units and their inventory on the concentration at the 100-m point of assessment downgradient from the facility. For CIG-1 and CIG-2, the combined future (preliminary) inventory limit for each radionuclide was computed based on a PORFLOW run where both CIG units were involved while the inventory in adjacent disposal units was held to zero.

In the 2008 PA, groundwater plume interaction was handled in a separate analysis where concentration multipliers were calculated which represented the ratio of peak concentration from all disposal units to that for the individual unit (or group) analyzed in isolation. This plume interaction analysis utilized a non-decaying, non-sorbing tracer source in the aquifer beneath each group of disposal units to be measured against a hypothetical allowable maximum peak concentration at the 100-m boundary surrounding E-Area (simulating a DOE groundwater performance measure such as the 4 mrem/yr MCL for beta-gamma radionuclides). The source strength (i.e., allowable tracer inventory) for each disposal unit group was adjusted to achieve this hypothetical peak concentration in a calibration step in order to accurately account for the PIF for each disposal group. A description of the general approach, calibration, validation and refinement of the final PIFs is documented in Chapter 6 of the 2008 PA.

Utilizing the 2008 PA method, the existing inventory outside of the two CIG units elevates the background dose impact because their concentration plumes commingle along the downgradient 100-m boundary. As stated above, this effect was handled by employing a unique CIG group plume interaction factor reducing the allowable radionuclide inventory. However, the CIG trench was analyzed differently in the 2008 PA from the other trenches and the E-Area Vaults. The CIG analysis accounted for the presence of existing inventory within CIG-1. For CIG-1 there existed inventory buried in Segments 1 through 8. The aquifer PORFLOW runs supplied the existing burial inventories in Segments 1-8 and placed a uniformly distributed future inventory over all of the remaining future available CIG trench space (i.e., referred to as Segment 9). The general approach to handling plume interaction was new for the 2008 PA, which may have contributed to the incorrect accounting for the contribution of the internal existing inventory to the background dose impact in the calculation of the final CIG inventory limits. A discussion of the CIG-specific PIF calculation and details of the correction made to the CIG final limits calculation for the key CIG-1 radionuclides has been placed in Appendix C. The ratio of the PIF-corrected limits to the current WITS limits have been included as impact factors for CIG in item 15 in the detailed analysis spreadsheet in Appendix A and the impact factors have been set to one (i.e., no impact to key radionuclide fractions).

3.16 Groundwater pathway screening

New sorption coefficient data and All Pathways dose conversion factors represent new information with respect to groundwater pathway screening that precedes the more detailed limits analysis. Re-screening with new data will likely change the lists of nuclides retained for limits analysis. However, any new parents identified through re-screening are unlikely to contribute significant fractions to the sum and thus be key contributors. A quantitative assessment of re-screening was judged to be unwarranted, and the impact for new information item 16 is set to "UQ".

3.17 PORFLOW definition of retardation factor

The PORFLOW code defaults to a non-standard definition of retardation compared to the standard given earlier by Equation (2):

$$R = 1 + \frac{\rho_b K_d}{n}. \tag{6}$$

where n for porosity replaces water content (θ) in the denominator of Equation (2). The 2008 PA used Equation (6), which is conservative because $n > \theta$ produces lower retardation. The conservatism of new information item 17 has not been quantified in this UDQE. GoldSim was used to produce limits for NRCDA (643-26E), thus item 17 is not applicable to that disposal unit.

3.18 Cumulative impact of new information

The cumulative impact of new information items 1 through 17 on each active E-Area disposal unit is summarized in Table 10 with additional detail being presented in Appendix A. The "Current SOF" is slightly lower than the WITS SOF on the same date because only nuclides contributing at least 1% to the SOF are included in the former. The "Impacted SOF" is a projection of what the "Current SOF" would become if all quantified new information items were reflected in a new set of disposal limits. Similarly the "Impacted Projected Final SOF" is the WITS Admin Limit (0.95) as impacted by new information.

Table 10 - Overall impacts of new information on E-Area sums of fractions.

Disposal Unit	Pathway	Snapshot	Current SOF (>1% fractions)	Projected Final SOF	Impacted SOF	Impacted Projected Final SOF
SLIT6	Alpha2	6/18/2014	0.09	0.95	0.03	0.72
SLIT6	BG2	6/16/2014	0.82	0.95	0.53	0.62
SLIT7	BG2	6/16/2014	0.55	0.95	0.51	0.89
SLIT8	BG1	6/16/2014	0.89	0.95	0.45	0.48
SLIT9	BG3	6/16/2014	0.78	0.95	0.41	0.41
SLIT9	AP1	6/18/2004	0.67	0.95	0.06	0.06
SLIT14	AP2	6/16/2014	0.38	0.95	0.04	0.11
SLIT14	BG2	6/18/2014	0.33	0.95	0.24	0.69
ET1	BG2	6/16/2014	0.85	0.95	0.67	0.74
ET2	BG2	6/16/2014	0.53	0.95	0.51	0.91
ET2	AP2	6/18/2014	0.50	0.95	0.06	0.11
CIG-1	BG2	6/16/2014	0.43	0.95	0.12	0.27
CIG-1	AP2	6/18/2014	0.25	0.95	0.01	0.03
LAWV	BG	6/16/2014	0.15	0.95	0.06	0.41
ILV	BG2	6/16/2014	0.08	0.95	0.04	0.47
NRCDA (643-26E)	BG	6/16/2014	0.02	0.95	0.02	0.95

Note: See Table 4 notes for definition of pathway groups.

4.0 DISCUSSION

The "Impacted Projected Final SOF" values in Table 10 are less than or equal to the WITS Admin Limit, often substantially lower. Therefore, the new information in general indicates a higher likelihood of meeting DOE 435.1 performance objectives than indicated by current SOFs. Among the major quantified impact factors, updated sorption coefficients are nearly always beneficial, elimination of CDP factors is either neutral or beneficial (SLIT6 excepted), the CIG plume interaction correction is neutral, potential delay in interim closure beyond 2025 is neutral for multiple disposal units (ILV, LAWV, NRCDAs, CIG and Center ST's), dose conversion factors have mixed effect depending on nuclide, and the factors affecting plume spreading uniformly have a negative impact. The unquantified items are a mixture of conservative (items 4a, 5a-b, 5c-ET's and East and West ST's, 6a, 7b-bulk waste, 7c-containerized waste, 8, 11, 12b, 17), insignificant, not applicable, neutral (items 3, 7a&7c-bulk waste, 7b-containerized waste, 9a, 10, 13a-c, 16), non-conservative (items 7a-containerized waste), and unknown (items 4b, 12a, 14c) influences, as discussed previously. The conservative-tending influences are judged to significantly outweigh the non-conservative items. Therefore, lack of quantification does not challenge the conclusion that new information indicates a higher likelihood of meeting performance objectives.

The concern with SLIT9 having a projected impacted final SOF greater than the WITS Admin Limit (at the time of Revision 0 of this UDQE (Flach, 2013)), has been alleviated without further analysis by recognizing that no non-crushable waste has been buried to date in SLIT9 and ensuring that the non-crushable percentage remains zero through disposal unit closure. SW has placed an administrative control on SLIT9 that prevents acceptance of non-crushable containers. Sr-90 contributed a fraction of 0.5 to the impacted final fraction for the Beta-Gamma3 (Beta-Gamma 100-1130 year period) pathway in Revision 0 of this UDQE (Flach, 2013). The disposal limit in the Beta-Gamma3 timeframe is set by a 10% non-crushable modeling scenario. The Sr-90 disposal limits for 0% non-crushable cases are orders of magnitude greater than those of the 10% non-crushable cases, as evidenced by the unit curie flux comparison for the CDP "off" cases in Figure 8. By employing the 0% non-crushable case in limit setting, the Sr-90 fraction effectively becomes zero (see Table 4) and the impacted final SOF becomes 0.41. This change has been reflected for SLIT9 in item 1c in Appendix A.

With respect to future disposal unit operations in the east Slit Trench area, consideration of new information for SLIT14 reduced the current SOF for the limiting All-Pathways 200-1000 year period (AP2) by an order of magnitude and by one quarter for the Beta-Gamma2 (beta-gamma 12-100 year period) pathway. On the balance, updates to K_d values and dose coefficients (generally favorable) and elimination of CDP factors more than compensated for the detrimental impact of a more rigorous treatment of plume dispersion. These observations suggest that future operations in the east Slit Trench area can be conducted with increased confidence using current limits, and that limits could be increased if desired for future disposal units. The same general conclusion applies to the west Slit Trench area based on the Impacted Final SOFs for existing ST's in that area.

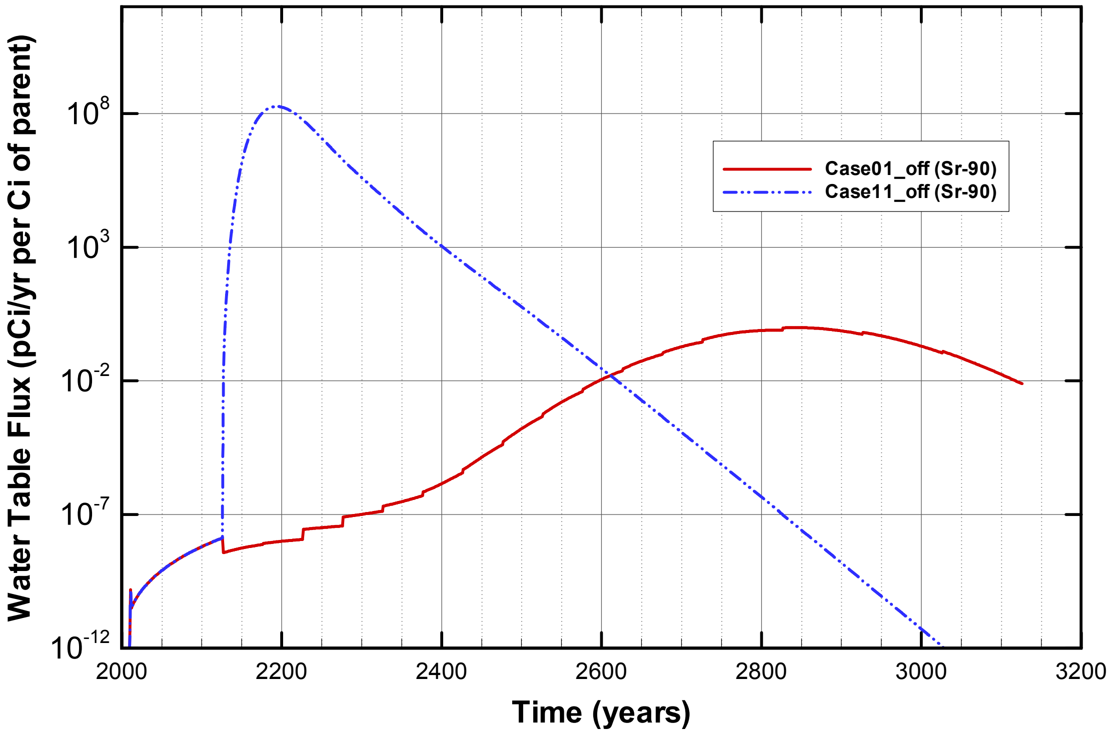


Figure 8 - Water table flux comparison for 0% (Case01) and 10% (Case11) non-crushable waste content in Slit Trenches (modified from Figure 4-25, SRNL-STI-2010-00760).

5.0 EVALUATION

1.a. Is the proposed activity or new information outside the bounds of the approved PA/CA (e.g., does the proposed activity or new information involve a change to the basic disposal concept as described in the PA/CA such as critical inputs/assumptions or an increase in inventory analyzed in the CA)?

No. This UDQE demonstrates that consideration of new information since the 2008 PA does not require a change to current E-Area low-level waste inventory limits and associated critical modeling inputs/assumptions to ensure compliance with performance objectives for projected dose. Therefore the new information is considered within the bounds of the approved PA.

1.b. Would the proposed activity if implemented, or does the new information result in the PA/CA performance measures being exceeded?

No. For each disposal unit, the final SOF with consideration of new information and associated new administrative controls is projected to be lower than the WITS Administrative Limit under current disposal limits, indicating greater likelihood of meeting PA/CA performance objectives. For SLIT9, prior implementation by SW of an *administrative control prohibiting disposal of non-crushable containers based on results of Revision 0 of this UDQE ensures that SLIT9 will be operated to maintain the same level of confidence that performance objectives will be satisfied.*

1.c. Would the radionuclide disposal limits in the approved PA need to be changed to implement the proposed activity?

No. Consideration of new information in this UDQE precludes a need to consider changes to radionuclide disposal limits.

1.d. Does the new information result in a change in the radionuclide disposal limits in the approved PA?

No. Consideration of new information in this UDQE has demonstrated that the current and final projected SOFs, as impacted by these changes and existing administrative control, will remain below the WITS administrative limit and therefore existing radionuclide disposal limits can remain unchanged.

1.e. Would the proposed activity if implemented, or does the new information result in a change to the Disposal Authorization Statement?

No. The ELLWF Disposal Authorization Statement (DOE 2008) requires the site to follow the guidance found in the Maintenance Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses (DOE 1999c). The Maintenance Guide states;

> Conduct of a performance assessment and/or composite analysis is not a static process. Rather, these analyses are initially prepared before the start of disposal facility operations and then reviewed, revised, and updated throughout the lifetime of the facility, up until the time of unrestricted release of the site. It will often be necessary to initiate this process using uncertain or incomplete data, thus yielding uncertain results. As the facility is operated and better data are obtained, the analyses will be refined and the uncertainty of results reduced. The process of reviewing and, as new information becomes available, updating the performance assessment and composite analysis comprises the maintenance activities described in this guidance document....If (the new data) indicate that the facility is functioning within the performance envelope (i.e., results indicate that parameter values are conservative in terms of projected dose), then the information should be noted as confirming the adequacy of the current performance assessment analysis.

Thus, the maintenance process described in the Maintenance Guide provides a means for incorporating results of research and development (e.g., laboratory measured K_d data) without triggering a Performance Assessment revision and associated change to the Disposal Authorization Statement.

6.0 CONCLUSION

Consideration of new information relative to the 2008 PA baseline generally indicates greater confidence that PA performance objectives will be met than indicated by current SOF metrics. For SLIT9, the previous prohibition of non-crushable containers in revision 0 of this UDQE has rendered the projected final SOF for SLIT9 less than the WITS Admin Limit.

With respect to future disposal unit operations in the East Slit Trench Group, consideration of new information for SLIT14 reduced the current SOF for the limiting All-Pathways 200-100 year period (AP2) by an order of magnitude and by one quarter for the Beta-Gamma2 pathway. On balance, updates to K_d values and dose factors (generally favorable) and elimination of CDP factors more than compensated for the detrimental impact of a more rigorous treatment of plume dispersion. These observations suggest that future operations in the East Slit Trench Group can be conducted with higher confidence using current inventory limits, and that limits could be increased if desired for future low-level waste disposal units. The same general conclusion applies to future ST's in the West Slit Trench Group based on the Impacted Final SOFs for existing ST's in that area. Finally, the resulting Impacted Final SOFs for SLIT6 and SLIT7 in the Center Slit Trench Group provide greater confidence that closed ST disposal units (i.e., SLIT1 - SLIT5) will continue to meet performance objectives.

7.0 KEY INPUTS AND ASSUMPTIONS

Revision 1 supersedes revision 0 of this UDQE upon SW approval of this report. The following key input and assumption from revision 0 is still required to be protected:

- Administrative control be placed on SLIT9 that prohibits acceptance of non-crushable waste containers though disposal unit closure. See Section 4.0 for more details.

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APPENDIX A

Detailed Analysis Spreadsheet - sheet 1

ID#	New Information Item	Default	SLIT6		βγ2	6/16/14				SLIT6		α2	6/18/14		
		Waste form:	WITS limit	WITS SOF	Σf	I-129	Tc-99	H-3	C-14	WITS limit	WITS SOF	Σf	Ra226T	Th230T	Np-237
		Limits fraction:	0.95	0.822	0.816	0.522	0.165	0.098	0.031	0.95	0.12	0.089	0.040	0.022	0.027
		Volume fraction:		0.91							0.91				
		Projected final fraction:			0.95	0.61	0.19	0.11	0.04			0.95	0.04	0.02	0.89
		Cumulative impacts:				**0.46**	**0.74**	**1.56**	**0.53**				**0.00**	**0.19**	**0.81**
		Impacted current fraction:			0.53	0.24	0.12	0.15	0.02			0.03	0.00	0.00	0.02
	red - new /updated data in revision 1	**Impacted final fraction:**			0.62	0.28	0.14	0.18	0.02			0.72	0.00	0.00	0.72
	Revised Input Parameters														
1a	Updated soil sorption coefficients (Kd)	N/A				0.34	0.55	1	0.34				1.1E-13	0.01	2.25
1b	Updated cement sorption coefficients (Kd)	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A
1c	Elimination of CDP factors (incl. eliminating non-crush case for ST9)					0.86	0.85	1.00	1.00				25.12	17.23	0.23
2a	Revised MCLs for βγ	1				1	1	1	1				1	1	1
2b	Revised AllPathway Dose Calculations	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A
3	Updated radioactive decay data (half-lives and branching fractions)	1				1	1	1	1				1	1	1
	Revised Facility Design														
4a	Revised cover system - unsubsided condition	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
4b	Revised cover system - subsided condition	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
	Evolving Facility Operation														
5a	Different durations of operations / placement of first cover	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
5b	Changes in transport behavior of mobile radionuclides	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
5c	Potential delay in interim closure beyond 2025	1				1	1	1	1				1	1	1
	Modeling Approach - Design and Operation Assumptions														
6a	Variable depth to water	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
6b	Variable thickness of upper vadose zone (higher Kd zone)	1				1	1	1	1				1	1	1
7a	Waste zone initial density / porosity	N/A				UQ	UQ	UQ	UQ				UQ	UQ	UQ
7b	Waste zone compacted thickness	N/A				UQ	UQ	UQ	UQ				UQ	UQ	UQ
7c	No credit for waste form containment, e.g. shed water	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
8	Credit can be taken for non-crushable failure over time	N/A				UQ	UQ	UQ	UQ				UQ	UQ	UQ
9a	Volume- vs. area-based aquifer source distribution - impact within DU	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
~~**9b**~~	~~Volume- vs. area-based aquifer source distribution - impact across DUs~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~
10	Non-crushable infiltration rates for ETs	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A
11	Influence of adjoining trenches on flow through a physical trench	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
12a	Waste distribution in space	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A
12b	Waste distribution in time	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A
	Modeling Approach - Physical Phenomena														
13a	Secular equilibrium may not be accurate due to time scale	N/A				N/A	N/A	N/A	N/A				N/A	N/A	UQ
13b	Secular equilibrium may not be accurate due to transient equilibrium	N/A				N/A	N/A	N/A	N/A				N/A	N/A	1
13c	Adequacy of and variable half-life cutoff	N/A				N/A	N/A	N/A	N/A				N/A	N/A	UQ
14a	Variable and evolving physical dispersion assignments	1				1.42	1.42	1.42	1.42				1.42	1.42	1.42
14b	Practice has evolved to more refined aquifer grid resolution	1.1				1.1	1.1	1.1	1.1				1.1	1.1	1.1
14c	Vertical separation of source nodes	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
15	Plume interaction correction to CIG limits	1				N/A	N/A	N/A	N/A				N/A	N/A	N/A
16	Groundwater screening used NCRP Kds in many instances	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ
17	Alternative definitions of retardation	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ

Detailed Analysis Spreadsheet – sheet 2

ID#	SLIT7		βγ2	6/16/14				SLIT8		βγ1	6/16/14				SLIT9		βγ3	6/16/14		SLIT9		allPath1	6/18/04		
	WITS limit	WITS SOF	Σf	I-129	H-3	C-14	Tc-99	WITS limit	WITS SOF	Σf	I-129	H-3	C-14	Tc-99	WITS limit	WITS SOF	Σf	C-14hx	Sr-90	WITS limit	WITS SOF	Σf	C-14hx	Np-237	Sr-90
	0.95	0.555	0.551	0.195	0.216	0.083	0.057	0.95	0.886	0.886	0.578	0.135	0.119	0.054	0.95	0.806	0.777	0.319	0.458	0.95	0.680	0.670	0.3190	0.338	0.013
		0.66							0.95							0.81					0.81				
			0.95	0.34	0.37	0.14	0.10			0.95	0.62	0.14	0.13	0.06			0.95	0.32	0.63			0.95	0.32	0.61	0.02
				0.48	**1.56**	**0.53**	**0.68**				**0.35**	**1.30**	**0.44**	**0.41**				**1.30**	**0.00**				**0.18**	**0.00**	**0.00**
			0.51	0.09	0.34	0.04	0.04			0.45	0.20	0.18	0.05	0.02			0.41	0.41	0.00			0.06	0.06	0.00	0.00
			0.89	0.16	0.58	0.08	0.07			0.48	0.21	0.19	0.06	0.02			0.41	0.41	0.00			0.06	0.06	0.00	0.00
1a				0.34	1	0.34	0.55				0.34	1	0.34	0.55				1	1				1	0.10	1
1b				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				N/A	N/A	N/A
1c				0.91	1.00	1.00	0.79				0.78	1.00	1.00	0.58				1.00	1.1E-05				1.00	0.03	1.1E-05
2a				1	1	1	1				1	1	1	1				1	1				N/A	N/A	N/A
2b				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				0.14	0.04	0.43
3				1	1	1	1				1	1	1	1				1	1				1	1	1
4a				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
4b				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
5a				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
5b				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
5c				1	1	1	1				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
6a				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
6b				1	1	1	1				1	1	1	1				1	1				1	1	1
7a				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
7b				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
7c				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
8				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
9				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
~~9b~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~
10				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				N/A	N/A	N/A
11				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
12a				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				N/A	N/A	N/A
12b				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				N/A	N/A	N/A
13a				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	UQ				N/A	UQ	UQ
13b				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	1				N/A	1	1
13c				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	UQ				N/A	UQ	UQ
14a				1.42	1.42	1.42	1.42				1.18	1.18	1.18	1.18				1.18	1.18				1.18	1.18	1.18
14b				1.1	1.1	1.1	1.1				1.1	1.1	1.1	1.1				1.1	1.1				1.1	1.1	1.1
14c				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
15				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A				N/A	N/A	N/A
16				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ
17				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ				UQ	UQ	UQ

Detailed Analysis Spreadsheet – sheet 3

ID#	SLIT14		allPath2	6/16/14		SLIT14		βγ2	6/18/14				ET1		βγ2	6/16/14				
	WITS limit	WITS SOF	Σf	Np-237	C-14NR	WITS limit	WITS SOF	Σf	C-14	I-129	Tc-99	H-3	WITS limit	WITS SOF	Σf	C-14	I-129	H-3	Tc-99	Nb-94
	0.95	0.398	0.377	0.362	0.015	0.95	0.343	0.329	0.117	0.082	0.080	0.050	0.95	0.868	0.854	0.262	0.245	0.185	0.145	0.017
		0.56					0.56							0.99						
			0.95	0.91	0.04			0.95	0.34	0.24	0.23	0.14			0.95	0.29	0.27	0.21	0.16	0.02
				0.11	**0.07**				**0.53**	**0.48**	**0.73**	**1.56**				**0.53**	**0.43**	**1.56**	**0.73**	**1.81**
			0.04	0.04	0.00			0.24	0.06	0.04	0.06	0.08			0.67	0.14	0.11	0.29	0.11	0.03
			0.11	0.10	0.00			0.69	0.18	0.11	0.17	0.22			0.74	0.15	0.12	0.32	0.12	0.03
1a				1.83	0.34				0.34	0.34	0.55	1.00				0.34	0.34	1	0.55	1
1b				N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
1c				1.00	1.00				1.00	0.92	0.85	1.00				1.00	0.81	1.00	0.85	1.00
2a				N/A	N/A				1	1	1	1				1	1	1	1	1.16
2b				0.04	0.14				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
3				1	1				1	1	1	1				1	1	1	1	1
4a				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
4b				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
5a				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
5b				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
5c				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
6a				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
6b				1	1				1	1	1	1				1	1	1	1	1
7a				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
7b				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
7c				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
8				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
9				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
~~**9b**~~				~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~
10				N/A	N/A				N/A	N/A	N/A	N/A				UQ	UQ	UQ	UQ	UQ
11				UQ	UQ				UQ	UQ	UQ	UQ				N/A	N/A	N/A	N/A	N/A
12a				N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
12b				N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
13a				UQ	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
13b				1	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
13c				UQ	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
14a				1.42	1.42				1.42	1.42	1.42	1.42				1.42	1.42	1.42	1.42	1.42
14b				1.1	1.1				1.1	1.1	1.1	1.1				1.1	1.1	1.1	1.1	1.1
14c				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
15				N/A	N/A				N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A	N/A
16				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ
17				UQ	UQ				UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ	UQ

Detailed Analysis Spreadsheet – sheet 4

ID#	ET2		βγ2	6/16/14				ET2		allPath2	6/18/14	CIG-1		βγ2	6/16/14						CIG-1		allPath2	6/18/14			
	WITS limit	WITS SOF	Σf	H-3	Tc-99	I-129	C-14	WITS limit	WITS SOF	Σf	Np-237	WITS limit	WITS SOF	Σf	C-14	I-129	H-3	Tc-99	C-14K	I-129K	WITS limit	WITS SOF	Σf	C-14	Np-237	C-14K	Tc-99
	0.95	0.54	0.528	0.202	0.152	0.107	0.067	0.95	0.529	0.503	0.503	0.95	0.444	0.434	0.17	0.149	0.059	0.023	0.022	0.011	0.95	0.266	0.252	0.159	0.057	0.021	0.015
		0.75							0.75				0.28									0.28					
			0.95	0.36	0.27	0.19	0.12			0.95	0.95			0.95	0.37	0.33	0.13	0.05	0.05	0.02			0.95	0.60	0.21	0.08	0.06
				1.56	**0.73**	**0.43**	**0.53**				**0.11**				**0.00**	**0.34**	**1.07**	**0.08**	**0.00**	**0.65**				**0.00**	**0.05**	**0.00**	**0.24**
			0.51	0.31	0.11	0.05	0.04			0.06	0.06			0.12	0.00	0.05	0.06	0.00	0.00	0.01			0.01	0.00	0.00	0.00	0.00
			0.91	0.57	0.20	0.08	0.06			0.11	0.11			0.27	0.00	0.11	0.14	0.00	0.00	0.02			0.03	0.00	0.01	0.00	0.01
1a				1.00	0.55	0.34	0.34				1.83				0.34	0.34	1	0.55	0.34	0.34				0.34	3.81	0.34	0.55
1b				N/A	N/A	N/A	N/A				N/A				0.0067	1.33	1	0.16	0.0067	1.33				0.0067	0.20	0.0067	0.16
1c				1.00	0.85	0.81	1.00				1.00				0.88	0.69	1.00	0.89	1.14	1.30				0.89	1.66	1.14	0.89
2a				1	1	1	1				N/A				1	1	1	1	1	1				N/A	N/A	N/A	N/A
2b				N/A	N/A	N/A	N/A				0.04				N/A	N/A	N/A	N/A	N/A	N/A				0.14	0.04	0.14	2.74
3				1	1	1	1				1				1	1	1	1	1	1				1	1	1	1
4a				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
4b				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
5a				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
5b				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
5c				UQ	UQ	UQ	UQ				UQ				1	1	1	1	1	1				1	1	1	1
6a				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
6b				1	1	1	1				1				1	1	1	1	1	1				1	1	1	1
7a				UQ	UQ	UQ	UQ				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
7b				UQ	UQ	UQ	UQ				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
7c				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
8				UQ	UQ	UQ	UQ				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
9				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
~~9b~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~	~~N/A~~	~~N/A~~
10				UQ	UQ	UQ	UQ				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
11				N/A	N/A	N/A	N/A				N/A				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
12a				N/A	N/A	N/A	N/A				N/A				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
12b				N/A	N/A	N/A	N/A				N/A				N/A	N/A	N/A	N/A	N/A	N/A				N/A	N/A	N/A	N/A
13a				N/A	N/A	N/A	N/A				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	UQ	N/A	N/A
13b				N/A	N/A	N/A	N/A				1				N/A	N/A	N/A	N/A	N/A	N/A				N/A	1	N/A	N/A
13c				N/A	N/A	N/A	N/A				UQ				N/A	N/A	N/A	N/A	N/A	N/A				N/A	UQ	N/A	N/A
14a				1.42	1.42	1.42	1.42				1.42				1	1	1	1	1	1				1	1	1	1
14b				1.1	1.1	1.1	1.1				1.1				1.1	1.1	1.1	1.1	1.1	1.1				1.1	1.1	1.1	1.1
14c				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
15				N/A	N/A	N/A	N/A				N/A				1.0	1.0	1.0	1.0	1.0	1.0				1.0	1.0	1.0	1.0
16				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ
17				UQ	UQ	UQ	UQ				UQ				UQ	UQ	UQ	UQ	UQ	UQ				UQ	UQ	UQ	UQ

Detailed Analysis Spreadsheet – sheet 5

ID#	LAWV		βγ	6/16/14		ILV		βγ2	6/16/14		NRCDA (643-26E)		βγ	6/16/14
	WITS limit	WITS SOF	Σf	I-129	C-14	WITS limit	WITS SOF	Σf	I-129	I-129C	WITS limit	WITS SOF	Σf	Ni-59
	0.95	0.155	0.145	0.104	0.041	0.95	0.078	0.076	0.039	0.037	0.95	0.026	0.015	0.015
		0.30					0.56					0.26		
			0.95	0.68	0.27			0.95	0.49	0.46			0.95	0.95
				0.60	**0.00**				**0.50**	**0.50**				**1.00**
			0.06	0.06	0.00			0.04	0.02	0.02			0.02	0.02
			0.41	0.41	0.00			0.47	0.24	0.23			0.95	0.95
1a				0.34	0.34				0.34	0.34				1
1b				2.21	0.0067				1.33	1.33				N/A
1c				0.73	0.72				1.00	1.00				1.00
2a				1	1				1	1				1
2b				N/A	N/A				N/A	N/A				N/A
3				1	1				1	1				1
4a				UQ	UQ				UQ	UQ				UQ
4b				UQ	UQ				UQ	UQ				UQ
5a				UQ	UQ				UQ	UQ				UQ
5b				UQ	UQ				UQ	UQ				UQ
5c				1	1				1	1				1
6a				UQ	UQ				UQ	UQ				UQ
6b				1	1				1	1				1
7a				N/A	N/A				N/A	N/A				N/A
7b				N/A	N/A				N/A	N/A				N/A
7c				UQ	UQ				UQ	UQ				N/A
8				N/A	N/A				N/A	N/A				
9				UQ	UQ				UQ	UQ				N/A
~~**9b**~~				~~N/A~~	~~N/A~~				~~N/A~~	~~N/A~~				~~N/A~~
10				N/A	N/A				N/A	N/A				N/A
11				N/A	N/A				N/A	N/A				N/A
12a				N/A	N/A				N/A	N/A				N/A
12b				N/A	N/A				N/A	N/A				N/A
13a				N/A	N/A				N/A	N/A				N/A
13b				N/A	N/A				N/A	N/A				N/A
13c				N/A	N/A				N/A	N/A				N/A
14a				1	1				1	1				1
14b				1.1	1.1				1.1	1.1				N/A
14c				UQ	UQ				UQ	UQ				N/A
15				N/A	N/A				N/A	N/A				N/A
16				UQ	UQ				UQ	UQ				UQ
17				UQ	UQ				UQ	UQ				N/A

APPENDIX B

Sum-of-Fractions snapshot on 6/16/2014 (Sink 2014a)

LLW Facility	Disposed Inventory (Ci)	Limiting PA Pathway Group	Current SOF Status (%)	WITS Admin Limit (%)	Isotopes Greater Than 1% in Limiting PA Pathway Group SOF	Volume Filled (%)
LAWV	3.74E+05	Beta-Gamma	15.5%	95.0%	**I-129**: 10.4%, **C-14**: 4.1%	30%
ILV	1.38E+06	Beta-Gamma 2	7.8%	95.0%	**I-129**: 3.9%, **I-129C**: 3.7%	56%
NR1 (643-26E)	4.17E+05	Beta-Gamma	2.6%	95.0%	**Ni-59**: 1.5%	26%
CIG Trenches	9.42E+03	Beta-Gamma 2	44.4%	95.0%	**C-14**: 17.0%, **I-129**: 14.9%, **H-3**: 5.9%, **Tc-99**: 2.3%, **C-14K**: 2.2% & **I-129K**: 1.1%	28%
ET#1	2.26E+02	Beta-Gamma 2	86.8%	95.0%	**C-14**: 26.2%, **I-129:** 24.5%, **H-3:** 18.5%, **Tc-99**: 14.5% & **Nb-94**: 1.7%	99%
ET#2	2.76E+02	Beta-Gamma 2	54.0%	95.0%	**H-3:** 20.2%, **Tc-99**: 15.2%, **I-129:** 10.7% & **C-14:** 6.7%	75%
ET#3	1.11E-02	Beta-Gamma 1	0.003%	95.0%	**None**	0.4%
SLIT6	1.56E+02	Beta-Gamma 2	82.2%	95.0%	**I-129**: 52.2%, **Tc-99**: 16.5%, **H-3**: 9.8% & **C-14**: 3.1%	91%
SLIT7	9.64E+01	Beta-Gamma 2	55.5%	95.0%	**I-129**: 19.5%, **H-3**: 21.6%, **C-14**: 8.3% & **Tc-99**: 5.7%	66%
SLIT8	9.41E+01	Beta-Gamma 1	88.6%	95.0%	**I-129**: 57.8%, **H-3**: 13.5%, **C-14**: 11.9% & **Tc-99**: 5.4%	95%
SLIT9	3.19E+02	Beta-Gamma 3	80.6%	95.0%	**C-14 Heat Exch**: 31.9%, **Sr-90**: 45.8%	81%
SLIT14	3.63E+03	All-Pathway 2	39.8%	95.0%	**Np-237**: 36.2%, **C-14 NR:** 1.5%	56%

Sum-of-Fractions snapshot on 6/18/2014 (Sink 2014b)

LLW Facility	Questioned PA Pathway Group	Current SOF Status (%)	WITS Admin Limit (%)	Isotopes Greater Than 1% in SOF
SLIT6	Alpha2	12.1%	95.0%	**Ra-226T:** 4.0%, **Np-237:** 2.7% & **Th-230T:** 2.2%
SLIT9	AP1	68.0%	95.0%	**Np-237:** 33.8%, **C-14X:** 31.9% & **Sr-90:** 1.3%
SLIT14	BG2	34.3%	95.0%	**C-14:** 11.7%, **I-129:** 8.2%, **Tc-99:** 8.0% & **H-3:** 5.0%
ET#2	AP2	52.9%	95.0%	**Np-237:** 50.3%
CIG	AP2	26.6%	95.0%	**C-14:** 15.9%, **Np-237:** 5.7%, **C-14K:** 2.1% & **Tc-99:** 1.5%

Unique Isotopes

Ra-226T	Ra-226 for 285F Cooling Tower
Th-230T	Th-230 for 285F Cooling Tower
C-14X	C-14 for Reactor Heat Exchangers
C-14K	C-14 for Reactor K / L Basin Resin

APPENDIX C

CIG Plume Interaction Correction

The 2008 PA inventory limits for the two CIG disposal units are revisited here to determine the impact associated with an incorrect application of the Plume-Interaction Factor (PIF) during the calculation of individual unit limits from the "combined" future inventory limits. For each radionuclide parent its combined future inventory limit was computed based on a PORFLOW run where both CIG units were involved. For CIG-1 existing inventory was buried within Segments 1 through 8 while the remaining trenches within CIG-1 and all of CIG-2 were considered as future trenches (i.e., referred to as Segment 9 in the 2008 PA report). The aquifer PORFLOW runs supplied the existing burial inventories in Segments 1-8 and placed a uniformly distributed future inventory of one gmole over all of the future available trenches (i.e., Segment 9). Preliminary future inventory limits were directly obtained from these PORFLOW runs (i.e., preliminary implies limits where the plume interaction factor was not yet applied).

The following series of equations describe how final inventory limits were computed in the 2008 PA. Within the 2008 PA report, Chapter 2 describes the process to compute preliminary CIG limits while Chapter 7 indicates how these limits were converted into final limits for each CIG unit.

The first step (performed in Chapter 2 of the 2008 PA report) was the estimation of preliminary future inventory limits starting with:

$$I_i^{Fut-Prelim} = f_i \cdot I_{Comb}^{Fut-Prelim} \tag{1}$$

where $I_i^{Fut-Prelim}$ Preliminary future inventory limit for ith CIG unit

f_i Fraction of available future trench length for ith CIG unit

$I_{Comb}^{Fut-Prelim}$ Combined future preliminary inventory limit

The fraction of future trench length available for future burial was computed as shown in the summary table below. This fraction is employed to allocate out to each unit its future allowable inventory. The values highlighted in peach were the rounded-off values actually employed.

Variable	CIG-1	CIG-2	CIG Combined
Trenches per unit (-)	5	5	10
Length per trench (ft)	656	656	-
Total unit trench length (ft)	3280	3280	6560
Used trench length (ft)	493.4	0.0	493.4
Unused trench length (ft)	2786.6	3280	6066.6
Fraction employed in 2008 PA	0.459	0.541	1.0

The preliminary total inventory limits then followed as:

$$I_1^{Prelim} = I_1^{Exist} + f_1 \cdot I_{Comb}^{Fut-Prelim} \tag{2a}$$

and

$$I_2^{Prelim} = f_2 \cdot I_{Comb}^{Fut-Prelim} \tag{2b}$$

where I_i^{Prelim} Preliminary inventory limit for ith CIG unit

I_1^{Exist} Existing inventory within Segments 1-8 in CIG-1

The second step (performed in Chapter 7 of the 2008 PA report) was the estimation of final inventory limits to account for plume-interaction:

$$I_i^{Final} = \left(\frac{1}{PIF}\right) \cdot I_i^{Prelim} = (\eta) \cdot I_i^{Prelim} \tag{3}$$

where I_i^{Final} Final inventory limit for ith CIG unit

PIF Plume interaction factor for combined CIG units

η Reciprocal value of PIF employed in 2008 PA

Plume interaction factors were computed for each group of disposal units by type. For the combined CIG units the values computed and employed in the 2008 PA are provided below. The values highlighted in peach were the rounded-off values actually employed.

Variable	CIG Combined
Plume interaction factor (PIF)	1.53
Reciprocal value of PIF (η)	0.6536
η used in 2008 PA	0.650

The above sequence of calculations does not correctly account for how plume interaction and existing inventory impact the future allowable inventory limit and thus the final inventory limit. The correct sequence of calculations can be better understood by considering dose.

Figure 9 below highlights the various aspects being addressed for computing CIG disposal unit inventory limits. The two units form a group (i.e., combined CIG) where existing inventory is present only within CIG-1. Due to transverse dispersion, neighboring units such as SLIT4 and SLIT5 contribute to the dose observed along the 100 meter boundary directly down-gradient of the CIG units.

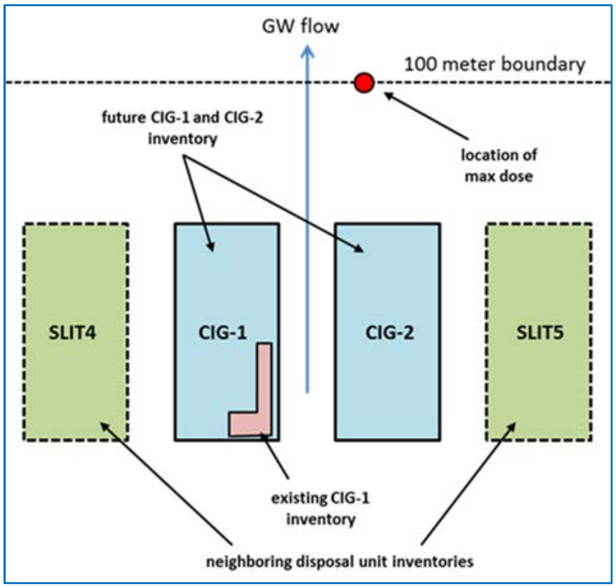


Figure 9 -The various aspects being addressed to compute CIG disposal unit inventory limits.

Along the 100 meter boundary there will exist a location where the maximum total dose will occur. For example, assume that the maximum computed dose will occur at the location indicated in Figure 9 where the red circle is placed. This maximum computed dose is made up from several inventory sources (i.e., inventory from neighboring units, existing inventory within CIG-1, and future available inventory within CIG-1 and CIG-2). In Figure 10 below the transient doses seen at this 100 meter boundary location are shown for one radionuclide parent (and its progeny; here total dose is a rollup of the entire chain members contributions).

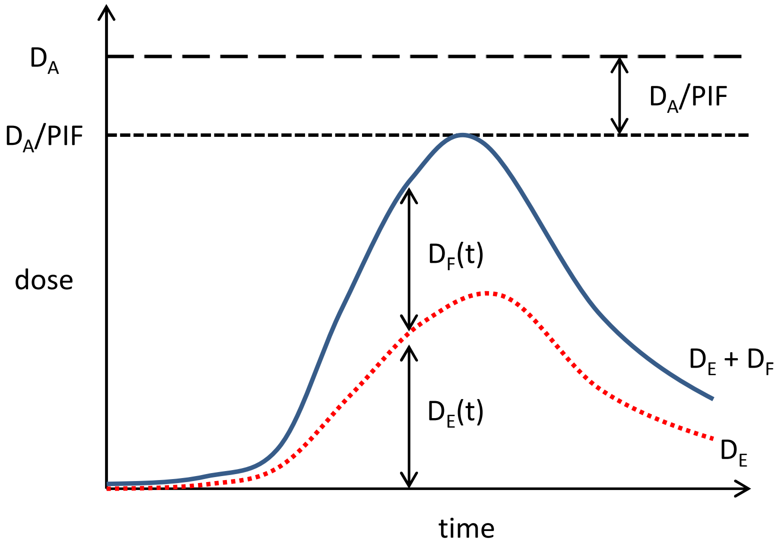


Figure 10 - Dose versus time at the 100 meter boundary where existing inventory is present.

For this particular radionuclide existing inventory is also present. This existing inventory establishes a background dose profile as shown by the red dashed curve. The upper black dashed line represents the allowable dose (e.g., 4 mrem/yr for the beta-gamma pathway). The margin between the allowable dose and the dose associated with existing inventory is available for accommodating future inventory. Existing inventory outside of the two CIG units elevates the background dose because their concentration plumes extend/comingle within this region (i.e., this effect is handled by employing a CIG plume interaction factor). The net effect of neighboring units is to effectively reduce this overall margin.

There are two ways of computing or viewing the future allowable inventory limit as shown in the equations:

$$I_{\mathrm{Comb}}^{\mathrm{Fut-Final}} = \frac{D_A - (\mathrm{PIF}) \cdot D_E}{(\mathrm{PIF}) \cdot \hat{D}_F} \tag{4a}$$

or

$$I_{\mathrm{Comb}}^{\mathrm{Fut-Final}} = \frac{\frac{D_A}{\mathrm{PIF}} - D_E}{\hat{D}_F} \tag{4b}$$

where $I_{\mathrm{Comb}}^{\mathrm{Fut-Final}}$ Final future combined inventory limit
$\hat{D}_F$ Future dose on a gmole of parent buried basis
D_A Allowable dose for specified pathway
D_E Dose associated with existing inventory buried

As Eq. (4b) indicates, the future allowable inventory can be computed by simply reducing the dose allowable by the plume interaction factor (i.e., an effective value).

With Eq. (4a or 4b) the final total inventory limits become:

$$I_1^{\mathrm{Final}} = I_1^{\mathrm{Exist}} + f_1 \cdot I_{\mathrm{Comb}}^{\mathrm{Fut-Final}} \tag{5a}$$

and

$$I_2^{\mathrm{Final}} = f_2 \cdot I_{\mathrm{Comb}}^{\mathrm{Fut-Final}} \tag{5b}$$

Dose for a specific radionuclide parent involves contributions from the parent as well as all of its progeny. The doses shown in Eqs. (4) are pathway dependent (i.e., beta-gamma, all-pathways, gross alpha, radium, or uranium) and can be computed for each selected pathway by:

$$D_{\mathrm{Pathway}}(t) = \sum_{i=1}^{N} \left[\mathrm{DCF}_i^{\mathrm{Pathway}} \right] \cdot C_i(t) \tag{6}$$

where D_{Pathway} Dose for selected pathway (e.g., all pathways)
$\mathrm{DCF}_i^{\mathrm{Pathway}}$ Dose conversion factor for given pathway and i$^{\mathrm{th}}$ progeny
N Chain length (parent plus its progeny)
C_i Concentration of i$^{\mathrm{th}}$ nuclide in chain at max location

In computing the dose as shown in Eq. (6), Dose Conversion Factors (DCFs) are required. These DCFs are computed from:

$$\mathrm{DCF}_i^{\mathrm{Pathway}} = \mathrm{Funct}\left(\overline{\mathrm{DC}}, \overline{\mathrm{CR}}, \overline{\mathrm{DPF}}\right) \qquad (7)$$

where $\overline{\mathrm{DC}}$ Dose coefficients for each member in the chain (e.g., water ingestion)

$\overline{\mathrm{CR}}$ Consumption rates (e.g., water consumption per day)

$\overline{\mathrm{DPF}}$ Dose parameter factors (e.g., fraction of time watering garden)

Below the CIG inventory limits are reviewed where two sets of limits are compared back to those presented in the 2008 PA report (i.e., those currently employed in WITS). These two sets are:

1. CIG inventory limits re-calculated consistent with the methods employed during the time frame of the 2008 PA. This assessment helps to verify that the method used and inputs employed are consistent with the results presented within the 2008 PA.
2. CIG inventory limits calculated using the corrected equations described above to address existing inventory and plume interaction impacts. Here the same set of parameters and inputs as employed in the 2008 PA are considered. The only difference observed here is the use of the corrected limits equations.

From a comparison of these two sets of limits we can assess the potential need for performing a SA to address updated CIG inventory limits. But, first ideal files must be addressed.

We are using the original set of codes for these analyses where confirmation of results from the archive was part of this effort. These codes are:

- "**Ideal FileMaker v1.2 12-07-2006.xls**" – an Excel based Visual Basic code that was updated on 12/7/2006 prior to the creation of the CIG ideal files contained within the archives. This code creates the ideal files from the PORFLOW generated stat files for both existing (Seg1-8) and future (Seg9) inventories.
- "**All-Pathways.exe**" – a Visual Basic code that is dated 11/28/2006 and was prior to the creation of the CIG limits results contained within the archives. This code takes the **Ideal FileMaker v1.2 12-07-2006.xls** ideal file results and generates dose information on both the existing and future inventories.
- "**FutureLimits.exe**" – a Visual Basic code that is dated 4/13/2010 and was after the creation of the CIG limits results contained within the archives. The version dated as of 10/18/2006 was actually employed in the creation of the CIG limits results contained within the archives. We chose to use the newer one which does not impact limits results but so an improvement in logic for reading in input data. This code takes the existing and future dose results from **All-Pathways.exe** and computes the future inventory limits.

Recalculation of Ideal Files

Both sets of calculations above will require use of ideal files. Prior to performing these two sets of calculations a confirmation step has been performed where the ideal files were recomputed based on the PA Archive files taken from the PORFLOW CDP on case:

- PORFLOW run.out (provides the short chain information)
- PORFLOW wells.stat (more recently named stat.out files with short chain member concentrations versus time at the 100 m boundary)

To create the ideal files for the existing (or future) inventories the following steps were performed (here one answer's [by entering] to questions as various dialog boxes popup):

- Initiated the **Ideal FileMaker v1.2 12-07-2006.xls** code.
- Indicate directory where the PORFLOW stat files are located for existing (or future) inventory.
- Select conversion of units from Ci/ft3 to pCi/L for both existing and future inventory cases.
- Select to normalize activities per activity of parent for the future only case (not for existing case).
- Provide name of PORFLOW output file (i.e., run.dat).
- Provide name of PORFLOW state file (i.e., wells.stat or stat.out etc.).
- Provide scale factor. Here for the first set of limits calculations, this value is set to one for without PIF conditions while for the second set of limits calculations its value is set to 1.53 for with PIF (the CIG PIF value).
- An ideal file directory is then created in the directory where the stat files are located.

The above series of steps were performed to generate:

1. Ideal files without PIF for existing inventory
2. Ideal files without PIF for future inventory
3. Ideal files with PIF (=1.53) for existing inventory
4. Ideal files with PIF (=1.53) for future inventory

The ideal file generated in steps 1 and 2 above were compared to those contained within the archive and were found to be "identical." The ideal files generated in steps 3 and 4 above are new and are employed in the creation of new CIG inventory limits.

Recalculation of 2008 PA Limits and New Limits

The specific steps taken are listed below for creating first the dose information and then the future "preliminary" or "final" inventory limits.

To create the dose information for the existing inventory and then the future inventory the following steps are taken:

- Initiated the **All-Pathways.exe** code
- Indicate directory where the appropriate ideal files are located for existing (or future) inventory and for without or with PIF applied.
- Select all radionuclide parent contained within the listing.

- Select the read these files into code.
- Merge the times contained within these files.
- Choose time windowing. Here we must choose the entire time period of compliance (model time from 0 yr to 1,125 yr) and we opted to include the entire 10,000 yr runs (i.e., 0 yr to 10,125 yr).
- Choose calculation type to be maximum dose in time for inventory.
- Select the Excel file containing the parent inventories. Here all parent inventories are set to 1 Ci for both existing and future cases. For existing case we do this because PORFLOW was run employing the actual inventories present and here we do not wish to alter the doses computed. For the future case we actually want the computed doses to reflect a per Ci buried condition.
- Select the pathways of interest. Here for both cases all 5 pathways are chosen. For the LADTAP option we only choose water ingestion along with veg, milk, and meat consumption.
- Select to write out results to an Excel file.
- Provide location and name of Excel file to contain the results.
- Calculate and save results obtained.

The same set of steps as above are done for each set of limits calculations where we only select the appropriate set of ideal files for the case of interest. To create the follow on future inventory limits (either “preliminary” or “final”) the following steps are taken:

- Initiated the **FutureLimits.exe** code
- Indicate directory where the appropriate existing dose information is located for the case of interest (i.e., without or with PIF applied).
- Indicate directory where the appropriate future dose information is located for the case of interest (i.e., without or with PIF applied).
- Choose all 5 pathways.
- Choose the time window of interest. Here we had two time windows set to 0-125yr and 125-1,125yr. We also ran the 1,125-10,125yr time window for sensitivity reasons.
- Provide location and name of Excel file to contain the future inventory limits results.
- Calculate and save results obtained.

Note that because PORFLOW was run with both CIG-1 and CIG-2 combined, the future inventory limits computed above represent the combined future values. These combined values must then be allocated out to each unit separately.

Step 1 (checking that current inventory limits are consistent with 2008 PA report)

Given the ideal files generated above under the without PIF option (i.e., scale factor = 1.0), “preliminary” combined inventory limits were created consistent with the methods employed during the 2008 PA effort. These limits are provided in the 2008 PA report (see Table 2-1 of that report) where the combined values were allocated out by using the future trench length fractions provided earlier (i.e., f_1=0.459 and f_2=0.541).

To confirm these recomputed limits, first the preliminary future CIG combined inventory limits were extracted from the 2008 PA Archives and placed within an Excel spreadsheet. The current WITS CIG inventory limits were also placed in the same Excel spreadsheet. With this spreadsheet the CIG-1 and CIG-2 inventory limits were re-calculated employing the Eqs. (1 through 3) above using the rounded-off parameters highlighted above as well. For all 39 radionuclide parents the re-calculated versus WITS values were within 5% of each other. Slight differences are expected to be seen given that WITS inventory limits are rounded-off the two significant digits.

The results of this step provide insurance that the following calculational aspects are being employed correctly:

- The CDP baseline case combined CIG Ideal Files taken from the archives is the correct case to use;
- Our current **All-Pathways** and **FutureLimits** codes provide the same results as the original codes, employed during the 2008 PA effort (see Koffman 2006);
- The dose parameters used as input are consistent with those employed in the 2008 PA; and
- The rounded off plume-interaction factor and future trench length fractions are consistent with the ones employed in the 2008 PA effort.

Step 2 (Calculating inventory limits based on new equations and 2008 PA dose model inputs)

Given the ideal files generated above under the with PIF option (i.e., scale factor = 1.53), “final” combined inventory limits were created consistent with the methods employed during the 2008 PA effort. The future inventory limits for each unit were then computed by the allocation method as before (i.e., f_1=0.459 and f_2=0.541) where Eqs. (4 and 5) were employed.

An impact factor for each parent nuclide is defined as the ratio of the inventory limits:

$$F_i = \frac{I_i^{CIG1}(\text{new PIF method})}{I_i^{CIG1}(\text{PA2008 PIF method})} \quad (8)$$

As the inventory limits in WITS are rounded-off values, the re-calculated 2008 PA values discussed above are employed in Eq. (8). To compare these newly computed inventory limits to the current WITS CIG inventory limits, both sets of values were placed within an Excel spreadsheet.

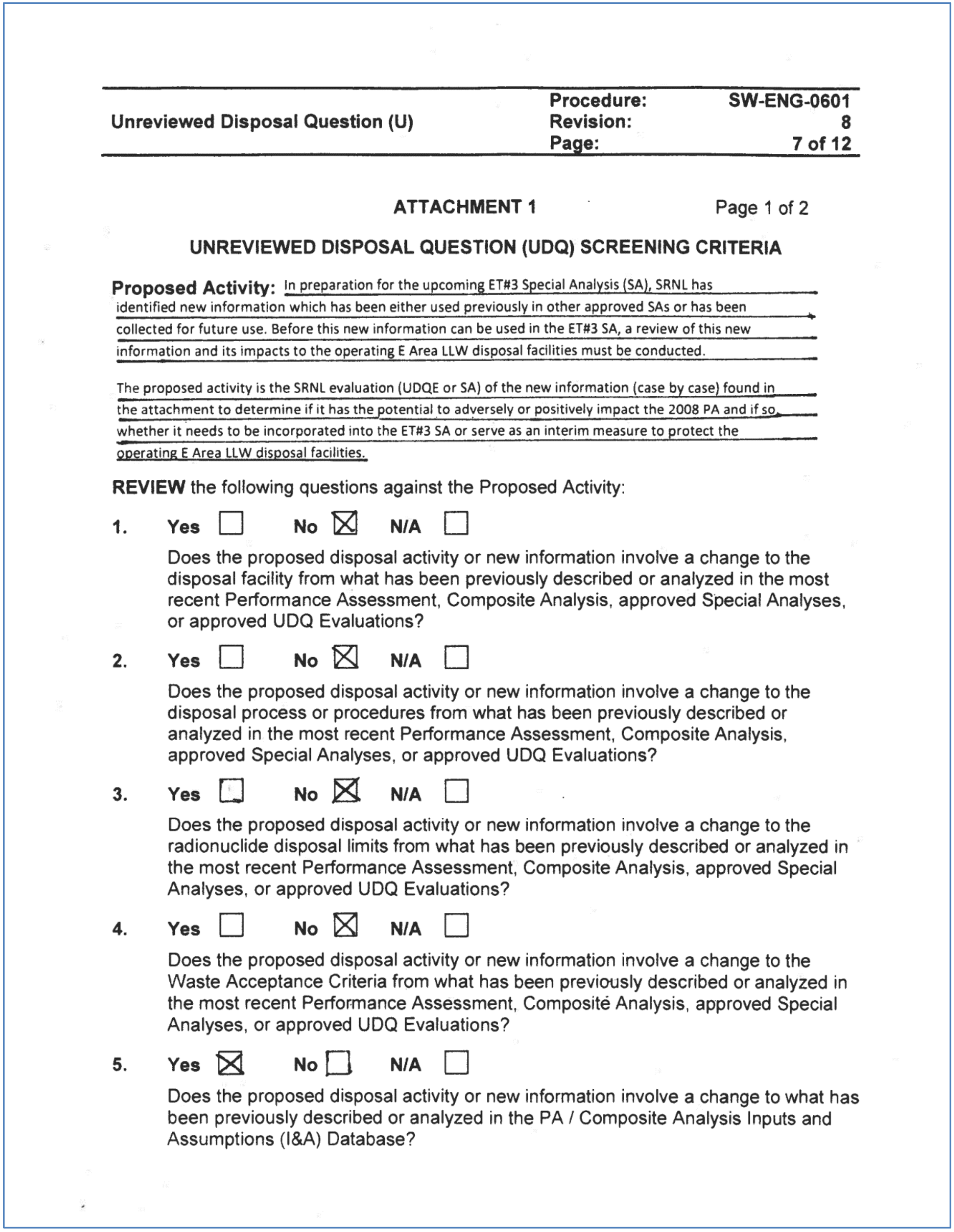
Table 11 lists the impact factors for the nuclides of interest in the first two limiting pathways. The effect of these corrections results in no change to the key radionuclides of interest (i.e., impact factor of 1.0 in Appendix A) as new limits fall within 5% of the current WITS limit.

Table 11 - CIG-1 PIF re-calculation impact factors.

Nuc	BG2	AP2
C-14	0.997	1.005
C-14_K	1.002	1.011
H-3	0.978	0.983
I-129	0.988	1.016
I-129_K	1.006	1.008
Np-237	0.987	0.985
Tc-99	0.978	1.000

ATTACHMENT 1

UDQ Screening



Unreviewed Disposal Question (U)	**Procedure:**	**SW-ENG-0601**
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UNREVIEWED DISPOSAL QUESTION (UDQ) SCREENING CRITERIA

Proposed Activity: In preparation for the upcoming ET#3 Special Analysis (SA), SRNL has identified new information which has been either used previously in other approved SAs or has been collected for future use. Before this new information can be used in the ET#3 SA, a review of this new information and its impacts to the operating E Area LLW disposal facilities must be conducted.

The proposed activity is the SRNL evaluation (UDQE or SA) of the new information (case by case) found in the attachment to determine if it has the potential to adversely or positively impact the 2008 PA and if so, whether it needs to be incorporated into the ET#3 SA or serve as an interim measure to protect the operating E Area LLW disposal facilities.

REVIEW the following questions against the Proposed Activity:

1. **Yes** ☐ **No** ☒ **N/A** ☐

   Does the proposed disposal activity or new information involve a change to the disposal facility from what has been previously described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, or approved UDQ Evaluations?

2. **Yes** ☐ **No** ☒ **N/A** ☐

   Does the proposed disposal activity or new information involve a change to the disposal process or procedures from what has been previously described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, or approved UDQ Evaluations?

3. **Yes** ☐ **No** ☒ **N/A** ☐

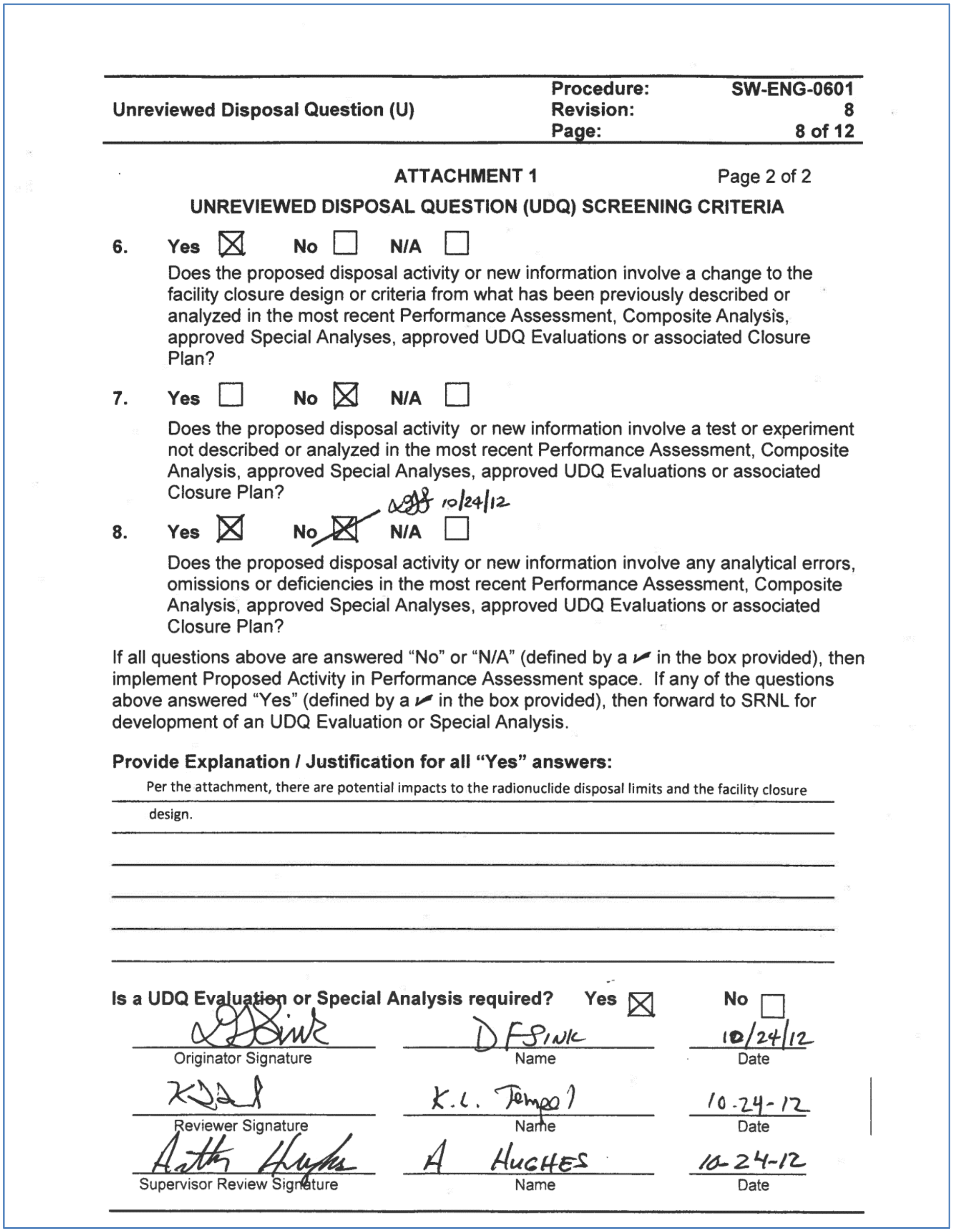
   Does the proposed disposal activity or new information involve a change to the radionuclide disposal limits from what has been previously described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, or approved UDQ Evaluations?

4. **Yes** ☐ **No** ☒ **N/A** ☐

   Does the proposed disposal activity or new information involve a change to the Waste Acceptance Criteria from what has been previously described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, or approved UDQ Evaluations?

5. **Yes** ☒ **No** ☐ **N/A** ☐

   Does the proposed disposal activity or new information involve a change to what has been previously described or analyzed in the PA / Composite Analysis Inputs and Assumptions (I&A) Database?



Unreviewed Disposal Question (U)	**Procedure:** **Revision:** **Page:**	**SW-ENG-0601** **8** **8 of 12**

ATTACHMENT 1 Page 2 of 2

UNREVIEWED DISPOSAL QUESTION (UDQ) SCREENING CRITERIA

6. **Yes** ☒ **No** ☐ **N/A** ☐

Does the proposed disposal activity or new information involve a change to the facility closure design or criteria from what has been previously described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, approved UDQ Evaluations or associated Closure Plan?

7. **Yes** ☐ **No** ☒ **N/A** ☐

Does the proposed disposal activity or new information involve a test or experiment not described or analyzed in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, approved UDQ Evaluations or associated Closure Plan?

10/24/12

8. **Yes** ☒ **No** ~~☒~~ **N/A** ☐

Does the proposed disposal activity or new information involve any analytical errors, omissions or deficiencies in the most recent Performance Assessment, Composite Analysis, approved Special Analyses, approved UDQ Evaluations or associated Closure Plan?

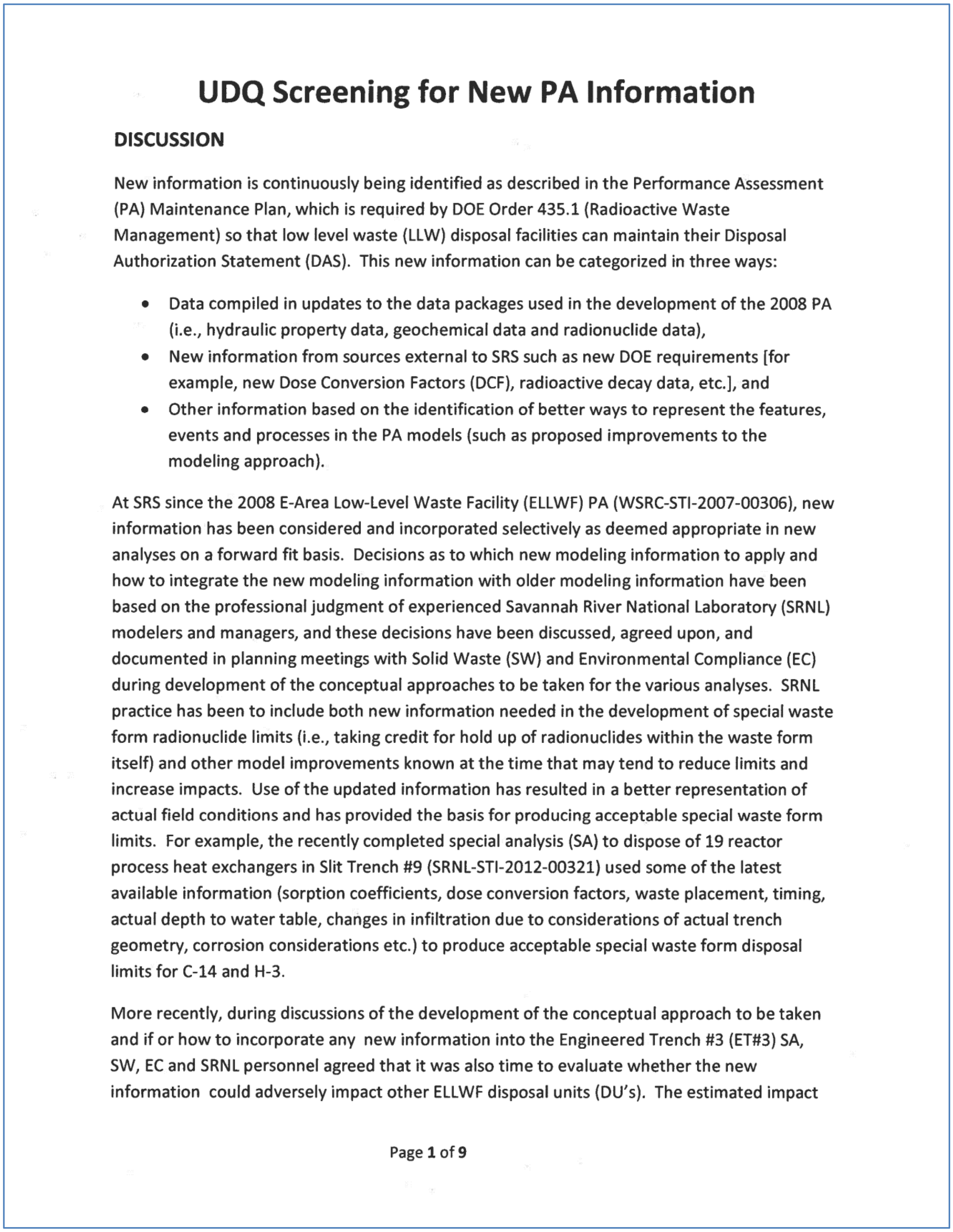
If all questions above are answered "No" or "N/A" (defined by a ✓ in the box provided), then implement Proposed Activity in Performance Assessment space. If any of the questions above answered "Yes" (defined by a ✓ in the box provided), then forward to SRNL for development of an UDQ Evaluation or Special Analysis.

Provide Explanation / Justification for all "Yes" answers:

Per the attachment, there are potential impacts to the radionuclide disposal limits and the facility closure design.

Is a UDQ Evaluation or Special Analysis required? **Yes** ☒ **No** ☐

	D F SINK	10/24/12
Originator Signature	Name	Date
	K.L. Tempel	10-24-12
Reviewer Signature	Name	Date
	A HUGHES	10-24-12
Supervisor Review Signature	Name	Date



UDQ Screening for New PA Information

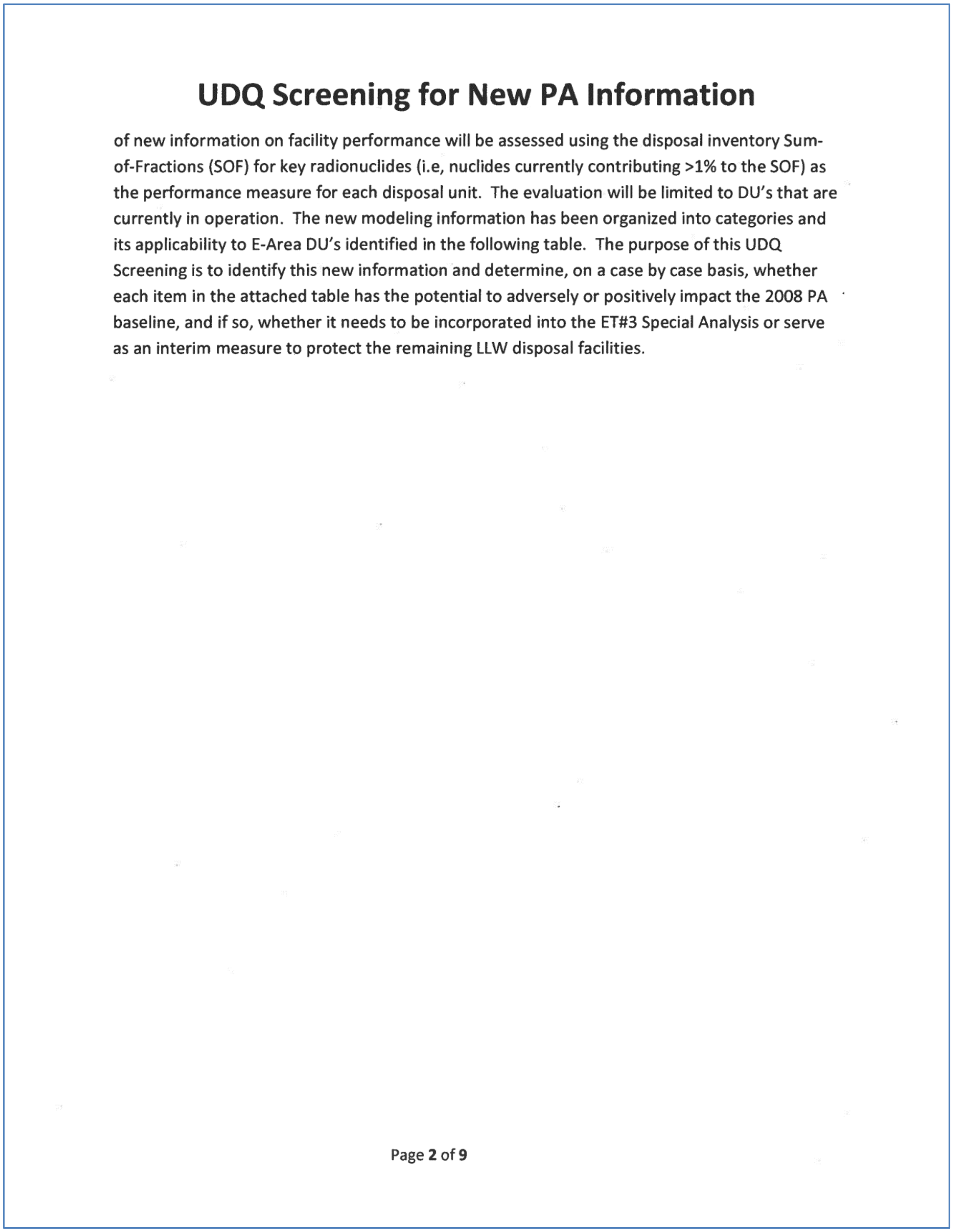
DISCUSSION

New information is continuously being identified as described in the Performance Assessment (PA) Maintenance Plan, which is required by DOE Order 435.1 (Radioactive Waste Management) so that low level waste (LLW) disposal facilities can maintain their Disposal Authorization Statement (DAS). This new information can be categorized in three ways:

- Data compiled in updates to the data packages used in the development of the 2008 PA (i.e., hydraulic property data, geochemical data and radionuclide data),
- New information from sources external to SRS such as new DOE requirements [for example, new Dose Conversion Factors (DCF), radioactive decay data, etc.], and
- Other information based on the identification of better ways to represent the features, events and processes in the PA models (such as proposed improvements to the modeling approach).

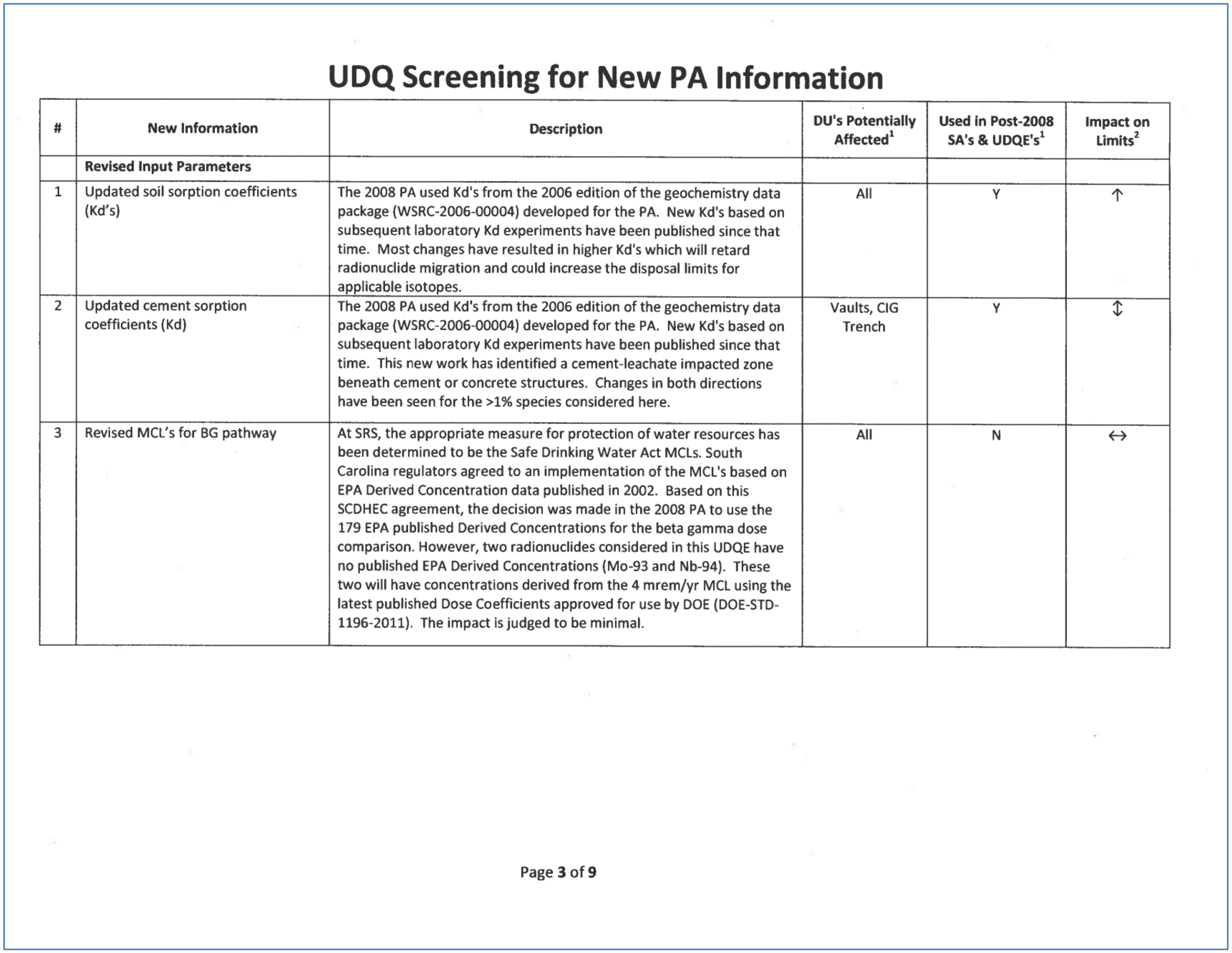
At SRS since the 2008 E-Area Low-Level Waste Facility (ELLWF) PA (WSRC-STI-2007-00306), new information has been considered and incorporated selectively as deemed appropriate in new analyses on a forward fit basis. Decisions as to which new modeling information to apply and how to integrate the new modeling information with older modeling information have been based on the professional judgment of experienced Savannah River National Laboratory (SRNL) modelers and managers, and these decisions have been discussed, agreed upon, and documented in planning meetings with Solid Waste (SW) and Environmental Compliance (EC) during development of the conceptual approaches to be taken for the various analyses. SRNL practice has been to include both new information needed in the development of special waste form radionuclide limits (i.e., taking credit for hold up of radionuclides within the waste form itself) and other model improvements known at the time that may tend to reduce limits and increase impacts. Use of the updated information has resulted in a better representation of actual field conditions and has provided the basis for producing acceptable special waste form limits. For example, the recently completed special analysis (SA) to dispose of 19 reactor process heat exchangers in Slit Trench #9 (SRNL-STI-2012-00321) used some of the latest available information (sorption coefficients, dose conversion factors, waste placement, timing, actual depth to water table, changes in infiltration due to considerations of actual trench geometry, corrosion considerations etc.) to produce acceptable special waste form disposal limits for C-14 and H-3.

More recently, during discussions of the development of the conceptual approach to be taken and if or how to incorporate any new information into the Engineered Trench #3 (ET#3) SA, SW, EC and SRNL personnel agreed that it was also time to evaluate whether the new information could adversely impact other ELLWF disposal units (DU's). The estimated impact



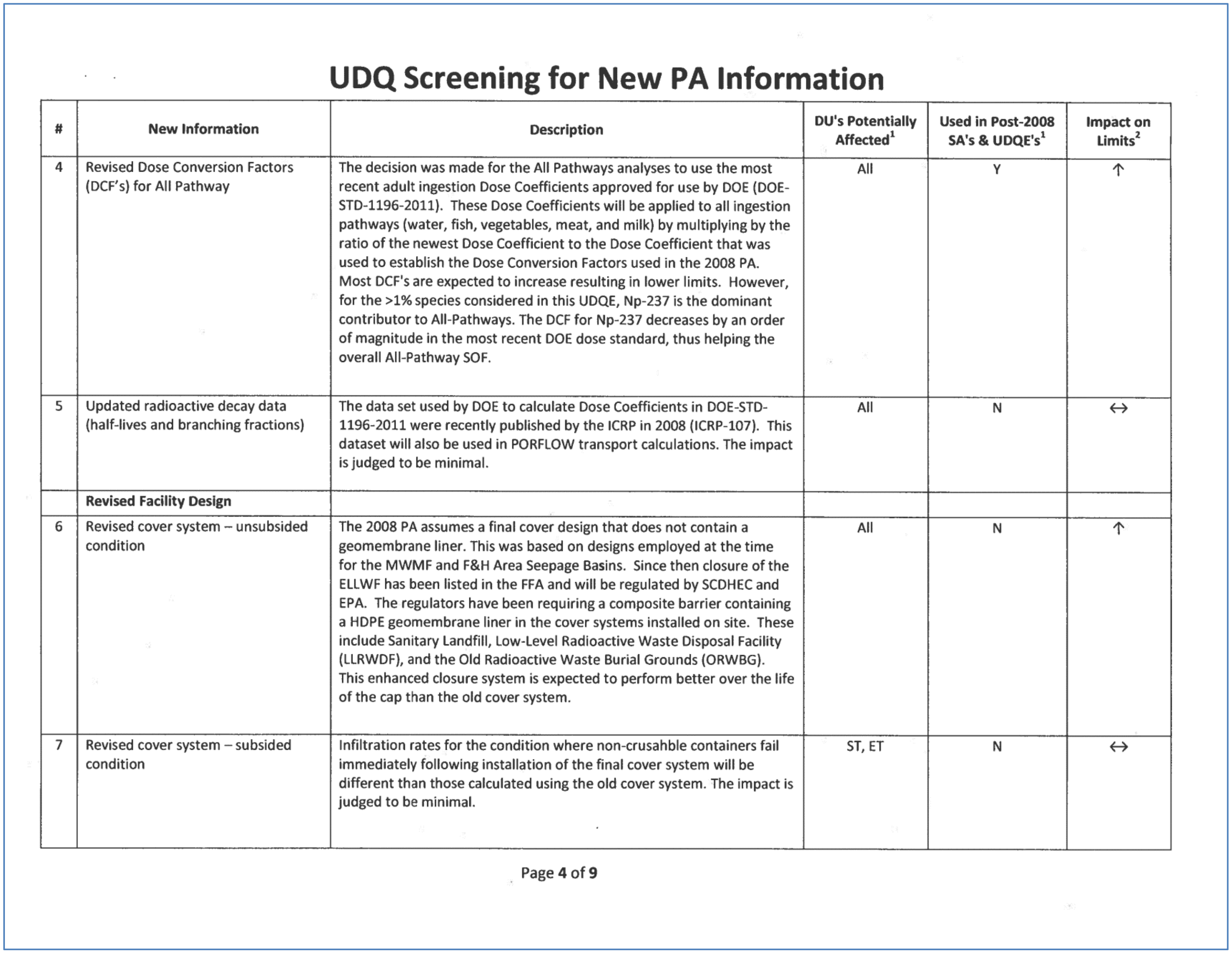
UDQ Screening for New PA Information

of new information on facility performance will be assessed using the disposal inventory Sum-of-Fractions (SOF) for key radionuclides (i.e, nuclides currently contributing >1% to the SOF) as the performance measure for each disposal unit. The evaluation will be limited to DU's that are currently in operation. The new modeling information has been organized into categories and its applicability to E-Area DU's identified in the following table. The purpose of this UDQ Screening is to identify this new information and determine, on a case by case basis, whether each item in the attached table has the potential to adversely or positively impact the 2008 PA baseline, and if so, whether it needs to be incorporated into the ET#3 Special Analysis or serve as an interim measure to protect the remaining LLW disposal facilities.



UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
	Revised Input Parameters				
1	Updated soil sorption coefficients (Kd's)	The 2008 PA used Kd's from the 2006 edition of the geochemistry data package (WSRC-2006-00004) developed for the PA. New Kd's based on subsequent laboratory Kd experiments have been published since that time. Most changes have resulted in higher Kd's which will retard radionuclide migration and could increase the disposal limits for applicable isotopes.	All	Y	↑
2	Updated cement sorption coefficients (Kd)	The 2008 PA used Kd's from the 2006 edition of the geochemistry data package (WSRC-2006-00004) developed for the PA. New Kd's based on subsequent laboratory Kd experiments have been published since that time. This new work has identified a cement-leachate impacted zone beneath cement or concrete structures. Changes in both directions have been seen for the >1% species considered here.	Vaults, CIG Trench	Y	↕
3	Revised MCL's for BG pathway	At SRS, the appropriate measure for protection of water resources has been determined to be the Safe Drinking Water Act MCLs. South Carolina regulators agreed to an implementation of the MCL's based on EPA Derived Concentration data published in 2002. Based on this SCDHEC agreement, the decision was made in the 2008 PA to use the 179 EPA published Derived Concentrations for the beta gamma dose comparison. However, two radionuclides considered in this UDQE have no published EPA Derived Concentrations (Mo-93 and Nb-94). These two will have concentrations derived from the 4 mrem/yr MCL using the latest published Dose Coefficients approved for use by DOE (DOE-STD-1196-2011). The impact is judged to be minimal.	All	N	↔



UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
4	Revised Dose Conversion Factors (DCF's) for All Pathway	The decision was made for the All Pathways analyses to use the most recent adult ingestion Dose Coefficients approved for use by DOE (DOE-STD-1196-2011). These Dose Coefficients will be applied to all ingestion pathways (water, fish, vegetables, meat, and milk) by multiplying by the ratio of the newest Dose Coefficient to the Dose Coefficient that was used to establish the Dose Conversion Factors used in the 2008 PA. Most DCF's are expected to increase resulting in lower limits. However, for the >1% species considered in this UDQE, Np-237 is the dominant contributor to All-Pathways. The DCF for Np-237 decreases by an order of magnitude in the most recent DOE dose standard, thus helping the overall All-Pathway SOF.	All	Y	↑
5	Updated radioactive decay data (half-lives and branching fractions)	The data set used by DOE to calculate Dose Coefficients in DOE-STD-1196-2011 were recently published by the ICRP in 2008 (ICRP-107). This dataset will also be used in PORFLOW transport calculations. The impact is judged to be minimal.	All	N	↔
	Revised Facility Design				
6	Revised cover system – unsubsided condition	The 2008 PA assumes a final cover design that does not contain a geomembrane liner. This was based on designs employed at the time for the MWMF and F&H Area Seepage Basins. Since then closure of the ELLWF has been listed in the FFA and will be regulated by SCDHEC and EPA. The regulators have been requiring a composite barrier containing a HDPE geomembrane liner in the cover systems installed on site. These include Sanitary Landfill, Low-Level Radioactive Waste Disposal Facility (LLRWDF), and the Old Radioactive Waste Burial Grounds (ORWBG). This enhanced closure system is expected to perform better over the life of the cap than the old cover system.	All	N	↑
7	Revised cover system – subsided condition	Infiltration rates for the condition where non-crusahble containers fail immediately following installation of the final cover system will be different than those calculated using the old cover system. The impact is judged to be minimal.	ST, ET	N	↔

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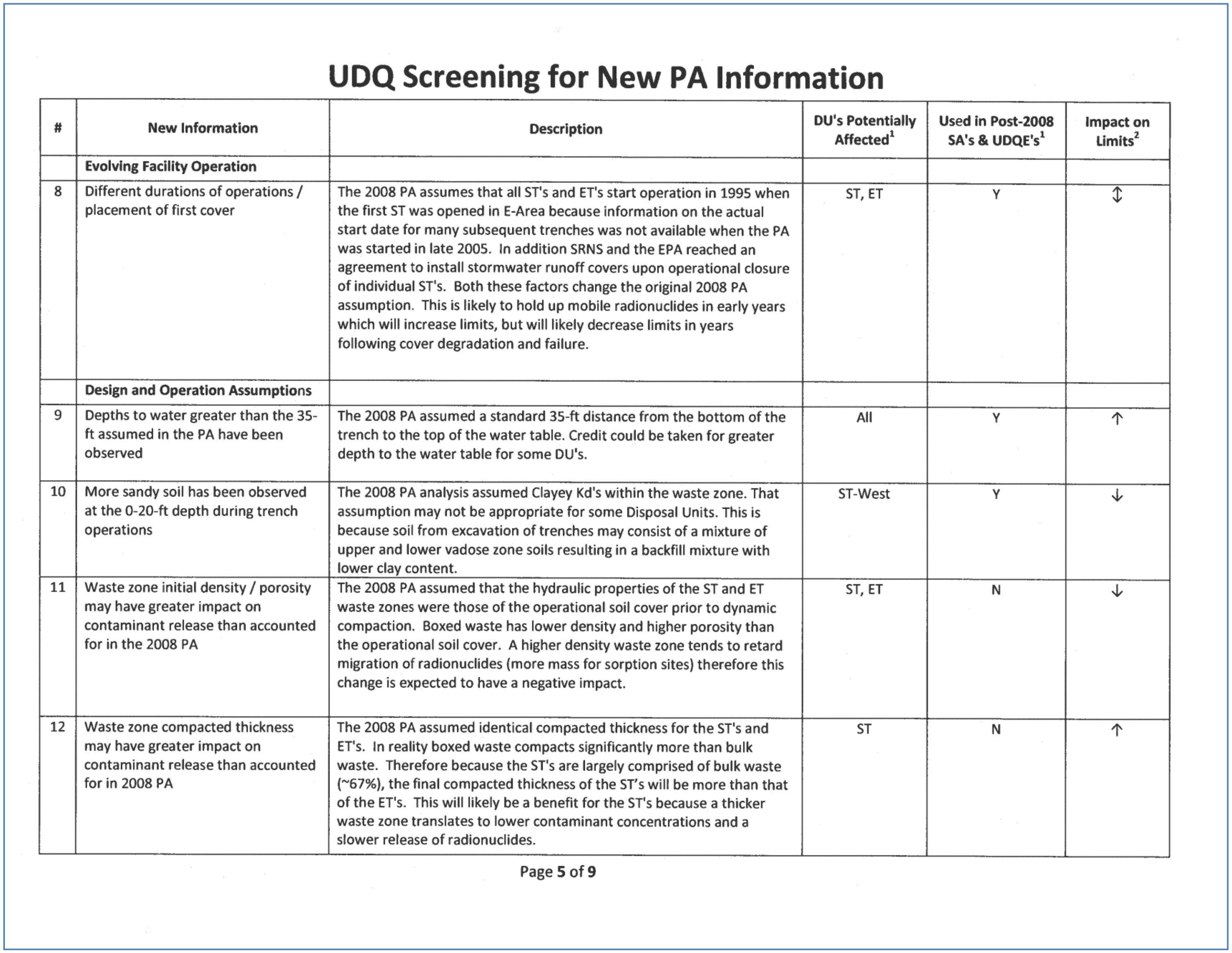

UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected^1	Used in Post-2008 SA's & UDQE's^1	Impact on Limits^2
	Evolving Facility Operation				
8	Different durations of operations / placement of first cover	The 2008 PA assumes that all ST's and ET's start operation in 1995 when the first ST was opened in E-Area because information on the actual start date for many subsequent trenches was not available when the PA was started in late 2005. In addition SRNS and the EPA reached an agreement to install stormwater runoff covers upon operational closure of individual ST's. Both these factors change the original 2008 PA assumption. This is likely to hold up mobile radionuclides in early years which will increase limits, but will likely decrease limits in years following cover degradation and failure.	ST, ET	Y	↕
	Design and Operation Assumptions				
9	Depths to water greater than the 35-ft assumed in the PA have been observed	The 2008 PA assumed a standard 35-ft distance from the bottom of the trench to the top of the water table. Credit could be taken for greater depth to the water table for some DU's.	All	Y	↑
10	More sandy soil has been observed at the 0-20-ft depth during trench operations	The 2008 PA analysis assumed Clayey Kd's within the waste zone. That assumption may not be appropriate for some Disposal Units. This is because soil from excavation of trenches may consist of a mixture of upper and lower vadose zone soils resulting in a backfill mixture with lower clay content.	ST-West	Y	↓
11	Waste zone initial density / porosity may have greater impact on contaminant release than accounted for in the 2008 PA	The 2008 PA assumed that the hydraulic properties of the ST and ET waste zones were those of the operational soil cover prior to dynamic compaction. Boxed waste has lower density and higher porosity than the operational soil cover. A higher density waste zone tends to retard migration of radionuclides (more mass for sorption sites) therefore this change is expected to have a negative impact.	ST, ET	N	↓
12	Waste zone compacted thickness may have greater impact on contaminant release than accounted for in 2008 PA	The 2008 PA assumed identical compacted thickness for the ST's and ET's. In reality boxed waste compacts significantly more than bulk waste. Therefore because the ST's are largely comprised of bulk waste (~67%), the final compacted thickness of the ST's will be more than that of the ET's. This will likely be a benefit for the ST's because a thicker waste zone translates to lower contaminant concentrations and a slower release of radionuclides.	ST	N	↑

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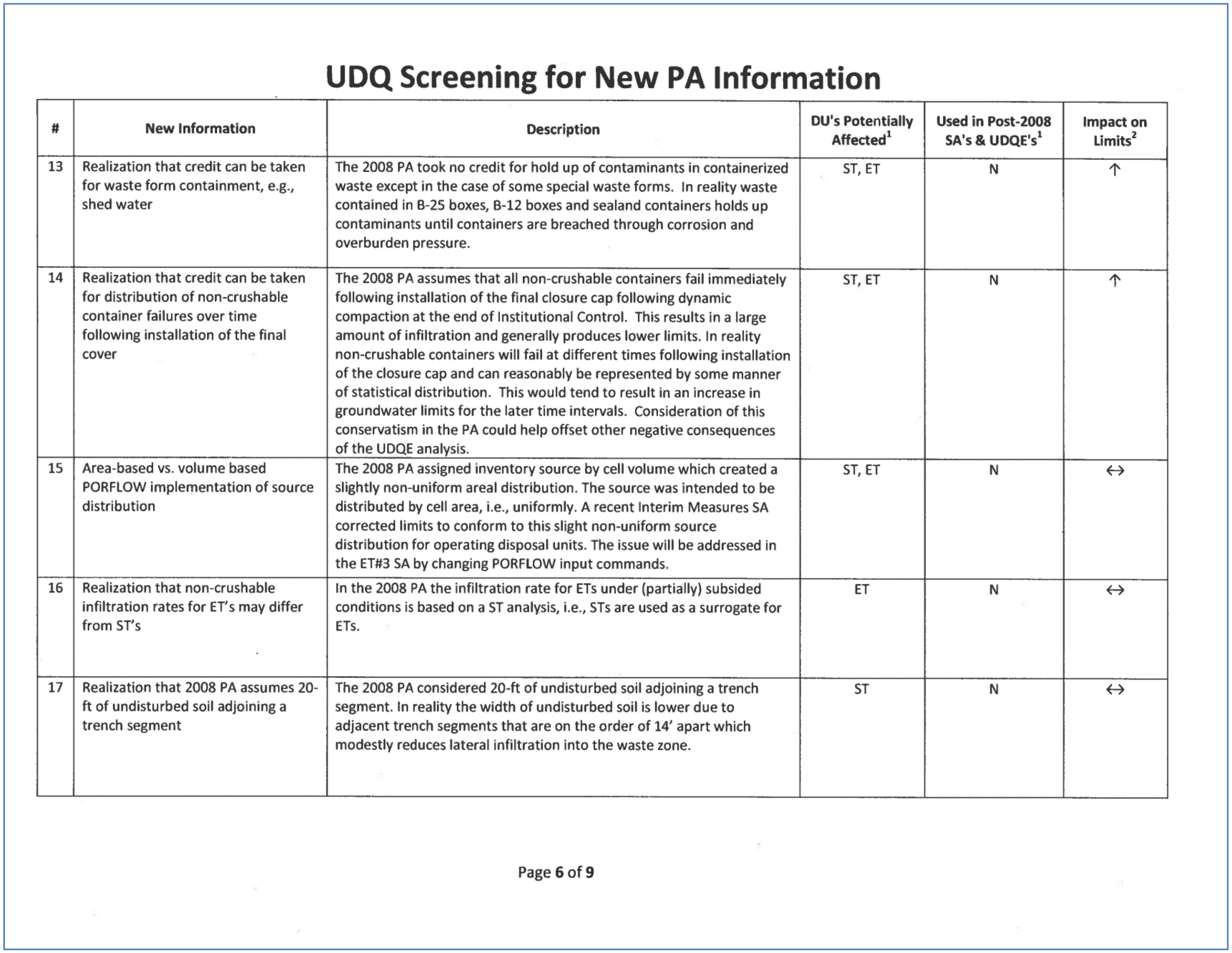

UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
13	Realization that credit can be taken for waste form containment, e.g., shed water	The 2008 PA took no credit for hold up of contaminants in containerized waste except in the case of some special waste forms. In reality waste contained in B-25 boxes, B-12 boxes and sealand containers holds up contaminants until containers are breached through corrosion and overburden pressure.	ST, ET	N	↑
14	Realization that credit can be taken for distribution of non-crushable container failures over time following installation of the final cover	The 2008 PA assumes that all non-crushable containers fail immediately following installation of the final closure cap following dynamic compaction at the end of Institutional Control. This results in a large amount of infiltration and generally produces lower limits. In reality non-crushable containers will fail at different times following installation of the closure cap and can reasonably be represented by some manner of statistical distribution. This would tend to result in an increase in groundwater limits for the later time intervals. Consideration of this conservatism in the PA could help offset other negative consequences of the UDQE analysis.	ST, ET	N	↑
15	Area-based vs. volume based PORFLOW implementation of source distribution	The 2008 PA assigned inventory source by cell volume which created a slightly non-uniform areal distribution. The source was intended to be distributed by cell area, i.e., uniformly. A recent Interim Measures SA corrected limits to conform to this slight non-uniform source distribution for operating disposal units. The issue will be addressed in the ET#3 SA by changing PORFLOW input commands.	ST, ET	N	↔
16	Realization that non-crushable infiltration rates for ET's may differ from ST's	In the 2008 PA the infiltration rate for ETs under (partially) subsided conditions is based on a ST analysis, i.e., STs are used as a surrogate for ETs.	ET	N	↔
17	Realization that 2008 PA assumes 20-ft of undisturbed soil adjoining a trench segment	The 2008 PA considered 20-ft of undisturbed soil adjoining a trench segment. In reality the width of undisturbed soil is lower due to adjacent trench segments that are on the order of 14' apart which modestly reduces lateral infiltration into the waste zone.	ST	N	↔

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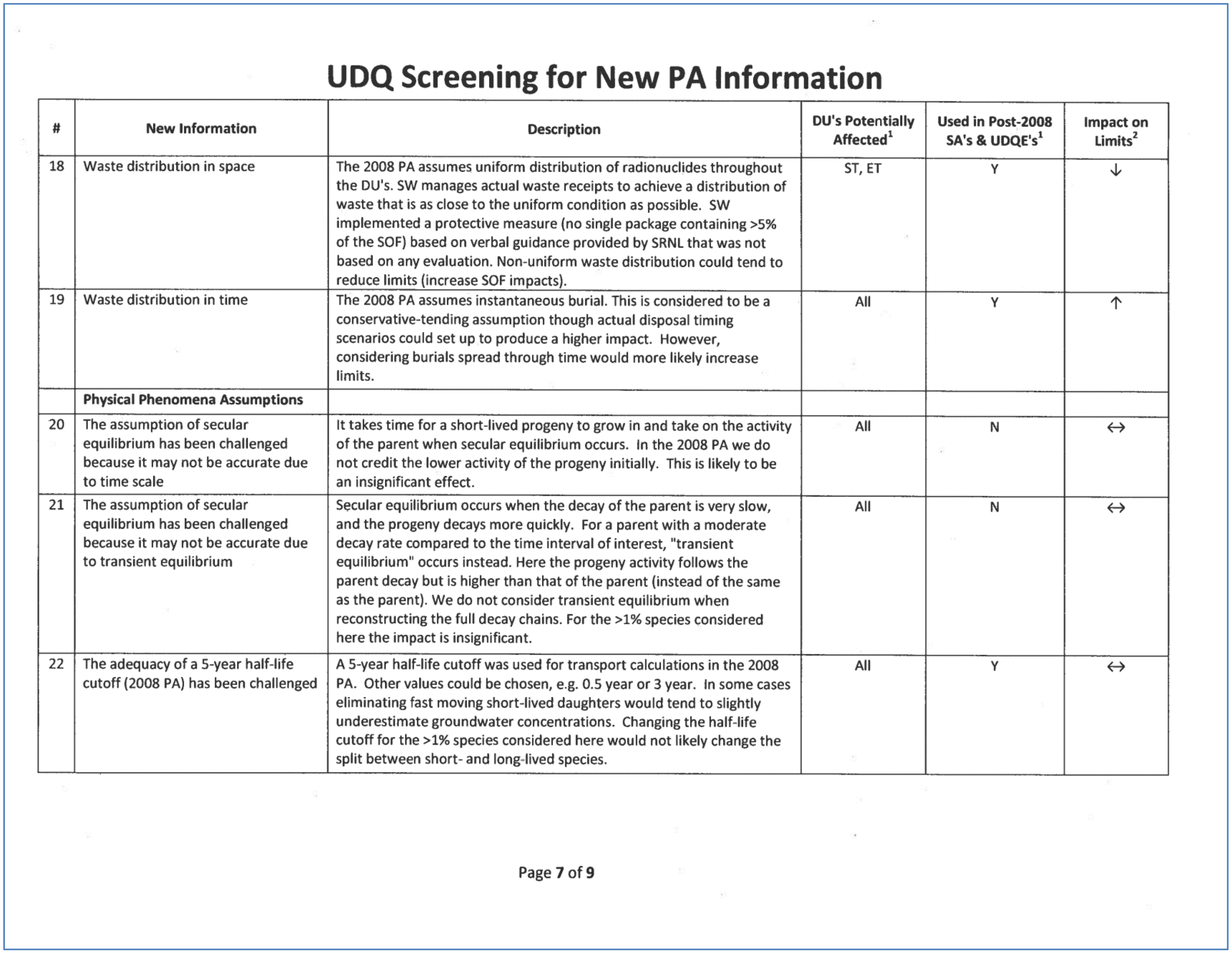
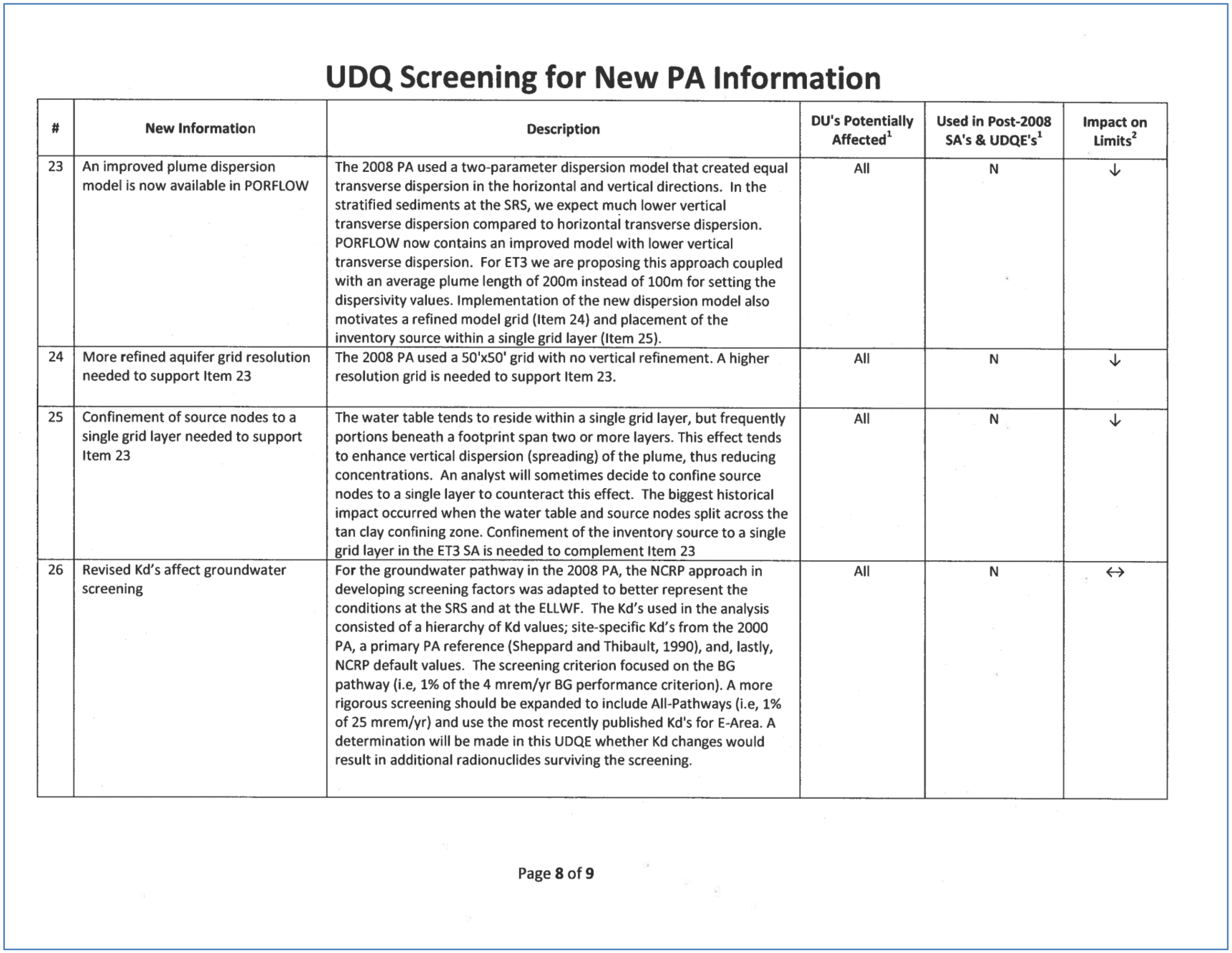


UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
18	Waste distribution in space	The 2008 PA assumes uniform distribution of radionuclides throughout the DU's. SW manages actual waste receipts to achieve a distribution of waste that is as close to the uniform condition as possible. SW implemented a protective measure (no single package containing >5% of the SOF) based on verbal guidance provided by SRNL that was not based on any evaluation. Non-uniform waste distribution could tend to reduce limits (increase SOF impacts).	ST, ET	Y	↓
19	Waste distribution in time	The 2008 PA assumes instantaneous burial. This is considered to be a conservative-tending assumption though actual disposal timing scenarios could set up to produce a higher impact. However, considering burials spread through time would more likely increase limits.	All	Y	↑
	Physical Phenomena Assumptions				
20	The assumption of secular equilibrium has been challenged because it may not be accurate due to time scale	It takes time for a short-lived progeny to grow in and take on the activity of the parent when secular equilibrium occurs. In the 2008 PA we do not credit the lower activity of the progeny initially. This is likely to be an insignificant effect.	All	N	↔
21	The assumption of secular equilibrium has been challenged because it may not be accurate due to transient equilibrium	Secular equilibrium occurs when the decay of the parent is very slow, and the progeny decays more quickly. For a parent with a moderate decay rate compared to the time interval of interest, "transient equilibrium" occurs instead. Here the progeny activity follows the parent decay but is higher than that of the parent (instead of the same as the parent). We do not consider transient equilibrium when reconstructing the full decay chains. For the >1% species considered here the impact is insignificant.	All	N	↔
22	The adequacy of a 5-year half-life cutoff (2008 PA) has been challenged	A 5-year half-life cutoff was used for transport calculations in the 2008 PA. Other values could be chosen, e.g. 0.5 year or 3 year. In some cases eliminating fast moving short-lived daughters would tend to slightly underestimate groundwater concentrations. Changing the half-life cutoff for the >1% species considered here would not likely change the split between short- and long-lived species.	All	Y	↔



UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
23	An improved plume dispersion model is now available in PORFLOW	The 2008 PA used a two-parameter dispersion model that created equal transverse dispersion in the horizontal and vertical directions. In the stratified sediments at the SRS, we expect much lower vertical transverse dispersion compared to horizontal transverse dispersion. PORFLOW now contains an improved model with lower vertical transverse dispersion. For ET3 we are proposing this approach coupled with an average plume length of 200m instead of 100m for setting the dispersivity values. Implementation of the new dispersion model also motivates a refined model grid (Item 24) and placement of the inventory source within a single grid layer (Item 25).	All	N	↓
24	More refined aquifer grid resolution needed to support Item 23	The 2008 PA used a 50'x50' grid with no vertical refinement. A higher resolution grid is needed to support Item 23.	All	N	↓
25	Confinement of source nodes to a single grid layer needed to support Item 23	The water table tends to reside within a single grid layer, but frequently portions beneath a footprint span two or more layers. This effect tends to enhance vertical dispersion (spreading) of the plume, thus reducing concentrations. An analyst will sometimes decide to confine source nodes to a single layer to counteract this effect. The biggest historical impact occurred when the water table and source nodes split across the tan clay confining zone. Confinement of the inventory source to a single grid layer in the ET3 SA is needed to complement Item 23	All	N	↓
26	Revised Kd's affect groundwater screening	For the groundwater pathway in the 2008 PA, the NCRP approach in developing screening factors was adapted to better represent the conditions at the SRS and at the ELLWF. The Kd's used in the analysis consisted of a hierarchy of Kd values; site-specific Kd's from the 2000 PA, a primary PA reference (Sheppard and Thibault, 1990), and, lastly, NCRP default values. The screening criterion focused on the BG pathway (i.e, 1% of the 4 mrem/yr BG performance criterion). A more rigorous screening should be expanded to include All-Pathways (i.e, 1% of 25 mrem/yr) and use the most recently published Kd's for E-Area. A determination will be made in this UDQE whether Kd changes would result in additional radionuclides surviving the screening.	All	N	↔

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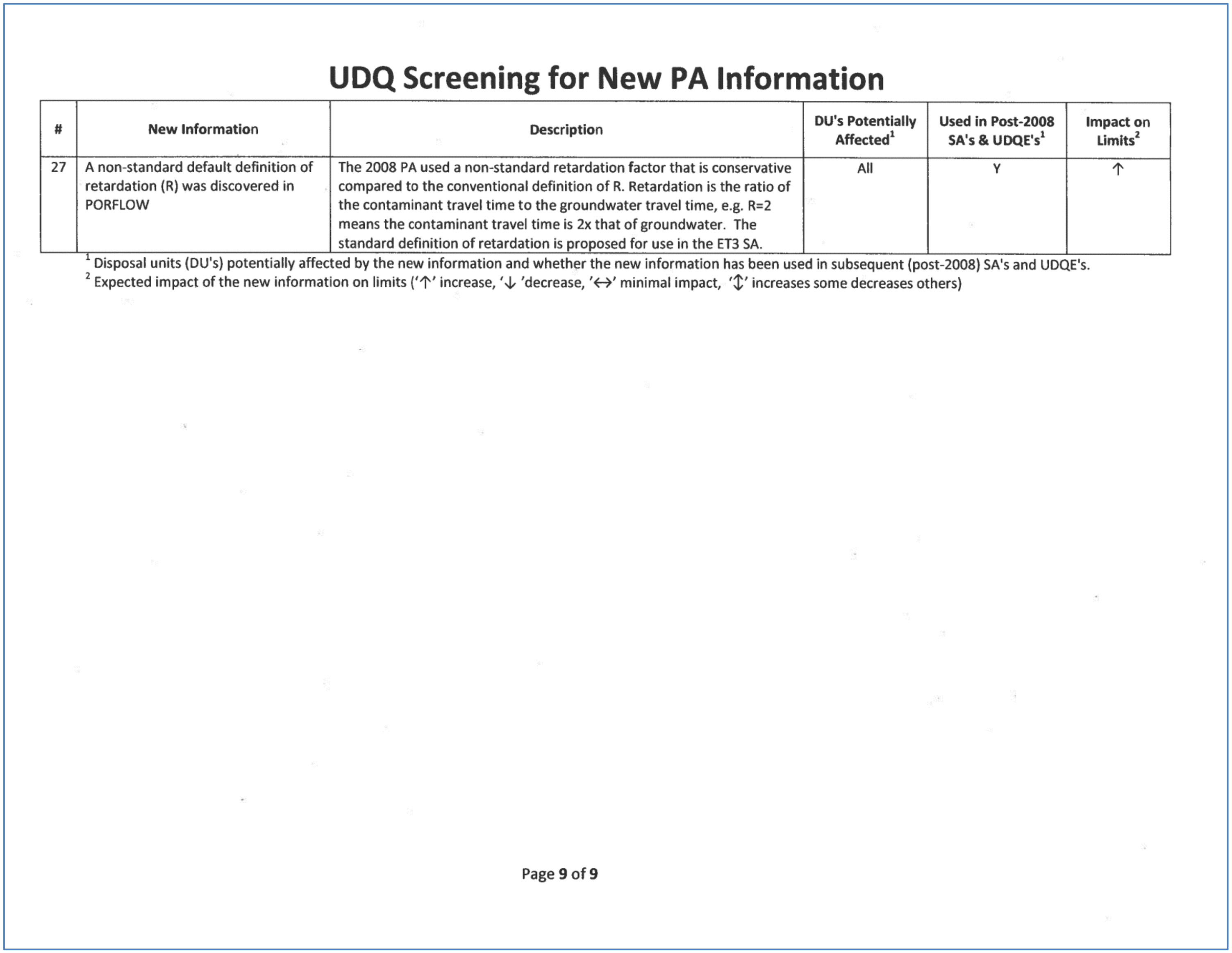

UDQ Screening for New PA Information

#	New Information	Description	DU's Potentially Affected[1]	Used in Post-2008 SA's & UDQE's[1]	Impact on Limits[2]
27	A non-standard default definition of retardation (R) was discovered in PORFLOW	The 2008 PA used a non-standard retardation factor that is conservative compared to the conventional definition of R. Retardation is the ratio of the contaminant travel time to the groundwater travel time, e.g. R=2 means the contaminant travel time is 2x that of groundwater. The standard definition of retardation is proposed for use in the ET3 SA.	All	Y	↑

[1] Disposal units (DU's) potentially affected by the new information and whether the new information has been used in subsequent (post-2008) SA's and UDQE's.

[2] Expected impact of the new information on limits ('↑' increase, '↓ 'decrease, '↔' minimal impact, '↕' increases some decreases others)

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Distribution:

R. S. Aylward, 773-42A
B. T. Butcher, 773-43A
D. A. Crowley, 773-43A
G. P. Flach, 773-42A
F. L. Fox, Jr, 704-59E
J. C. Griffin, 773-A
L. L. Hamm, 773-42A
R. A. Hiergesell, 773-43A
G. K. Humphries, 730-4B
J. M. Jordan, 703-41A
D. I. Kaplan, 773-43A
T. F. Kmetz, 730-4B
D. Li, 999-W
M. G. Looper, 707-F
S. L. Marra, 773-A
J. L. Mooneyhan, 704-60E
T. O. Oliver, 773-42A
M. A. Phifer, 773-42A
K. A. Roberts, 773-43A
R. R. Seitz, 773-43A
D. F. Sink, 704-56E
F. G. Smith, III 773-42A
G. A. Taylor, 773-43A
K. L. Tempel, 704-56E
D. H. Turno, 704-60E
T. S. Whiteside, 773-42A
C. Wilson (1 file copy & 1 electronic copy), 773-43A - Rm.213