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UNREVIEWED DISPOSAL QUESTION EVALUATION: Disposal of the Idaho Nuclear Technology and Engineering Center Mixed Low-Level Waste Requiring Macroencapsulation at the Area 5 Radioactive Waste Management Site, Nevada National Security Site, Nye County, Nevada

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Prepared by

Mission Support and Test Services, LLC
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Acronyms and Abbreviations

BN	Bechtel Nevada
Bq	becquerel
Bq m^{-3}	becquerel per cubic meter
Bq m^{-2} s^{-1}	becquerel per square meter per second
Cs	cesium
DOE	U.S. Department of Energy
FY	(Federal) fiscal year
GM	geometric mean
GSD	geometric standard deviation
Ho	holmium
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
K	potassium
LHS	Latin hypercube sample
m	meter(s)
m^3	cubic meter
MLLW	mixed low-level waste
mSv	millisievert(s)
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
PA	performance assessment
Rn	radon
RWMS	Radioactive Waste Management Site
SLB	shallow land burial
SOFs	sum of fractions
Sr	strontium
TED	total equivalent dose
UDQE	unreviewed disposal question evaluation

WAC	Waste Acceptance Criteria
y	years

1.0 Executive Summary

This Unreviewed Disposal Question Evaluation (UDQE) assesses whether the Idaho National Laboratory (INL), Idaho Nuclear Technology and Engineering Center (INTEC) Mixed Low-Level Waste (MLLW) requiring macroencapsulation (INEL166322NR1, Revision 0 [INL 2019]) is suitable for shallow land burial (SLB) at the Area 5 Radioactive Waste Management Site (RWMS) on the Nevada National Security Site (NNSS). Disposal of the INTEC MLLW requiring macroencapsulation waste stream meets all the performance objectives contained in U.S. Department of Energy (DOE) Manual DOE M 435.1-1, "Radioactive Waste Management Manual," Chapter IV, Section P (DOE 2011). The INTEC MLLW requiring macroencapsulation waste stream is recommended for acceptance without conditions.

2.0 Introduction

This UDQE addresses disposal of the INTEC MLLW requiring macroencapsulation waste stream at the Area 5 RWMS on the NNSS. The waste stream requires a UDQE because the waste stream NNSS Waste Acceptance Criteria (WAC) Action Level sum of fractions (SOFs) is greater than 1.0 (U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office [NNSA/NFO] 2016). The major radionuclides contributing to the SOFs are potassium-40 (^{40}K), strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), and holmium-166m (^{166m}Ho).

3.0 Analysis of Performance

The UDQE addresses the long-term performance of the Area 5 RWMS with the INTEC MLLW requiring macroencapsulation waste stream disposed in a SLB disposal cell.

3.1 Waste Description

This waste stream consists of macroencapsulated MLLW debris waste generated by maintenance, operations, deactivation, decontamination and decommissioning, and repackaging activities at the INTEC facility (INL 2019). The debris waste forms include filters, metal, plastic, glass, wood, personnel protective equipment, non-biodegradable absorbents, soil, and sweepings.

The waste stream radionuclide activities are assumed to be lognormally distributed. The geometric mean (GM) of the distribution is assumed to be the product of the representative activity concentration and the total remaining volume, 204 cubic meters (m^3), as reported on the waste profile (INL 2019, Section D.5) (Table 1).

Table 1. INTEC MLLW requiring Macroencapsulation Activity Concentration and Total Activity at the Time of Disposal Assumed for Performance Assessment Modeling

Nuclide	GM Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	GM Activity (Bq)	95th Percentile Activity (Bq)	GSD
^{227}Ac	2.0E+05	3.0E+06	2.6E+07	3.9E+08	5.16
^{108m}Ag	3.0E+06	4.0E+07	3.9E+08	5.2E+09	4.81
^{241}Am	2.0E+09	3.0E+10	2.6E+11	3.9E+12	5.16
^{242m}Am	8.1E+04	2.4E+05	1.1E+07	3.2E+07	1.95
^{243}Am	4.0E+06	5.0E+07	8.2E+08	1.0E+10	4.62
^{133}Ba	3.0E+02	5.0E+03	3.9E+04	6.5E+05	5.50

Nuclide	GM Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	GM Activity (Bq)	95th Percentile Activity (Bq)	GSD
^{207}Bi	1.0E-02	2.0E-01	1.3E+00	2.6E+01	6.14
^{14}C	1.0E+07	2.0E+08	1.3E+09	2.6E+10	6.14
^{113m}Cd	6.0E+07	8.0E+08	7.8E+09	1.0E+11	4.81
^{36}Cl	4.0E+03	6.0E+04	5.2E+05	7.8E+06	5.16
^{243}Cm	1.0E+06	2.0E+07	1.3E+08	2.6E+09	6.14
^{244}Cm	4.0E+08	5.0E+09	5.2E+10	6.5E+11	4.62
^{245}Cm	4.0E+06	5.0E+07	5.2E+08	6.5E+09	4.62
^{248}Cm	3.0E-04	4.0E-03	3.9E-02	5.2E-01	4.81
^{60}Co	2.0E+10	3.0E+11	2.6E+12	3.9E+13	5.16
^{135}Cs	1.0E+07	2.0E+08	1.3E+09	2.6E+10	6.14
^{137}Cs	1.5E+11	1.2E+13	3.0E+13	2.3E+15	13.99
^{152}Eu	5.0E+08	7.0E+09	6.5E+10	9.1E+11	4.95
^{154}Eu	6.0E+10	8.0E+11	7.8E+12	1.0E+14	4.81
^{3}H	1.0E+09	2.0E+10	1.3E+11	2.6E+12	6.14
^{166m}Ho	4.0E+09	6.0E+10	8.2E+11	1.2E+13	5.16
^{129}I	1.0E+08	2.0E+09	1.3E+10	2.6E+11	6.14
^{40}K	7.0E+10	1.0E+12	1.4E+13	2.0E+14	5.01
^{85}Kr	1.0E+13	2.0E+14	1.3E+15	2.6E+16	6.14
^{93m}Nb	2.0E+07	3.0E+08	2.6E+09	3.9E+10	5.16
^{94}Nb	2.0E+07	3.0E+08	2.6E+09	3.9E+10	5.16
^{59}Ni	4.0E+08	6.0E+09	5.2E+10	7.8E+11	5.16
^{63}Ni	4.0E+10	6.0E+11	5.2E+12	7.8E+13	5.16
^{237}Np	3.4E+08	1.0E+09	4.4E+10	1.3E+11	1.95
^{231}Pa	7.0E+05	9.0E+06	9.1E+07	1.2E+09	4.70
^{210}Pb	1.0E+04	2.0E+05	1.3E+06	2.6E+07	6.14
^{107}Pd	2.0E+05	3.0E+06	2.6E+07	3.9E+08	5.16
^{146}Pm	1.0E+06	2.0E+07	1.3E+08	2.6E+09	6.14
^{238}Pu	2.4E+09	7.1E+09	3.1E+11	9.2E+11	1.95
^{239}Pu	1.2E+09	3.6E+09	1.6E+11	4.7E+11	1.95
^{240}Pu	1.1E+08	3.4E+08	1.5E+10	4.5E+10	1.95
^{241}Pu	3.2E+08	5.0E+09	4.1E+10	6.5E+11	5.31
^{242}Pu	1.4E+06	4.1E+06	1.8E+08	5.3E+08	1.95
^{226}Ra	3.2E-02	9.6E-02	4.1E+00	1.2E+01	1.95
^{87}Rb	4.0E+09	6.0E+10	5.2E+11	7.8E+12	5.16
^{79}Se	6.0E+06	8.0E+07	7.8E+08	1.0E+10	4.81
^{151}Sm	5.0E+09	7.0E+10	6.5E+11	9.1E+12	4.95
^{121m}Sn	1.0E+06	2.0E+07	1.3E+08	2.6E+09	6.14
^{126}Sn	6.0E+06	8.0E+07	7.8E+08	1.0E+10	4.81

Nuclide	GM Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	GM Activity (Bq)	95th Percentile Activity (Bq)	GSD
^{90}Sr	1.5E+11	4.4E+11	3.0E+13	9.0E+13	1.94
^{99}Tc	2.0E+08	3.0E+09	2.6E+10	3.9E+11	5.16
^{229}Th	7.0E+02	9.0E+03	9.1E+04	1.2E+06	4.70
^{230}Th	2.0E+06	3.0E+07	2.6E+08	3.9E+09	5.16
^{232}Th	3.0E+05	4.0E+06	3.9E+07	5.2E+08	4.81
^{232}U	3.0E+07	4.0E+08	3.9E+09	5.2E+10	4.81
^{233}U	4.7E+06	1.4E+07	6.1E+08	1.8E+09	1.94
^{234}U	1.9E+06	5.6E+06	2.4E+08	7.3E+08	1.95
^{235}U	2.0E+08	3.0E+09	2.6E+10	3.9E+11	5.16
^{236}U	4.0E+07	6.0E+08	5.2E+09	7.8E+10	5.16
^{238}U	4.0E+07	5.0E+08	5.2E+09	6.5E+10	4.62
^{93}Zr	2.0E+08	3.0E+09	2.6E+10	3.9E+11	5.16

*GM = geometric mean
**GSD = geometric standard deviation

The high activity concentration is assumed to be the 95th percentile of the lognormal distribution. The geometric standard deviation of the lognormal distribution is calculated as:

$$GSD = e^{\frac{\ln(UL) - \ln(GM)}{1.65}}$$

where

GSD	=	geometric standard deviation (dimensionless)
UL	=	95th percentile activity, Bq
GM	=	geometric mean, Bq

The INTEC MLLW requiring macroencapsulation waste stream required a UDQE because the waste stream SOFs is greater than 1.0. Addition of the waste stream has a negligible impact on the fiscal year (FY) 2018 SLB SOFs (Table 2). Large relative increases are expected for the inventories of ^{40}K and ^{166m}Ho. Neither radionuclide is a key radionuclide with respect to disposal site performance.

Table 2. Expected Increase in the Area 5 RWMS SOFs and the Inventory of Radionuclides Contributing Significantly to the SOFs

Nuclide	FY 2018 SLB Disposed Geometric Mean Inventory	Geometric Mean INEL166322NR1_0 Inventory	Relative Percent Change
^{40}K	3.8E+10 Bq	9.1E+12 Bq	2.4E4
^{90}Sr	4.3E+16 Bq	1.9E+13 Bq	0.04
^{137}Cs	7.8E+15 Bq	1.9E+13 Bq	0.2
^{166m}Ho	6.3E+08 Bq	5.2E+11 Bq	8.3E4

Nuclide	FY 2018 SLB Disposed Geometric Mean Inventory	Geometric Mean INEL166322NR1_0 Inventory	Relative Percent Change
SLB SOFs	0.88	0.88	0.1

3.2 Performance Assessment Modeling

The performance assessment (PA) modeling adds the inventory of the INTEC MLLW requiring macroencapsulation waste stream to the Area 5 RWMS v4.203b model and determines if there is a reasonable expectation of meeting the performance objectives contained in DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual," Chapter IV, Section P (DOE 2011). The PA model evaluates the INTEC MLLW requiring macroencapsulation waste radionuclide activity added to the inventory of post-1988 SLB waste disposed through FY 2018. The UDQE inventory also includes the Pit 6, Pit 13, and post-1988 Greater Confinement Disposal borehole inventories. The model is run with a 2.5-meter (m) closure cover for SLB disposal units.

The mean and median model results are calculated using 5,000 Latin hypercube samples (LHS). A sample size of 5,000 provides stable estimates of the mean and 95th percentile results of the PA model (Bechtel Nevada [BN] 2006). A reasonable expectation of compliance with the performance objectives is assumed if the mean and median are less than the performance objectives for 1,000 years after closure. In every case, the mean was greater than the median. The UDQE only reports the mean results.

For comparison purposes, baseline results are obtained by running the model with the inventory disposed through FY 2018 and without the INTEC MLLW requiring macroencapsulation waste stream.

4.0 Results and Interpretation

4.1 Performance Assessment Results

4.1.1 Air Pathway Results

The air pathway annual total equivalent dose (TED) is evaluated for the resident exposure scenario using 5,000 LHS realizations. The resident exposure scenario estimates the dose to an adult residing in a home at the 100-m Area 5 RWMS boundary. A complete description of the exposure scenario can be found in the earlier PA documentation (BN 2006).

The annual TED is calculated for a period of 1,000 years after closure. The maximum mean and 95th percentile annual TED occur at 1,000 years and are both less than the 0.1 millisievert (mSv) limit (Table 3). Addition of the INTEC MLLW has no significant effect on the maximum resident air pathway TED at 1,000 years.

Table 3. Maximum Air Pathway Annual TED for a Resident at the Area 5 RWMS 100-m Site Boundary and the Waste Inventory Disposed through FY 2018

Scenario	Time of Maximum (years after closure)	Mean (mSv)	95th Percentile (mSv)
Resident without INEL166322NR1_0 Waste Stream	1,000	1.8E-4	6.2E-4
Resident with INEL166322NR1_0 Waste Stream	1,000	1.8E-4	6.2E-4

Addition of the INTEC MLLW increases the air pathways mean annual TED slightly throughout the compliance period (Figure 1). The maximum relative increase, 0.6%, occurs at 260 years and decreases thereafter.

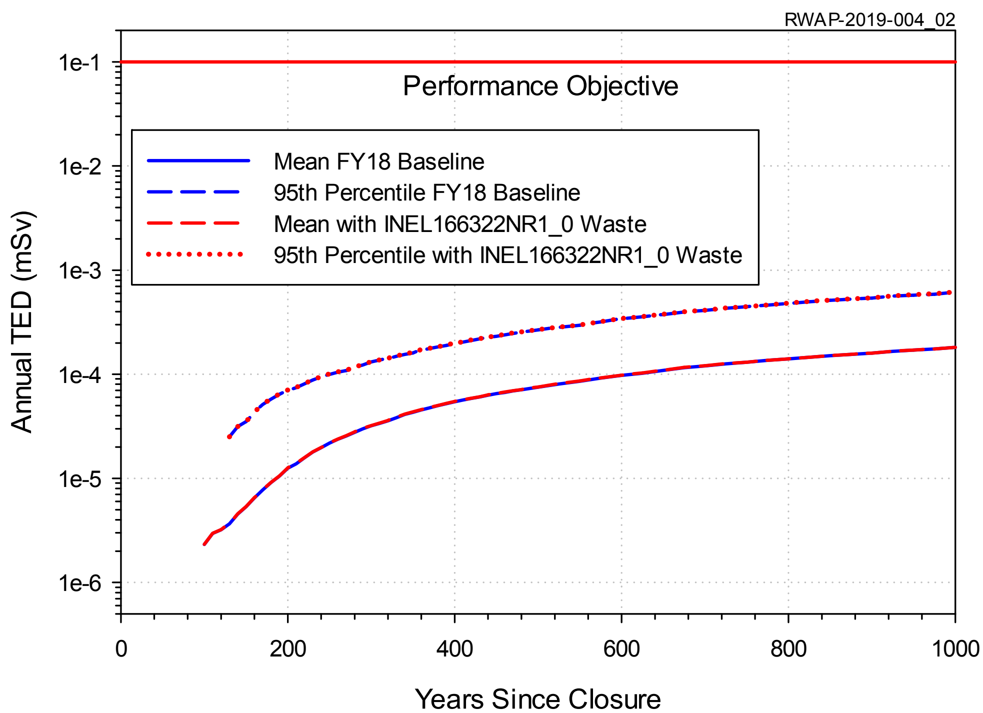

Figure 1. Air Pathway Annual TED Time History for a Resident at the 100-m Boundary with and without the INEL166322NR1_0 Waste Stream

4.1.1.1 Alternative Air Pathway Scenarios

Uncertainty contributed by the selected exposure scenario was evaluated by calculating the air pathway annual TED for alternative scenarios. The scenarios evaluated are the transient occupancy scenario, the resident with agriculture scenario, and open rangeland scenarios for a ranch at two plausible locations: one at the NNSS boundary closest to the Area 5 RWMS and another at Cane Spring. The scenarios and their assumptions are described in the PA (BN 2006).

The maximum of the mean and the 95th percentile TEDs are all less than the performance objective for all of the alternative scenarios (Table 4). Although the exposure scenario is a source of uncertainty, there is a high likelihood of compliance for a range of reasonable scenarios.

Addition of the INTEC MLLW requiring macroencapsulation waste stream has no significant effect on the maximum result for all scenarios.

Table 4. Maximum Air Pathway Annual TEDs for Alternative Scenarios with the FY 2018 Inventory

Scenario	Inventory	Time of Maximum (years after closure)	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2018 Baseline Inventory	1,000	7.3E-5	2.5E-4
	FY 2018 with INEL166322NR1_0	1,000	7.3E-5	2.5E-4
Resident with Agriculture	FY 2018 Baseline Inventory	1,000	3.9E-4	1.3E-3
	FY 2018 with INEL166322NR1_0	1,000	3.9E-4	1.3E-3
Open Rangeland/Cane Spring	FY 2018 Baseline Inventory	1,000	6.3E-9	1.5E-8
	FY 2018 with INEL166322NR1_0	1,000	6.3E-9	1.5E-8
Open Rangeland/NNSS Boundary	FY 2018 Baseline Inventory	1,000	1.1E-7	2.6E-7
	FY 2018 with INEL166322NR1_0	1,000	1.1E-7	2.6E-7

4.1.2 All-Pathways Results

The all-pathways annual TED is also calculated for the resident exposure scenario. The maximum mean and 95th percentile resident all-pathways annual TEDs are less than the 0.25 mSv limit (Table 5). Addition of INTEC MLLW waste stream increases the maximum resident all-pathways annual TED.

Table 5. Maximum All-Pathways Annual TED for a Resident at the Area 5 RWMS 100-m Site Boundary and the Waste Inventory Disposed through FY 2018

Scenario	Time of Maximum (years after Closure)	Mean (mSv)	95th Percentile (mSv)
Resident without INEL166322NR1_0 Waste Stream	1,000	1.0E-3	2.7E-3
Resident with INEL166322NR1_0Waste Stream	1,000	1.2E-3	3.6E-3

Addition of the INTEC MLLW waste stream increases the all-pathways TED throughout the compliance period. The maximum increase in the all-pathways annual TED is 18% at 825 years

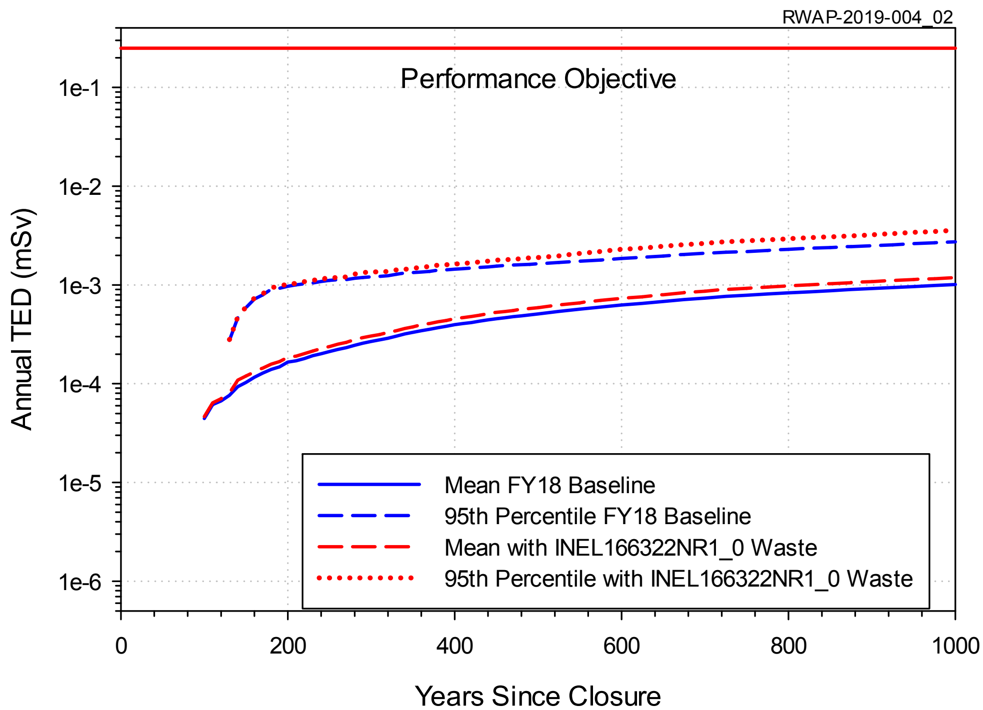

Figure 2. All-Pathways Annual TED Time History for a Resident at the 100-m Boundary with and without INEL166322NR1_0 Waste Stream

4.1.2.1 Alternative All-Pathways Scenarios

Uncertainty contributed by the selected exposure scenarios was evaluated by calculating the all-pathways annual TED for alternative scenarios. The mean and 95th percentile all-pathways annual TEDs are all less than the performance objective for all alternative scenarios (Table 6). Although the exposure scenario is a source of uncertainty, there is a high likelihood of compliance for a range of reasonable scenarios. Addition of the INTEC MLLW requiring macroencapsulation waste stream has no significant effect on the maximum annual TED for all scenarios.

Table 6. Maximum All-Pathways Annual TEDs for Alternative Scenarios with the FY 2018 Inventory

Scenario	Inventory	Time of Maximum (years after closure)	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2018 Baseline Inventory	1,000	6.3E-3	1.6E-2
	FY 2018 with INEL166322NR1_0	1,000	6.4E-3	1.5E-2
Resident with Agriculture	FY 2018 Baseline Inventory	1,000	2.6E-2	8.3E-2
	FY 2018 with INEL166322NR1_0	1,000	2.6E-2	8.3E-2
Open Rangeland/Cane Spring	FY 2018 Baseline Inventory	1,000	4.6E-3	1.6E-2
	FY 2018 with INEL166322NR1_0	1,000	4.6E-3	1.6E-2
Open Rangeland/NNSS Boundary	FY 2018 Baseline Inventory	1,000	4.8E-3	1.7E-2
	FY 2018 with INEL166322NR1_0	1,000	4.8E-3	1.7E-2

4.1.3 Intruder Results

Intruder results are evaluated for acute intruder scenarios only. NNSA/NFO institutional control policy is to maintain and enforce use restrictions (NNSA/NFO 2015). The proposed land-use restrictions are assumed to eliminate the possibility of chronic intrusion for 1,000 years.

The acute drilling scenario estimates the TED to a drill crew drilling a water well through a disposal unit. Exposure to contaminated drill cuttings occurs while augering a surface casing for the well. The acute construction scenario estimates the dose to construction workers building a residence on a disposal unit. Construction workers are exposed to waste exhumed from the construction excavation.

The maximum mean acute intruder TEDs occur at 1,000 years and are less than the 5 mSv performance measure for both the drilling and construction acute intrusion scenarios (Table 7). Addition of the INTEC MLLW requiring macroencapsulation waste stream increases the maximum acute intruder scenario mean results occurring at 1,000 years.

Table 7. Maximum TED for Acute Intrusion Scenarios at the Area 5 RWMS and the Waste Inventory Disposed through FY 2018

Scenario	Time of Maximum (years after closure)	Mean (mSv)	95th Percentile (mSv)
Drilling Intruder without INEL166322NR1_0	1,000	1.4E-3	2.4E-3
Drilling Intruder with INEL166322NR1_0	1,000	1.7E-3	3.1E-3
Construction Intruder without INEL166322NR1_0	1,000	1.0	1.8
Construction Intruder with INEL166322NR1_0	1,000	1.3	2.3

Addition of the INTEC MLLW requiring macroencapsulation waste stream increases the mean TED less than 28% at 370 years (Figure 3).

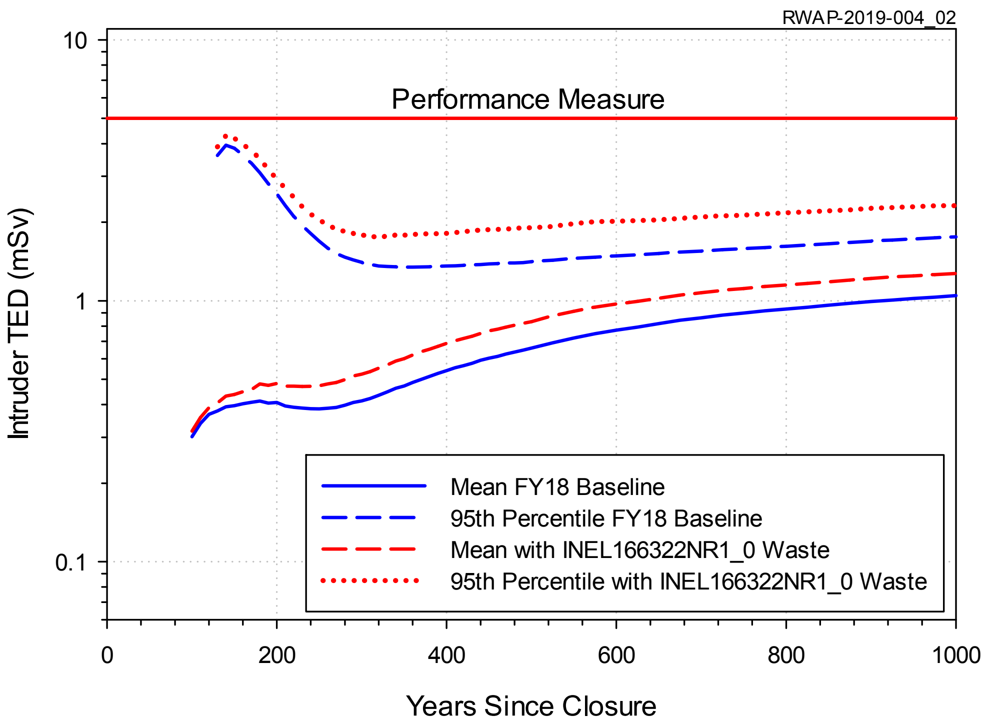

Figure 3. Acute Construction Intrusion Scenario TED Time History with and without the INEL166322NR1_0 Waste Stream

4.1.4 ^{222}Rn Flux Density Results

The radon-222 (^{222}Rn) flux density is averaged over the area of all post-1988 disposal units. The maximum mean and 95th percentile ^{222}Rn flux densities occur at 1,000 years and are less than the 0.74 becquerel per square meter per second (Bq m^{-2} s^{-1}) performance objective (Table 8).

Addition of the INTEC MLLW requiring macroencapsulation waste stream has no significant effect on the maximum ^{222}Rn flux density at 1,000 years. This waste stream does not require an increased depth of burial to attenuate ^{222}Rn flux.

Table 8. Maximum ^{222}Rn Flux Density at the Area 5 RWMS and the Waste Inventory Disposed through FY 2018

Inventory	Time of Maximum (years after closure)	Mean (Bq m^{-2} s^{-1})	95th Percentile (Bq m^{-2} s^{-1})
FY 2018 without INEL166322NR1_0	1,000	0.22	0.48
FY 2018 with INEL166322NR1_0	1,000	0.22	0.48

Addition of the INTEC MLLW requiring macroencapsulation waste stream has no significant effect on the mean ^{222}Rn flux density throughout the compliance period (Figure 4).

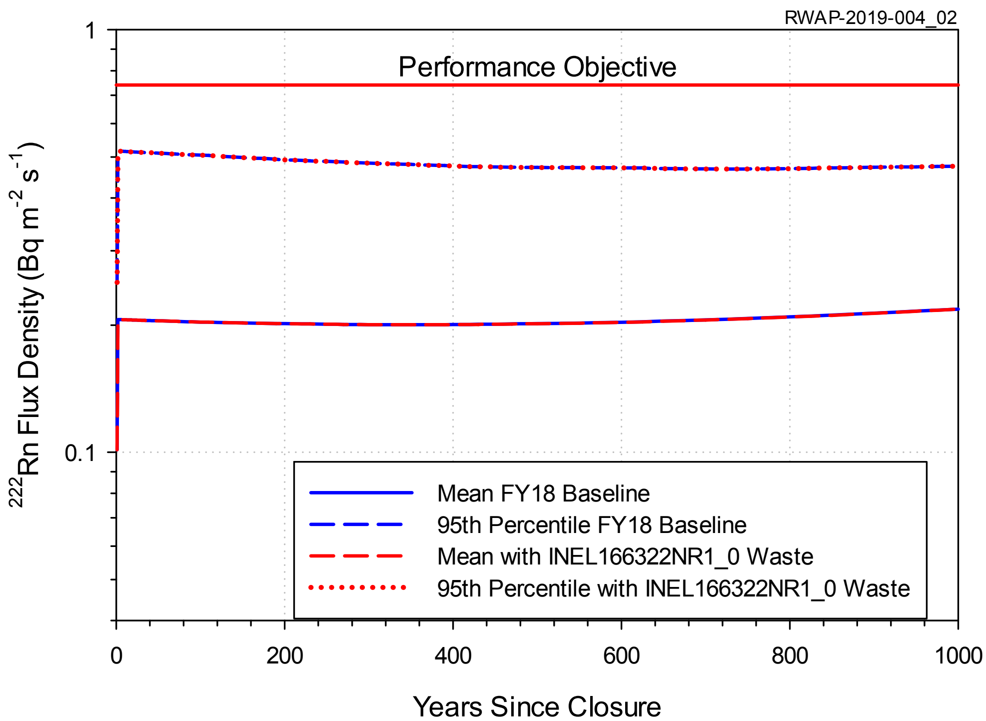

Figure 4. ^{222}Rn Flux Density Time History with and without the INEL166322NR1_0 Waste Stream

5.0 Conclusions

The effect of adding the INTEC MLLW requiring macroencapsulation waste stream to the inventory of waste disposed through the end of FY 2018 was evaluated with the Area 5 RWMS v 4.203b PA model. The results indicate that all performance objectives can be met with disposal of the INTEC MLLW requiring macroencapsulation waste in an Area 5 RWMS SLB unit. Addition of the waste stream inventory slightly increases the all-pathways annual TED and the acute intrusion TED. All maximum mean and 95th percentile results remain less than their respective performance objectives throughout the compliance period. No result exceeds the Low-Level Radioactive Waste Review Group notification criterion of exceeding 50% of a performance objective. The INTEC MLLW requiring macroencapsulation waste stream is acceptable for disposal without conditions.

6.0 References

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BN, see Bechtel Nevada.

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