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UNREVIEWED DISPOSAL QUESTION EVALUATION: Disposal of the Idaho National Laboratory Classified Mockup Low-Level Waste 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
INL	Idaho National Laboratory
LHS	Latin hypercube sample
LLW	low-level waste
m	meter(s)
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 effective dose
UDQE	unreviewed disposal question evaluation
UL	upper limit
WAC	Waste Acceptance Criteria
y	years

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1.0 Executive Summary

This Unreviewed Disposal Question Evaluation (UDQE) assesses whether the Idaho National Laboratory (INL) Classified Mockup Low-Level Waste (LLW) (INEL208599QR0, Revision 0 [INL 2020]) 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 INL Classified Mockup LLW meets all performance objectives of U.S. Department of Energy (DOE) Manual DOE M 435.1-1, *Radioactive Waste Management Manual*, Chapter IV, Section P (DOE 1999). The INL Classified Mockup LLW stream is recommended for acceptance without conditions.

2.0 Introduction

This UDQE addresses disposal of the INL Classified Mockup LLW at the Area 5 RWMS on the NNSS. The waste stream requires a UDQE because the waste stream sum of fractions (SOFs) exceeds 1.0. Although no individual radionuclide concentration exceeds the NNSS Waste Acceptance Criteria (WAC) Action Levels, strontium-90 (^{90}Sr) and cesium-137 (^{137}Cs) contribute 98% of the SOFs (U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office [NNSA/NFO] 2016).

3.0 Analysis of Performance

The UDQE addresses the long-term performance of the Area 5 RWMS with the INL Classified Mockup LLW disposed in a SLB disposal cell.

3.1 Waste Description

The INL Classified Mockup LLW stream consists of radioactively contaminated classified LLW and irradiated metals associated with the Idaho Nuclear Technology and Engineering Center (INTEC) fuel storage pool (INL 2020). The waste stream consists of a mockup apparatus used to train operators for removal of spent fuel from the storage pool and other co-mingled radioactive waste. The waste stream includes no spent nuclear fuel, fuel fragments, beryllium or graphite.

The INL Classified Mockup LLW radionuclide activities are assumed to be lognormally distributed. The geometric mean of the distribution is assumed to be the product of the representative activity concentration and the total remaining volume, 40 m^3, as reported on the waste profile (INL 2020, Section D.5) (Table 1).

Table 1. INL Classified Mockup LLW 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‡
^{241}Am	8.0E+07	3.0E+08	3.2E+09	1.2E+10	2.23
^{244}Cm	3.0E+05	8.0E+05	1.2E+07	3.2E+07	1.81
^{60}Co	1.0E+07	4.0E+07	4.0E+08	1.6E+09	2.32
^{137}Cs	2.0E+11	4.0E+11	8.0E+12	1.6E+13	1.52
^{154}Eu	5.0E+08	2.0E+09	2.0E+10	8.0E+10	2.32
^{238}Pu	8.0E+08	3.0E+09	3.2E+10	1.2E+11	2.23

Nuclide	GM† Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	GM Activity (Bq)	95th Percentile Activity (Bq)	GSD‡
^{239}Pu	6.0E+07	2.0E+08	2.4E+09	8.0E+09	2.07
^{240}Pu	1.0E+07	3.0E+07	4.0E+08	1.2E+09	1.95
^{241}Pu	5.0E+08	2.0E+09	2.0E+10	8.0E+10	2.32
^{242}Pu	7.0E+03	2.0E+04	2.8E+05	8.0E+05	1.89
^{151}Sm	1.0E+09	3.0E+09	4.0E+10	1.2E+11	1.95
^{90}Sr	1.0E+11	4.0E+11	4.0E+12	1.6E+13	2.32
^{99}Tc	9.0E+06	3.0E+07	3.6E+08	1.2E+09	2.07
^{233}U	1.0E+09	4.0E+09	4.0E+10	1.6E+11	2.32
^{234}U	6.0E+07	2.0E+08	2.4E+09	8.0E+09	2.07
^{235}U	2.0E+06	5.0E+06	8.0E+07	2.0E+08	1.74
^{238}U	2.0E+04	5.0E+04	8.0E+05	2.0E+06	1.74

† GM – geometric mean
‡ GSD – geometric standard deviation

The high activity concentration (upper limit, *UL*) 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 INL Classified Mockup LLW, revision 0, required a UDQE because the waste stream SOFs is greater than 1.0. The INL Classified Mockup LLW slightly increases the ^{90}Sr and ^{137}Cs inventory (Table 2).

Table 2. Expected Increase in the Disposed Inventory of Radionuclides Exceeding Their Action Levels and the Area 5 RWMS SOFs at Closure (10/1/2028)

Nuclide	FY 2020* SLB Disposed GM Inventory	INEL208599QR0_0 GM Inventory	Relative Percent Change
^{90}Sr	2.9E+15 Bq	4.0E+12 Bq	0.1
^{137}Cs	2.7E+15 Bq	8.0E+12 Bq	0.3
SLB SOFs	0.80	0.80	<1E-02

*FY – fiscal year

3.2 Performance Assessment Modeling

The performance assessment (PA) modeling adds the inventory of the INL Classified Mockup LLW stream to the Area 5 RWMS v4.208ba model and determines if there is a reasonable expectation of meeting the performance objectives of DOE M 435.1-1, *Radioactive Waste*

Management Manual, Chapter IV, Section P (DOE 1999). The PA model evaluates the INL Classified Mockup LLW stream radionuclide activity added to the inventory of post-1988 SLB waste disposed through FY 2020. 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 2020 and without the INL Classified Mockup LLW.

4.0 Results and Interpretation

4.1 Performance Assessment Results

4.1.1 Air Pathway Results

The air pathway annual total effective dose (TED) is evaluated for the resident exposure scenario using 5,000 LHS realizations. The resident exposure scenario estimates the dose to a representative person 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 INL Classified Mockup LLW has no significant effect on the maximum resident air pathway TED.

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 2020

Scenario	Time of Maximum†	Mean (mSv)	95th Percentile (mSv)
Resident without INEL208599QR0_0 Waste Stream	1,000 y	1.4E-4	4.4E-4
Resident with INEL208599QR0_0 Waste Stream	1,000 y	1.4E-4	4.4E-4

† - years after closure

Addition of the INL Classified Mockup LLW has no significant impact on the air pathway TED throughout the compliance period (Figure 1).

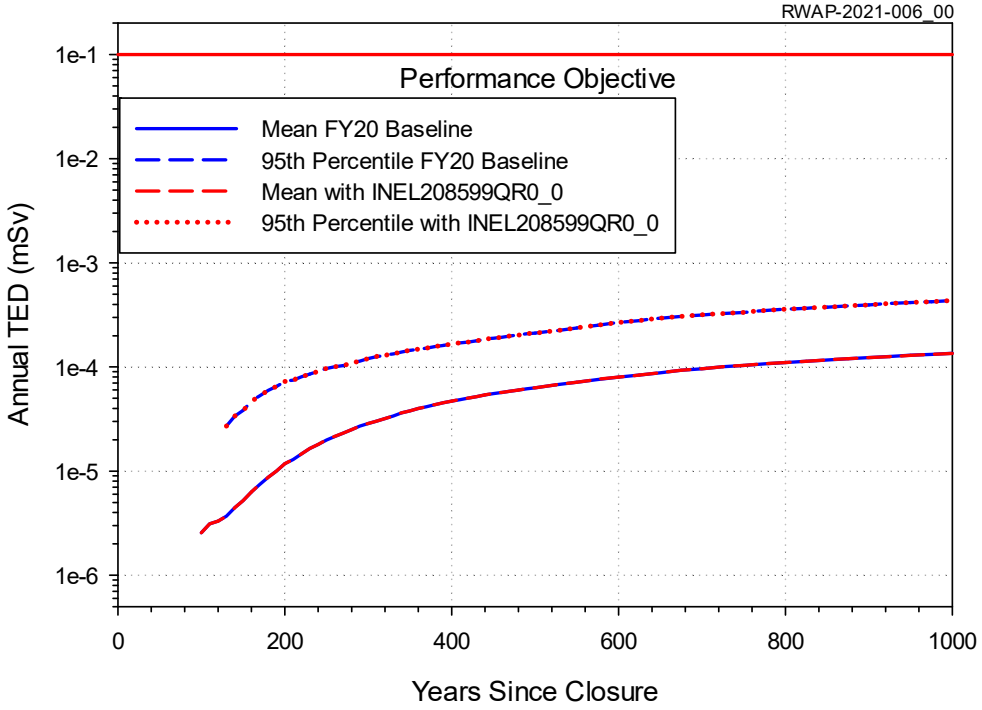

Figure 1. Air Pathway Annual TED Time History for a Resident at the 100-m Boundary with and without the INEL208599QR0_0 Waste Stream

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 INL Classified Mockup LLW has no significant effect on the maximum result for all scenarios.

Table 4. Maximum Air Pathway Annual TEDs for Alternative Scenarios with the FY 2020 Inventory

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2020 Baseline Inventory	1,000 y	5.5E-5	1.8E-4
	FY 2020 with INEL208599QR0_0	1,000 y	5.5E-5	1.8E-4
Resident with Agriculture	FY 2020 Baseline Inventory	1,000 y	2.9E-4	9.6E-4
	FY 2020 with INEL208599QR0_0	1,000 y	2.9E-4	9.6E-4
Open Rangeland/Cane Spring	FY 2020 Baseline Inventory	1,000 y	4.1E-9	1.1E-8
	FY 2020 with INEL208599QR0_0	1,000 y	4.1E-9	1.1E-8
Open Rangeland/NNSS Boundary	FY 2020 Baseline Inventory	1,000 y	7.0E-8	1.9E-7
	FY 2020 with INEL208599QR0_0	1,000 y	7.0E-8	1.9E-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 the INL Classified Mockup LLW has no significant effect on 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 2020

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Resident without INEL208599QR0_0 Waste Stream	1,000 y	9.8E-4	2.5E-3
Resident with INEL208599QR0_0 Waste Stream	1,000 y	9.8E-4	2.5E-3

Addition of the INL Classified Mockup LLW has no significant effect on the all-pathways TED throughout the compliance period (Figure 2).

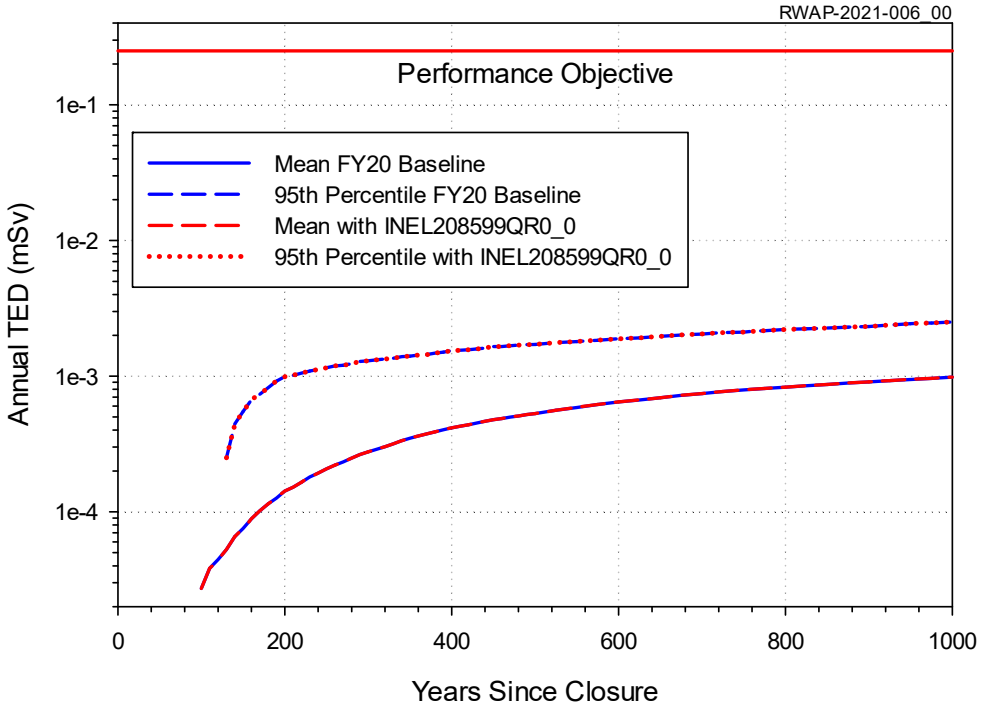

Figure 2. All-Pathways Annual TED Time History for a Resident at the 100-m Boundary with and without INEL208599QR0_0 Waste Stream

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 scenarios evaluated are the transient occupancy scenario, the resident with agriculture scenario, and open rangeland scenarios for a ranch with two plausible exposure 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 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 INL Classified Mockup LLW has no significant effect on the maximum annual TED for all alternative scenarios.

Table 6. Maximum All-Pathways Annual TEDs for Alternative Scenarios

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2020 Baseline Inventory	1,000 y	7.2E-3	1.7E-2
	FY 2020 with INEL208599QR0_0	1,000 y	7.3E-3	1.7E-2
Resident with Agriculture	FY 2020 Baseline Inventory	1,000 y	2.7E-2	8.5E-2
	FY 2020 with INEL208599QR0_0	1,000 y	2.7E-2	8.5E-2
Open Rangeland/Cane Spring	FY 2020 Baseline Inventory	1,000 y	4.7E-3	1.6E-2
	FY 2020 with INEL208599QR0_0	1,000 y	4.7E-3	1.6E-2
Open Rangeland/NNSS Boundary	FY 2020 Baseline Inventory	1,000 y	4.9E-3	1.7E-2
	FY 2020 with INEL208599QR0_0	1,000 y	4.9E-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 2019). 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 INL Classified Mockup LLW has no significant effect on the maximum acute intruder scenario mean result 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 2020

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Drilling Intruder without INEL208599QR0_0	1,000 y	1.5E-3	2.5E-3
Drilling Intruder with INEL208599QR0_0	1,000 y	1.5E-3	2.5E-3
Construction Intruder without INEL208599QR0_0	1,000 y	0.76	1.2
Construction Intruder with INEL208599QR0_0	1,000 y	0.76	1.2

Addition of the INL Classified Mockup LLW has no significant effect on the mean acute construction TED throughout the compliance period (Figure 3).

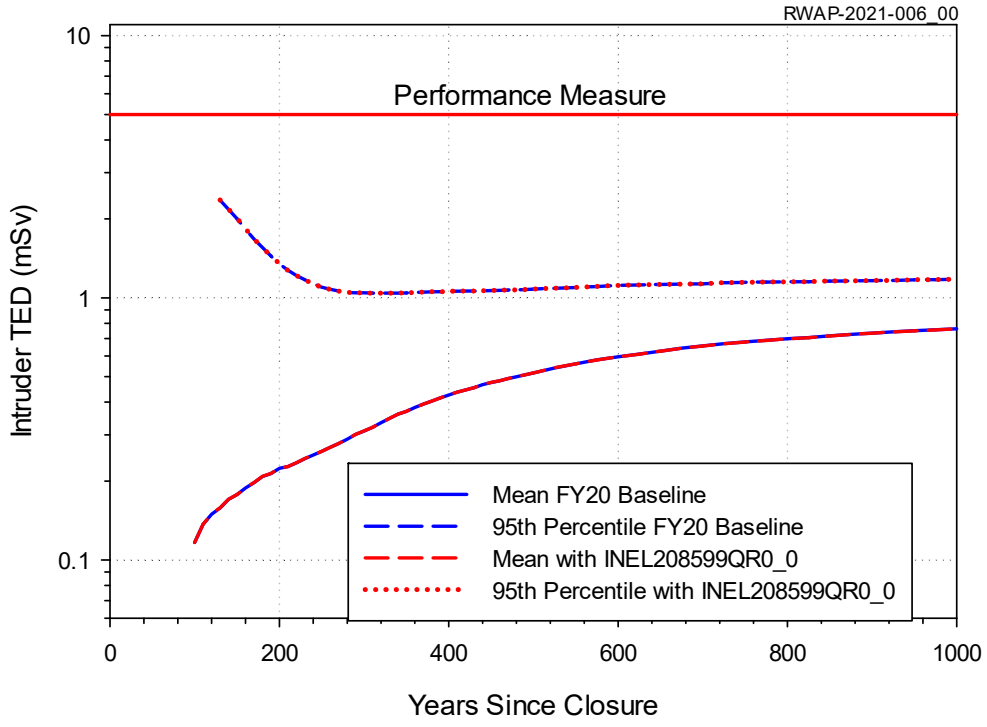

Figure 3. Acute Construction Intrusion Scenario TED Time History with and without the INEL208599QR0_0 Waste Stream

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 cells. 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 INL Classified Mockup LLW 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 2020

Inventory	Time of Maximum	Mean (Bq m^{-2} s^{-1})	95th Percentile (Bq m^{-2} s^{-1})
FY 2020 without INEL208599QR0_0	1,000 y	0.26	0.55
FY 2020 with INEL208599QR0_0	1,000 y	0.26	0.55

Addition of the INL Classified Mockup LLW has no significant effect on the mean ^{222}Rn flux density throughout the compliance period (Figure 4).

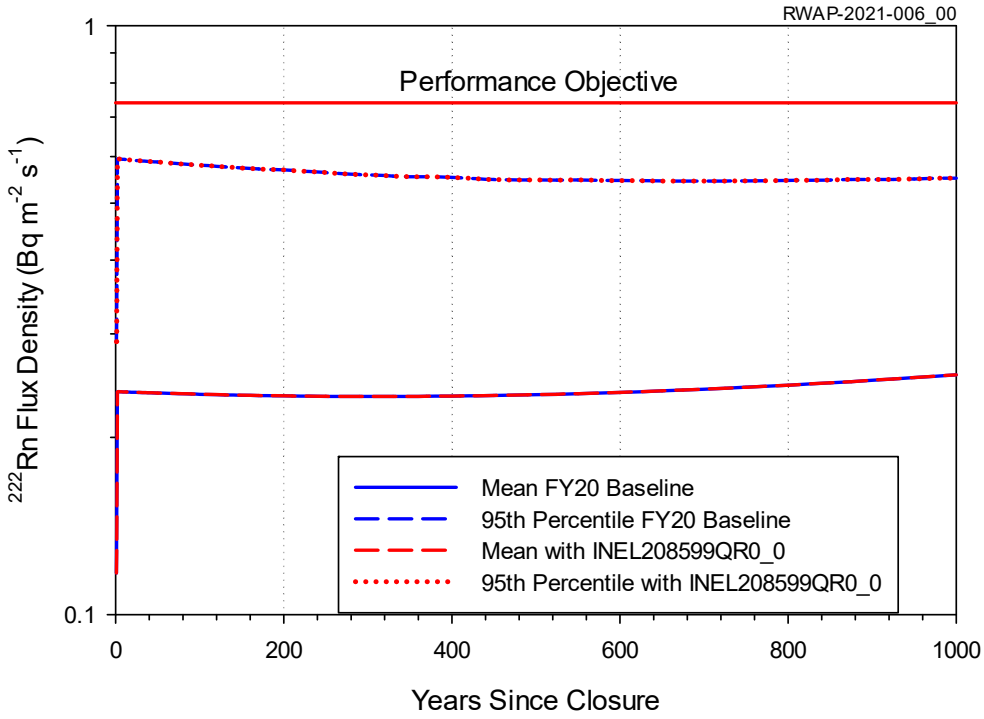

Figure 4. ^{222}Rn Flux Density Time History with and without the INEL208599QR0_0 Waste Stream

5.0 Conclusions

The effect of adding the INL Classified Mockup LLW inventory to the inventory of waste disposed through the end of FY 2020 was evaluated with the Area 5 RWMS v 4.208ba PA model. The results indicate that all performance objectives can be met for 1,000 years with disposal of the INL Classified Mockup LLW in an Area 5 RWMS SLB disposal cell. Addition of the INL Classified Mockup LLW inventory has no significant effect on the PA results. All maximum mean and 95th percentile results remain less than their respective performance objectives throughout the compliance period. No mean result exceeds the Low-Level Radioactive Waste Review Group notification criterion of exceeding 50% of a performance objective. The INL Classified Mockup LLW is acceptable for disposal without conditions.

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6.0 References

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