



Department of Energy
200 Grand Avenue
Grand Junction, Colorado 81501

March 24, 2011

Ms. Kimberly Conway, Project Manager
FSME Division of Waste Management and Environmental Protection
U.S. Nuclear Regulatory Commission
Mail Stop T8F5
Washington, DC 20555-0001

Subject: Radon Emanation from the Crescent Junction, Utah, Disposal Cell

Ms. Conway:

This letter is a follow up to a discussion held on November 17, 2010, regarding a design criteria of 707 picocuries per gram (pCi/g) of radium-226 (Ra-226) as the maximum activity for residual radioactive material (RRM) placed in the uppermost 7 feet of the Crescent Junction disposal cell. Enclosed is a report titled "Assessment of the Design of the Crescent Junction Disposal Cell Radon Barrier," dated March 23, 2011, prepared by a subcontractor to the Moab UMTRA Project.

As mentioned in the November meeting, the activity of the RRM varies such that some of the tailing slimes material could have an activity that exceeds the allowable limit in the upper portion of the cell. During the 2 years of placement of RRM, the project has compiled a substantial amount of data regarding actual Ra-226 activities. The activity data are required to ensure that the cover performance standard of 20 picocuries per square meter per second ($\text{pCi/m}^2\text{s}$) mean radon-222 emanation is not exceeded.

The subcontractor evaluated data from more than 900 samples of RRM whose Ra-226 activity was measured prior to shipment to Crescent Junction and found that the activity was within the range used in the radon barrier design. A probabilistic analysis was performed to determine the effect of placing RRM as in the design at an activity above the 707 pCi/g while keeping the overall RRM placed at the average activity. The assessment showed that as long as there was no systematic bias in placement of RRM (that is, intentionally placing higher activity RRM near the top of the cell), the mean radon emanation would be less than the 20 $\text{pCi/m}^2\text{s}$ limit.

Based on the results of this assessment, I am requesting that the requirement be waived to place RRM of less than 707 pCi/g Ra-226 in the upper 7 feet of the disposal cell. If approved, the Moab Project would continue to monitor the activity in RRM shipped to verify that the average value has not changed, or that any RRM of abnormally high activity is not placed in the top 7 feet of the cell.

FSME21

Ms. Kimberly Conway

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March 24, 2011

If you have any questions or comments, please feel free to contact me at (970) 257-2115.

Sincerely,

A handwritten signature in black ink, appearing to read "Donald R. Metzler", with a large, stylized flourish at the end.

Donald R. Metzler
Moab Federal Project Director

Enclosure

cc w/enclosure:

L. Chang, NRC

J. Berwick, DOE

K. Wethington, DOE

L. Brede, RAC

C. Niemeyer, RAC

J. Ritchey, TAC

Project File MOA 2.12 (C. Smith)

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TECHNICAL EVALUATION REPORT

ASSESSMENT OF THE DESIGN OF THE CRESCENT JUNCTION DISPOSAL CELL RADON BARRIER

Prepared for:

S&K AEROSPACE, LLC
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Prepared by:

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March 23, 2011



TECHNICAL EVALUATION REPORT

ASSESSMENT OF THE DESIGN OF THE CRESCENT JUNCTION DISPOSAL CELL RADON BARRIER

Prepared by:
MACTEC Development Corp., Inc.
751 Horizon Court, Suite 104
Grand Junction, Colorado 81506

Written By:

A stylized logo consisting of three stacked, slightly offset rectangular blocks is positioned to the left of a handwritten signature in black ink that reads "Jeffrey W. Lively".

Jeffrey Lively
Signed with Permission from C. A. Bloink
Chief Scientist | Senior Principal Health Physicist
2011.03.22 17:37:08 -06'00'

Carrie Bloink, MS
Project Health Physicist

Reviewed By:

A stylized logo consisting of three stacked, slightly offset rectangular blocks is positioned to the left of a handwritten signature in black ink that reads "Jeffrey W. Lively".

Jeffrey Lively
I have reviewed this document
Chief Scientist | Senior Principal Health Physicist
2011.03.22 17:37:21 -06'00'

Jeffrey W. Lively, CSP, RRPT
Senior Principal Health Physicist

1.0 INTRODUCTION

As part of the Moab Uranium Mill Tailings Remedial Action (UMTRA) Project, the Department of Energy (DOE) is moving 16 million tons of uranium tailings from Moab, Utah to a dedicated disposal site in Crescent Junction, Utah. The disposal site in Crescent Junction is currently accepting these tailings from the Moab location. The Crescent Junction disposal cell, located 30 miles north of Moab, encompasses about 200 acres.

This work was performed under contract to S&K Aerospace, LLC Technical Assistance Contractor (TAC) to the DOE for the Moab UMTRA Project.

Environmental Protection Agency (EPA) standards set forth in 40 CFR 192, require that the disposal cell cover be designed to limit the radon-222 atmospheric release rate from the disposal cell to 20 picocuries per square meter per second ($\text{pCi}/\text{m}^2\text{s}$) or less. The cells cover barrier must be designed to retain its effectiveness for 1,000 years, as best as is reasonably achievable, and 200 years at a minimum (EPA, 2005). Jacobs Engineering, under contract to EnergySolutions Federal Services, Inc. the Remedial Action Contractor, designed the Crescent Junction disposal cell and performed the calculations required to demonstrate that the design meets the radon-222 atmospheric release rate specification. The design calculations are documented in Addendum D (*Final Design Calculations*) of the *Final Remedial Action Plan* (DOE, 2008), which has been approved by the U.S. Nuclear Regulatory Commission (NRC).

The design calculations in Addendum D address the characteristics and thicknesses of various layers required to provide appropriate attenuation of the radon gas emanating through the cover, resistance to erosion, freezing temperatures (freeze-thaw cycles), earthquakes, biointrusion, and settling. The radon fluence calculations used in the cover design were performed with a computer modeling code (RADON) specifically designed for this purpose. It was thought that some of the parameters and design assumptions incorporated in the model might be more conservative than is necessary. Therefore S&K (DOE) asked MACTEC to evaluate the parameters and design assumptions used in the RADON model to assess whether there might be necessary to meet the requirements of the regulations.

More effective radon attenuation, and therefore more efficient cover design, can be realized if the residual radioactive material (RRM) with higher radium-226 (Ra-226) activity is placed in the bottom of the cell while RRM with lower Ra-226 activity is placed in the top of the cell. The radon attenuating capacity achieved in cover design was predicated on the assumption that radium bearing RRM would be placed in two discrete

layers within the cell. RRM with a *mean* Ra-226 activity concentration of no more than 707 pCi/g was assumed to occupy the top 7 feet of RRM placed in the disposal cell. RRM with a *mean* Ra-226 activity concentration of 1,349 pCi/g was assumed to occupy the lower 36 feet of RRM placed in the disposal cell. While allowing for a more efficient radon barrier layer design, the two-layer tailings design introduces a placement limitation that could impact constructability and overall project efficiency.

The objective of this scope of work is to identify unnecessary conservatism that may have been introduced into the assumptions and parameters used to model the radon-222 atmospheric release rate and to identify related supportable and defensible options that might alleviate impacts on constructability and overall project efficiency without changing the already approved physical design for the cover.

2.0 RADON BARRIER DESIGN

The Moab UMTRA Project radon cover design for the Crescent Junction disposal cell consists of an interim cover constructed of clean native alluvial materials to a minimum thickness of one foot, a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale, a 0.5-foot-thick infiltration and biointrusion barrier consisting of sandy gravel, and a 3.5-foot-thick frost protection layer that includes the 0.5-foot-thick rock mulch erosion protection layer (Figure 1). The designed thickness of the radon barrier for the Crescent Junction disposal cell is four feet with a one-foot-thick interim cover (DOE, 2008).

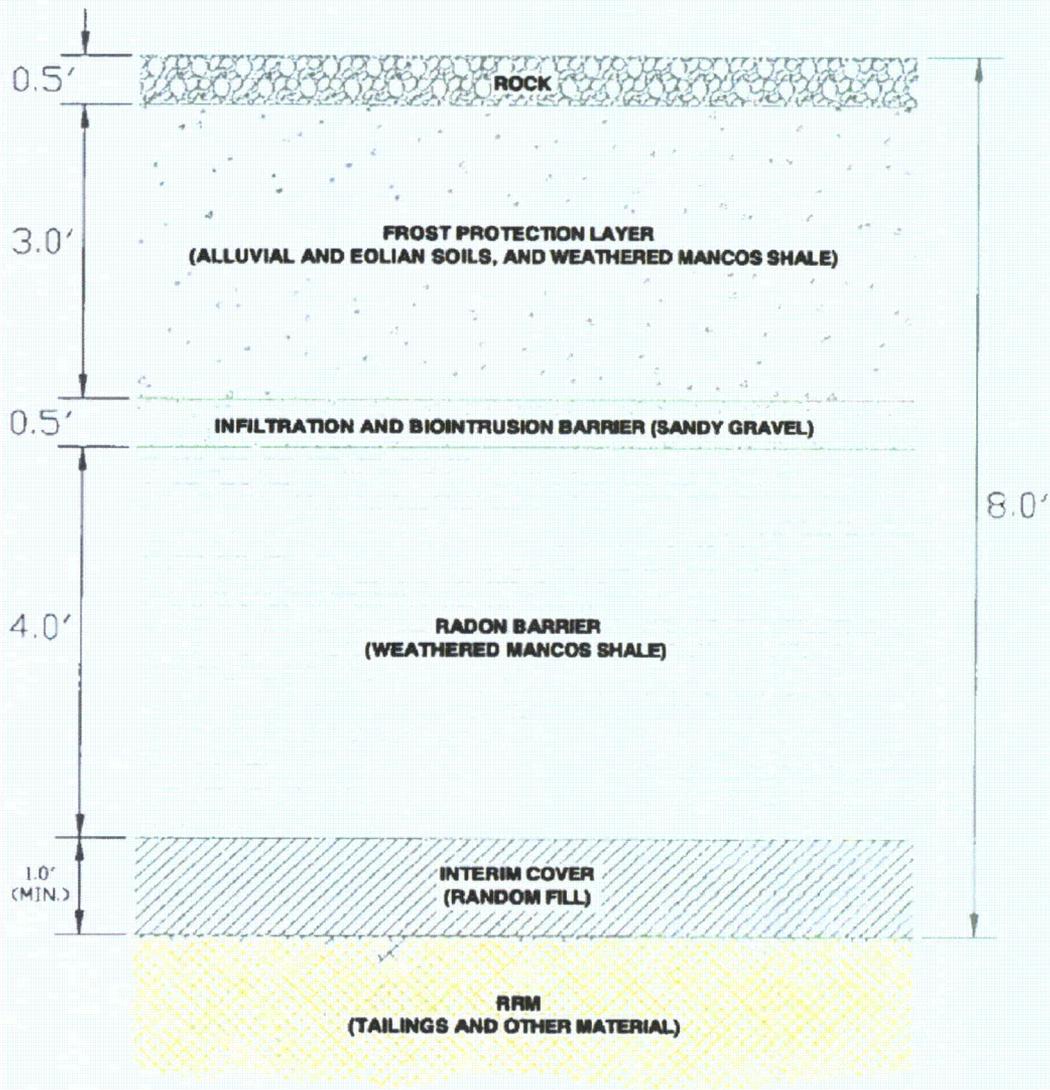


Figure 1 Example Cover Design (DOE, 2008)

3.0 CALCULATIONS

The goal of calculations presented in this report is to identify conservatism incorporated into the original cover design calculations and to determine the peak mean Ra-226 activity in RRM that can be placed in the disposal cell while remaining within the regulatory design requirement for the mean radon emanation of 20 picocuries per square meter per second ($\text{pCi}/\text{m}^2\text{s}$). The design approved in the Remedial Action Plan ([RAP], [DOE, 2008]) relies on a two-layer RRM concept in which it is assumed that the homogeneous mean Ra-226 activity of upper 7 feet of the tailing layer would remain below 707 pCi/g . While the modeled design assumption applies to the peak mean Ra-226 activity in the upper 7 feet of RRM, language in Sections 5.2.5 and 5.2.6 in the RAP suggest that RRM with Ra-226 activity greater than 707 pCi/g may not be placed in the upper seven feet of the tailings layer. The design limitation (and to an even greater degree, the interpretation and implementation of the limitation) presents logistical impediments to the efficient placement of RRM in the disposal cell. MACTEC sought to understand the implications of revising the two-layer model such that the logistical impediments and constraints currently imposed on the placement of RRM in two discrete layers in the disposal cell might be reduced or eliminated. For example, what impact would arise from the placement of relatively smaller volumes of RRM with Ra-226 activity in the range of 800-1,200 pCi/g in the upper 7 feet?

The regulation defines the disposal site to be the region inside the perimeter of residual radioactive material following the completion of control activities (EPA, 2005). By this regulatory requirement, if it can be shown that the cover design's average radon release rate over the entire disposal cell after completion does not exceed the limit, then higher localized release rates over the surface of the disposal cell would be insignificant and permissible. Several cases were modeled to determine the radon emanation given a specified tailing activity to demonstrate the disposal cell design is capable of providing adequate radon mitigation. Design considerations other than radon emanation flux are involved in the disposal cell design. Therefore, in performing these calculations, MACTEC has not made modifications to model parameters that would impact the overall cover thickness or dimensions. No changes have been made to the modeling code's parameters that would impact the cover's frost protectiveness, erosion resistance, permeability, or biointrusion protectiveness. Only changes that impact the cover's capacity to attenuate the radon-222 gas atmospheric release rate have been considered.

3.1 CALCULATION ASSUMPTIONS:

- The original design thickness for the interim cover and radon barrier will remain as designed. The interim cover has a thickness of 1 ft and the radon barrier 4ft.

-
- Bottom-boundary radon flux is equal to zero (no radon flux from the soil below the cell).
 - No ambient air radon concentration was assumed as no data was available. A conservative value of zero, as suggested by regulatory guidance, was modeled.
 - RADON modeling code's default value for the radon emanation coefficient (0.35) was assumed for all layers. The value is considered to be conservative (NRC, 1989).

3.2 LAYER PARAMETERS:

The layer parameters utilized in the RADON program for the calculation of radon emanation from the radon barriers are provided in the following sections. Parameters were calculated for the tailings, interim cover, radon barrier and erosion barrier/ interim cover layers.

- **Layer Thickness, T**

T_{Tailings} = Tailings total thickness of 43 feet.
 T_{Interim} = Interim cover thickness of 1 foot.
 T_{Radon} = Radon barrier thickness of 4 feet.

- **Porosity, η**

The porosities for the layers used in the analysis are obtained from the Equation 1 (NRC, 1989):

Equation 1

$$\eta = 1 - \frac{\rho_m}{SG * \rho_w}$$

Where:

η = Porosity
 SG = Specific Gravity
 ρ_m = dry bulk density of material
 ρ_w = density of water

- **Total Density, γ_t**

Calculated by the RADON program from dry density and the gravimetric moisture content

- **Moisture Saturation Fraction, m**

The volumetric fraction of saturation used in the diffusion coefficient calculations presented for the tailings or cover soils is expressed by the moisture saturation fraction, Equation 2 (NRC, 1989):

Equation 2

$$m = 10^{-2} \left(\frac{\rho_m * w}{\eta * \rho_w} \right)$$

Where:

- m = moisture saturation fraction
- ρ = dry bulk density of material
- w = average moisture content of the material
- η = Porosity
- ρ_w = density of water

- **Radon Diffusion Coefficient, D**

The radon diffusion coefficient of the tailings and cover soils was calculated using the moisture saturation fraction and porosity and calculated with Equation 3 (NRC, 1989):

Equation 3

$$D = (D_a) \eta^{(-6m\eta - 6m14\eta)}$$

Where:

- D = the ^{222}Rn diffusion coefficient (through the cover)
- D_a = the ^{222}Rn diffusion coefficient in air ($1.10 \times 10^{-5} \text{ m}^2/\text{s}$)
- m = the moisture saturation fraction
- η = porosity

- **Radon Emanation Coefficient, E**

The portion of radon that is released from the tailings or cover soil matrix into the pore space is expressed by the radon emanation coefficient. The reference value of 0.35 given in the NRC regulatory guide (NRC, 1989) was utilized for all materials.

- **Radium 226 Activity, RA_i (pCi/g)**

The uranium tailings activity source term is the average Ra-226 activity in a given layer. The RADON model assumes that the Ra-226 activity is homogeneously distributed in the layer. The approved design as calculated by Jacobs Engineering used a Ra-226 activity value of 707 pCi/g in the upper 7 feet of the RRM layer and 1,349 pCi/g in the lower 36 feet of the RRM layer.

3.3 GENERAL PARAMETERS

- **Radon Emanation Limit, J_c**

$J_c = 20 \text{ pCi m}^{-2}\text{s}^{-1}$, based on EPA and NRC regulations (EPA, 2005).

- **Radon Concentration Above Top Layer**

Radon concentration above top layer = 0 pCi/m²s Based on EPA and NRC default values (NRC, 1989).

- **Lower Boundary Radon Flux**

The lower boundary radon flux is calculated by the RADON program and adjusted the available radon for upward diffusion during radon flux computations.

- **Surface Flux Precision**

Surface flux precision = 0.001, acceptable level of computation error.

4.0 DISCUSSION

RADON is a computer modeling code specifically created to evaluate the capacity of a cover's design ability to attenuate radon fluence emanating through the cover. RADON is a one-dimensional deterministic model, meaning that it is only able to calculate flux at a single point. The modeler is compelled to use conservative estimates of parameters to account for the uncertainty introduced by the natural variation of material properties. Consequently, the model will tend to calculate a conservative estimate of the radon emanation at the surface of the radon barrier. Realistically, Ra-226 activity will vary from point to point (up and down and side to side) and radon emanation will vary accordingly, therefore the modeler is forced to examine conservative case scenarios.

Before any modifications to parameters were considered, MACTEC performed a baseline calculation to verify that the results we obtained were consistent with those obtained by Jacobs Engineering. In this way, we can be confident that the assessment performed is appropriately relevant and that potential differences in the code itself (e.g., versions) are not responsible for changes in the outcome of the modeled radon release rate. Jacobs Engineering found an exit flux of 19.98 pCi/m²s using a single layer model with a mean Ra-226 tailing activity of 707 pCi/g. The same model reproduced by MACTEC, also found an exit flux of 19.98 pCi/m²s.

A variety of cases were evaluated to achieve the desired objectives.

5.0 METHODOLOGY

The methodology presented is used to demonstrate compliance with the EPA design criteria without the constraint of the two layer model as originally designed by Jacobs Engineering. Statistical methods are coupled with RADON modeling to demonstrate compliance using a single layer model without constraints on tailing material placement within the disposal cell.

Between August 30, 2010 and February 16, 2011, 903 samples of RRM tailing material were collected from the shipments made to the Crescent Junction Disposal Cell. These samples were used to determine the mean volumetric Ra-226 concentrations of RRM in the shipments both for demonstrating compliance with the transportation regulations and to determine the appropriate placement of tailings upon arrival at Crescent Junction. The mean Ra-226 concentration in the RRM shipped to the Crescent Junction site for disposal between August 30, 2010 and February 16, 2011 was 618 pCi/g.

Using the provided sample data, a relative frequency histogram, Figure 2 , was created using NCSS statistical software (NCSS, 2001). The statistical software provides an equation that fits the curve of the histogram. This equation (Equation 4) can then be used to calculate the probability of occurrence (the relative volume) for a given Ra-226 concentration in RRM being placed in the disposal cell.

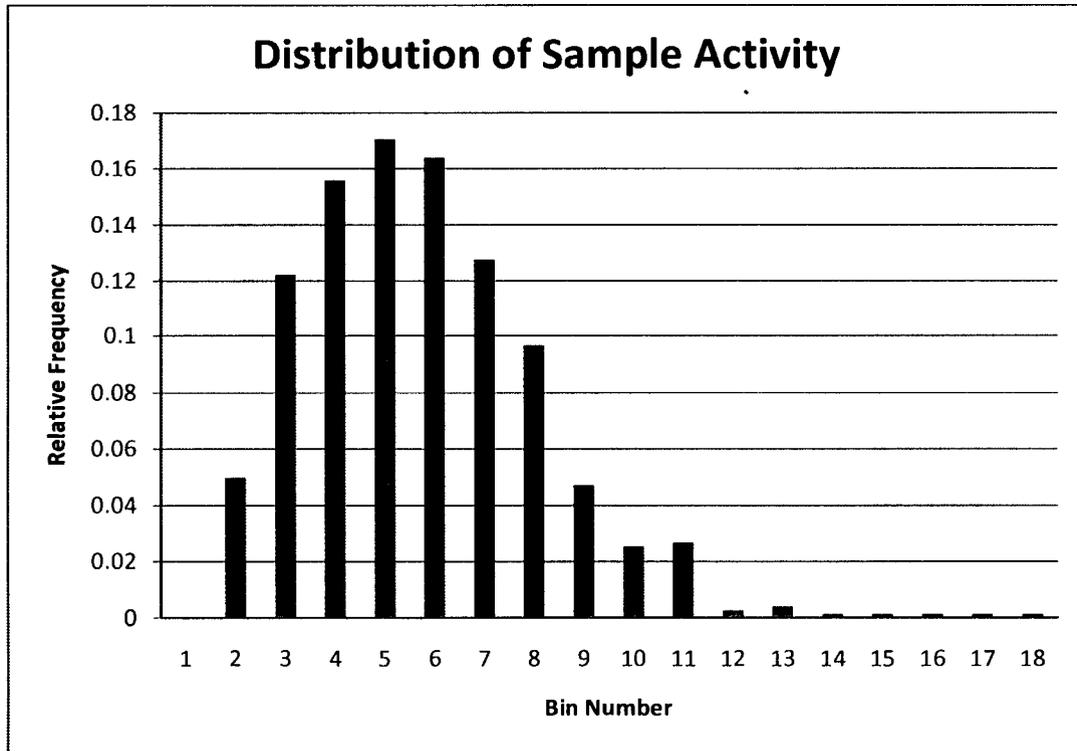


Figure 2

Equation 4

$$P = \frac{((0.02014753)-(0.00001214099)*\chi-(0.000000002540581)*\chi^2)}{(1-(0.002234867)*\chi+(0.000001599262)*\chi^2)}$$

Where,

P = probability of occurrence for Ra-226 concentration χ

χ = the concentration of Ra-226 in pCi/g of the tailing material

The RADON modeling code was then used to calculate radon emanation from the barrier using incremental Ra-226 concentrations from 100 to 2,600 pCi/g. The RADON model assumed a single tailing layer, interim cover, and radon barrier. All properties, except the tailing layer activity, were assumed to be the values provided by Jacobs Engineering in the original design (Table 1).

Table 1

Layer Type	Layer Thickness (cm)	Layer Thickness (ft)	Porosity	Density (g/cm ³)	Activity (pCi/g)	Moisture Content (%)	Calculated Diffusion Coefficient
Tailings	1310.64	43	0.44	1.57	Varied	15	0.01037
Interim Cover	30.48	1	0.38	1.66	1.9	9	0.016358
Radon Barrier	121.9	4	0.33	1.77	2.3	12	0.004636

The calculated flux for each concentration was then multiplied by the relative probability to yield a weighted flux. These values were then summed to find the total flux emanating from the radon barrier (Table 2). Although a local discrete flux may exceed the 20 pCi/m²s, the overall average flux over the surface of the cell will remain compliant as a result of the lower probability of occurrence for higher activities.

Table 2

Ra-226 Concentration [pCi/g]	Probability	Relative Probability	Calculated Flux [pCi/m²s]	Weighted Flux [pCi/m²s]
100.00	0.02	0.05	3.81	0.18
200.00	0.03	0.06	6.34	0.36
300.00	0.04	0.07	8.86	0.62
400.00	0.04	0.09	11.39	0.98
500.00	0.05	0.10	13.92	1.43
600.00	0.06	0.12	16.44	1.91
700.00	0.06	0.12	18.97	2.21
800.00	0.05	0.10	21.50	2.18
900.00	0.04	0.08	24.02	1.89
1000.00	0.03	0.06	26.55	1.52
1100.00	0.02	0.04	29.07	1.19
1200.00	0.01	0.03	31.60	0.93
1300.00	0.01	0.02	34.13	0.73
1400.00	0.01	0.02	36.65	0.59
1500.00	0.01	0.01	39.18	0.48
1600.00	0.00	0.01	41.70	0.39
1700.00	0.00	0.01	44.23	0.33
1800.00	0.00	0.01	46.76	0.28
1900.00	0.00	0.00	49.28	0.24
2000.00	0.00	0.00	51.81	0.21
2100.00	0.00	0.00	54.34	0.19
2200.00	0.00	0.00	56.86	0.17
2300.00	0.00	0.00	59.39	0.15
2400.00	0.00	0.00	61.91	0.14
2500.00	0.00	0.00	64.44	0.13
2600.00	0.00	0.00	66.97	0.13
Total Flux [pCi/m²s]				19.56

6.0 CONCLUSIONS AND RECOMMENDATIONS

To meet the design requirement set forth by the EPA, it need only be shown that the designed average radon flux from the entire cover surface does not exceed 20 pCi/m²s. The radon emanation calculated using the presented methodology was found to be 19.56 pCi/m²s. The result assumes there is no systematic bias in the placement of tailing material in either the lateral and vertical direction. Based on tailings sample data to date, the methodology demonstrates that the design of the Crescent Junction disposal cell is adequate to meet the EPA's regulatory requirement without constraint on the placement of tailing in two discrete layers within the cell. This modeling shows that the cell design is as effective using a single layer as it is with a two-layer RRM design.

7.0 REFERENCES

- EPA, 2005. *Code of Federal Regulations Title 40: Protection of the Environment, Part 192: Health and Environmental Protection Standards for Uranium and Thorium Mill Tailing*, U.S. Environmental Protection Agency.
- NRC, 1989. *Calculation of Radon Flux Attenuation By Earthen Uranium Mill Tailings Covers*, U.S. Nuclear Regulatory Commission Regulatory Guide 3.64.
- DOE, 2008. *Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah Disposal Site, Attachment 1: Draft RAP Disposal Cell Design Specifications*, U.S. Department of Energy, Office of Environmental Management.
- NCSS, 2001. Statistical Software