F.1 Introduction

This radiation dose/risk evaluation provides the methods and results from the calculation of the estimated dose/risk from radiation exposure for potential removal action alternatives for specific mining-related Site features (i.e., waste rock piles, ore storage area, mine portals) at the Ross-Adams Mine Site (Site). The method involves calculating potential radiation dose/risk to the recreational (Site Visitor) and occupational (Mineral Exploration Worker and Forest Service Worker) users from individual areas and mine features (i.e. the Ore Stockpile Area (OSA)) and the 300-, 700-, and 900-Foot Level mine rock pile areas for each removal action alternative. The concentrations attributable to each mining feature are calculated based on the measured and predicted gamma exposure rate, estimated radionuclide concentrations, measured radon concentrations at the portals, and calculated radon flux from the mine rock piles. The doses and risks are calculated in the same manner for each removal action alternative. The contribution to dose/risk from background is not evaluated for purpose of comparing dose/risks from individual mine-related features, and therefore these forward-looking calculations do not represent actual risks at the Site. The calculated dose/risks are estimated for purposes of alternative comparison within this EE/CA.

The total estimated dose for each potential removal action alternative is determined by summing the estimated radon radiation dose and the estimated gamma radiation dose for each user. The recreational and occupational users are Site Visitors, Mineral Exploration Workers, and Forest Service Workers. These are summarized in Section F2 and described in more detail in the Site Specific Human Health Risk Assessment (HHRA - Appendix C). The radon radiation dose and gamma radiation dose are calculated for each Site user for each alternative as described in Sections F.3.1 and F.3.2, respectively. The lifetime risk is calculated as described in Section F.4.

The dose calculations are intended only for the purpose of comparison of removal action alternatives and should not be construed to represent actual dose that the user might incur. The mine features with elevated radionuclide concentrations and radiation exposure rates attributable to mining operations at the Site occupy a very small percentage of the total Site area.

F.2 Site Users

The Human Health Risk Assessment (HHRA) included a Screening Level Risk Assessment (SLRA) and a Site-specific Risk Assessment (SSRA). The SLRA compared measured concentrations of mine related metals and radionuclides of environmental media and measured radiation exposure rates to regulatory requirements and guidance to identify constituents of potential concern (COPCs). The SSRA was then conducted to carry the risk analysis process to the next level of specificity, by evaluating the risk to potential receptors based on existing and projected future Site use. The potential Site receptors are Site Visitors (recreational use such as camping and hiking), Mineral Exploration Workers, and Forest Service Workers. Exposure parameters for the critical groups used in the SSRA are provided in Table F-1.

The approach used for the effectiveness calculations for determining dose/risk for each alternative differs from the approach used in the HHRA; the effectiveness calculations use slightly different exposure scenarios and dose rates. This was done to allow characterization of discrete areas affected by the various removal actions. Most notably calculated radon emanations from the discrete mine rock piles was used rather than the measured values which could not be applied to these discrete locations.

For the purpose of evaluating potential removal action alternatives, the radiation risks to the Site users are estimated based on residence times in the mine affected areas of the Site and, more specifically, on the mine features that will be the subject of the removal actions. For the purpose of this radiation dose/risk estimation, the fraction of time that the Site users would spend in each of the mine-affected areas is estimated based on a comparison of the area and an estimate of the area the user might access during his or her time on the Site. Due to the relatively short period of time an individual would be likely to spend in the vicinity of the mine road embankments and haul roads, they are not considered as a separate entity in these calculations. The amount of time spent traveling from one mine location to another is included in the estimated time spent in the mined areas (300-Foot, 700-Foot, and 900-Foot Levels). While institutional and access controls or land use restrictions will further reduce radiation exposure to human receptors for each alternative, the dose/risk calculations, conservatively do not account for these controls.

F.2.1 Site Visitor/Recreational User

The Site Visitor is assumed to spend 40 percent of his or her time on-site in the OSA area as was the assumption used in the SSRA. The OSA is a potentially attractive location for camping and it is possible that a Site Visitor would consider it a camping spot due to its accessibility by boat. However, in order to camp in that location, the visitor would have to ignore signs warning of the dangers. Even if a campsite was set up at the OSA, the average Site Visitor would not likely spend the rest of the time hiking or hunting in the area exclusively at the mined locations. Information obtained from residents in the regional area indicated that the Ross-Adams Mine Site is not an area that is often frequented. Therefore, for an evaluation of dose/risk to the user, only a fraction of the time assumed in the SSRA to be spent at the 300-Foot, 700-Foot, and 900-Foot Levels, is attributed to the mined locations and specifically to the mine features. While the recreational user might spend several days exploring such an area, it is unlikely that he or she would spend an entire two-week period adjacent to or on the mine rock piles or at the mine portals. Based on a reasonable estimate of two days exploring the Ross Adams mined area with the remaining 12 days per year in unaffected areas in the vicinity of Bokan Mountain, the fraction of the annual exposure frequency for the Site Visitor over which the gamma and radon doses were calculated is 0.14. Therefore, for the purpose of estimating a gamma and radon annual dose to a Site Visitor, the fraction of time the Site Visitor spends in the OSA was assumed to be 0.40 and the fraction in the mined areas, equal to 0.14 x (1-0.40) or 0.084 for a total of 28 hours per year divided among the three mined areas or 9.6 hours per year in each area. For the purpose of comparing the potential doses and risks for each of the removal action alternatives, the individual was assumed to spend all of his/her time in the mined area either on or adjacent to the mine feature (i.e., OSA, mine rock piles, or portals). This is a not a realistic assumption but is applied

only in order to compare the effectiveness of the removal action alternatives. The estimated amount of time spent on each mine feature for all land use scenarios are shown in Table F-2.

F.2.2 Mineral Exploration Worker and Forest Service Worker

The fraction of time the Mineral Exploration Worker might spend on the Ross-Adams mined areas in one year was estimated. The estimated fraction of the time a Mineral Exploration Worker might spend on the 85 acres that comprise the 300-Foot, 700-Foot, and 900-Foot Levels mined areas is 0.50. An even shorter period of time would be spent on or adjacent to the mine rock piles. The Forest Service Worker was assumed to divide his or her time at the Site in the same manner as the Mineral Exploration Worker. The workers are likely to only pass through the OSA since they generally operate out of a barge in the bay or a nearby base and are not likely to camp on the OSA. For the purpose of risk evaluation, the workers are assumed to spend 10% of their time on the OSA. The Mineral Exploration Worker would not likely spend more than one season in the mine-affected areas. Further work in that specific area would probably be classified as “mining” rather than exploration at which point Mine Safety and Health Administration (MSHA) radiation protection regulations would be applicable rather than population dose limits. MSHA regulations limit the direct gamma dose to a miner to 5000 mrem per year and the radon decay product dose to 4 working level months (WLM) (equivalent to 4000 mrem per year). While it is unlikely that the Mineral Exploration Worker would spend three consecutive years at the mine-affected areas, for the purpose of estimating lifetime risk for the removal action alternatives the three year duration period was retained for consistency. The estimated amount of time spent on each mine feature for all land use scenarios are shown in Table F-2. As for the Site Visitor, the occupational user was assumed to spend all of his/her time in the mined area either on or adjacent to the mine feature in order to compare the effectiveness of the removal action alternatives.

F.3 Methods for Calculating Dose/Risk from Radiation

The exposure pathways evaluated in the dose/risk calculations for each alternative include external exposure to direct gamma radiation from mine rock and inhalation of radon decay products generated from mine rock and mine openings. For purposes of simplifying the predicted dose/risk for the alternatives, the calculations assume that removal of mine rock piles under Mine Rock Alternatives M-4 and M-5 or closure of all the mine openings under Portal Alternative P-4 would eliminate the radiation exposure at the locations of the removed mine rock piles or at the closed portals. Minimal residual dose/risk to human receptors may remain following removal of the mine rock piles at their current locations or at the portals following closure; however, the calculations assume that the residual dose/risk to these areas is zero for comparative purposes. Human health risks at the Site due to background radiation exposures in the mineralized area exceed the dose and risk criteria regardless of which removal action is implemented. This is an important distinction because the calculated incremental risk reductions for the alternatives provide relative comparisons. However, the effectiveness in reducing risk to human exposure pathways at the Site is constrained by the natural mineralization in the Bokan Mountain area.

F.3.1 Estimated Dose from Radon Radiation

The potential dose due to inhalation of radon decay products for each potential removal action alternative is calculated as follows. Depending on the alternative, the estimated radon flux from either the existing or cover surface of the mine rock piles was calculated using the RADON Code (NRC, 1989), as described in Appendix C. The measured radon concentrations at the 300-Foot, 700-Foot, and 900-Foot Levels portals were used. The radon concentration in air in the center of the mine feature is then estimated based on the equations developed by Schiager (1974) that take into account radon flux, area of the mine feature and radon dispersion in air. The radon concentrations are calculated assuming a conservative wind speed of 2 meters per second and a vertical dispersion coefficient of 1 to 3 meters at a Class D stability class condition depending on the distance between the receptor and the source. The risk from radon is due to inhalation of radon decay products (Po-218, Pb-214, Bi-214, and Po-214) rather than inhalation of radon gas. Radon emanates from the soil as a gas; its decay products build up as a function of the "age" of the radon. The concentrations of the decay products reach equilibrium, which is the maximum radon decay product concentration relative to the radon gas concentration, in approximately four hours; however, the radon is diluted much more rapidly due to atmospheric dispersion. The "age" of the radon can be calculated as a function of wind speed and distance from the source. The fraction of equilibrium can then be estimated based on the age of the air using standard equations or a build-up curve (Schiager, 1974). The radon decay product exposure rate in Working Level Months per hour (WLM/hr) for each mine level is calculated by dividing the radon decay product concentration by 170 hour (as per the definition of WLM). The annual effective dose is calculated by multiplying the number of hours of exposure in each location by the calculated exposure rate (WLM/hr). The exposure in WLM is multiplied by a dose conversion factor of 1000 mrem per WLM (NCRP, 2009).

The potential dose from inhalation of radon and decay products exhaled from the mine portals for potential alternatives that do not include sealing the portals is calculated based on the measured radon gas concentrations at the portals and an estimated equilibrium factor of 0.1. The age of air exhaled from the mine portals is not known. The equilibrium factor of 0.1 assumes an average travel time through the mine workings of six minutes. At an average wind speed of 2 meters per second through the mine, the assumed average distance traveled is 720 meters.

F.3.2 Estimated Dose from Gamma Radiation

The average measured and predicted gamma exposure rate for each mine feature was used to calculate the annual direct radiation doses in using the exposure parameters given in Table F-2. The gamma exposure rates from the calculated concentrations of uranium and thorium decay products in the mine features was estimated for removal action alternatives using the MicroShield® computer code, as described in Appendix D. MicroShield® provides a calculated exposure rate at a user supplied location for each removal action alternative in the vicinity of the source based on the energy of the gamma emissions from each of the radionuclides. The maximum calculated exposure rate is used in the dose analysis. The calculated exposure rate is multiplied by a factor of 0.7 for an adult receptor and 0.8 for a child receptor to obtain an effective

dose rate. The effective dose rate is multiplied by the annual residence time to obtain an annual effective dose due to direct gamma radiation. For mine levels with more than one feature, the exposure time was apportioned among the features.

F.4 Calculated Lifetime Risk

The lifetime risk is calculated using the International Commission on Radiological Protection (ICRP) risk coefficient for inhalation of radon decay products, 5×10^{-4} per WLM (ICRP, 2007). The lifetime risk from direct gamma radiation was calculated using the ICRP coefficients for risk from radiation dose, 5.5×10^{-7} per mrem for members of the public and 4.1×10^{-7} per mrem for occupational exposure.

The SSRA assumed that a Site Visitor might camp at the OSA and explore the mined areas each year for 30 years. This assumption was retained for the risk evaluation in support of the evaluation of removal action alternatives. The Mineral Exploration Worker was assumed to work on the Site for the three years, consistent with the SSRA. The Forest Service Worker would be assumed to visit the Site each year for 25 years.

The lifetime radon risks were calculated by multiplying the duration of exposure by the annual radon decay product exposure in WLM and the ICRP dose coefficient. The lifetime direct gamma radiation risks were calculated by multiplying the annual effective dose by the exposure duration and the appropriate risk coefficient. The lifetime risk for the Site Visitor is calculated with an adjustment in the adult gamma dose to account for the slightly greater dose coefficient for a child.

F.5 Calculated Radiation Dose/Risk

The results from the calculated radon decay product exposures, doses, and lifetime risks for the mine affected areas and the three user groups are given in Tables F-3 through Table F-7 for Mine Rock Alternatives M-1 through M-5, respectively. The results from the calculations for the Portal Alternatives are shown in Table F-8.

F.6 References

International Commission on Radiological Protection (ICRP). 2007. The 2007 Recommendations of the International Commission on Radiological Protection. Publication 103. Volume 37, Nos. 2-4. Elsevier.

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Schiager, K. J. 1974. Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles. Radiation Data and Reports, Vol. 15, No. 7, July 1974.

U. S. Nuclear Regulatory Commission. 1989. Regulatory Guide 3.64.

Table F-1: Exposure Parameter Values (Exposure Period)

Parameter	Site Visitor	Mineral Exploration Worker	Forest Service Worker
Exposure frequency (days per year)	14	120	10
Exposure time (hours per day)	24	12	12
Exposure duration (years)	30	3	25

Table F-2. Estimated Number of Hours of Exposure in Specific Mine Areas

Location	Site Visitor (hours per year for 30 years)	Mineral Exploration Worker (hours per year for 3 years)	Forest Service Worker (hours per year for 25 years)
Ore Stockpile Area (OSA)	134.4	144	12
300-Foot Level Waste Rock Pile	9.6	216	18
700-Foot Level Waste Rock Pile	9.6	216	18
900-Foot Level North Waste Rock Pile	3.2	72	6
900-Foot Level South Waste Rock Pile	3.2	72	6
900-Foot Level Open Pit	3.2	72	6

Table F-3. Calculated Dose/Risk – Mine Rock Alternative M-1 – No Action

					Dose/Risk to Site Visitor						Dose to Mineral Exploration Worker						Dose to Forest Service Worker					
	Pile Area (SF)	Longest Length (ft)	Gamma Exposure[1] Rate (uR/hr)	Radon Exit Flux[2] (pCi/m^2/sec)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (30 years)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (3 year)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose Factor	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (25 years)
OSA	61,922	205	1253	83.7	134.4	0.642	60.4	6.5E - 05	5.2E - 02	1.0E - 03	144	0.642	64.7	6.5E - 05	5.5E - 02	8.0E - 05	12	0.642	5.4	6.5E - 05	4.6E - 03	5.5E - 05
300-Foot Level Pile	53,361	420	341	22.0	9.6	0.153	1.0	4.7E - 05	2.7E - 03	1.7E - 05	216	0.153	23.1	4.7E - 05	6.0E – 02	2.9E - 05	18	0.153	1.9	4.7E - 05	5.0E - 03	2.0E - 05
700-Foot Level Pile	39,717	550	960	65.4	9.6	0.473	3.2	1.8E - 04	1.0E - 02	5.3E - 05	216	0.473	71.5	1.8E - 04	2.3E - 01	8.9E - 05	18	0.473	6.0	1.8E - 04	1.9E - 02	6.1E - 05
900-Foot Level North Pile	42,237	370	683	45.9	3.2	0.323	0.7	1.3E - 04	2.4E - 03	1.2E - 05	72	0.323	16.3	1.3E - 04	5.5E - 02	2.0E - 05	6	0.323	1.4	1.3E - 04	4.6E - 03	1.4E - 05
900-Foot Level South Pile	5,292	90	1020	69.4	3.2	0.506	1.1	4.8E - 05	9.0E - 04	1.9E - 05	72	0.506	25.5	4.8E - 05	2.0E - 02	3.1E - 05	6	0.506	2.1	4.8E - 05	1.7E - 03	2.2E - 05
Open Pit		350	960	65.4	3.2	0.473	1.1	1.7E - 04	3.3E - 03	1.8E - 05	72	0.473	23.8	1.7E - 04	7.4E - 02	2.9E - 05	6	0.473	2.0	1.7E - 04	6.2E - 03	2.0E - 05
Pathway Dose							**67.5**		**7.1E - 02**	**1.1E - 03**			**225.0**		**5.0E - 01**	**2.8E - 04**			**18.7**		**4.1E - 02**	**1.9E - 04**

1 Mean measured Gamma exposure rate
2 RADON code calculated flux at pile surface

Table F-4. Calculated Dose/Risk – Mine Rock Alternative M-2 – Stabilize in Place

					Dose/Risk to Site Visitor						Dose to Mineral Exploration Worker						Dose to Forest Service Worker					
	Pile Area (SF)	Longest Length (ft)	Gamma Exposure[1] Rate (uR/hr)	Radon Exit Flux[2] (pCi/m^2/sec)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (30 years)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (3 year)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose Factor	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (25 years)
OSA	61,922	205	1253	83.7	134.4	0.642	60.4	6.5E - 05	7.3E - 02	1.0E - 03	144	0.642	64.7	6.5E - 05	7.8E - 02	8.0E - 05	12	0.642	5.4	6.5E - 05	6.5E - 03	5.5E - 05
300-Foot Level Pile	53,361	420	341	22.0	9.6	0.153	1.0	4.7E - 05	4.6E - 03	1.7E - 05	216	0.153	23.1	4.7E - 05	1.0E - 01	2.9E - 05	18	0.153	1.9	4.7E - 05	8.7E - 03	2.0E - 05
700-Foot Level Pile	39,717	550	960	65.4	9.6	0.473	3.2	1.8E - 04	1.6E - 02	5.3E - 05	216	0.473	71.5	1.8E - 04	3.5E - 01	8.9E - 05	18	0.473	6.0	1.8E - 04	2.9E - 02	6.1E - 05
900-Foot Level North Pile	42,237	370	683	45.9	3.2	0.323	0.7	1.3E - 04	2.4E - 03	1.2E - 05	72	0.323	16.3	1.3E - 04	5.5E - 02	2.0E - 05	6	0.323	1.4	1.3E - 04	4.6E - 03	1.4E - 05
900-Foot Level South Pile	5,292	90	1020	69.4	3.2	0.506	1.1	4.8E - 05	9.0E - 04	1.9E - 05	72	0.506	25.5	4.8E - 05	2.0E - 02	3.1E - 05	6	0.506	2.1	4.8E - 05	1.7E - 03	2.2E - 05
Open Pit		350	960	65.4	3.2	0.473	1.1	1.7E - 04	3.3E - 03	1.8E - 05	72	0.473	23.8	1.7E - 04	7.4E - 02	2.9E - 05	6	0.473	2.0	1.7E - 04	6.2E - 03	2.0E - 05
Pathway Dose							**67.5**		**1.0E - 01**	**1.1E - 03**			**225.0**		**6.8E - 01**	**2.8E - 04**			**18.7**		**5.7E - 02**	**1.9E - 04**

1 Mean measured Gamma exposure rate
2 RADON code calculated flux at pile surface

Table F-5. Calculated Dose/Risk – Mine Rock Alternative M-3- Mine Rock with 2-Foot Thick Onsite Cover

					Dose/Risk to Site Visitor						Dose/Risk Mineral Exploration Worker						Dose/Risk to Forest Service Worker					
	Pile Area (SF)	Longest Length (ft)	Gamma Exposure[1] Rate (uR/hr)	Radon Exit Flux[2] (pCi/m^2/sec)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (30 years)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (3 year)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose Factor	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (25 years)
OSA	43,950	145	5.92	33.5	134.4	5.92E - 03	0.56	3.7E - 05	2.9E - 02	9.6E - 06	144	5.92E - 03	0.60	3.7E - 05	3.1E - 02	7.8E - 07	12	5.9E-03	0.05	3.7E - 05	2.6E - 03	5.4E - 07
300-Foot Level Pile	105,668	490	1.46	14.9	9.6	1.46E - 03	0.01	3.7E - 05	2.1E - 03	1.9E - 07	216	1.46E - 03	0.22	3.7E - 05	4.7E - 02	3.4E - 07	18	1.5E-03	0.02	3.7E - 05	3.9E - 03	2.4E - 07
700-Foot Level Pile	36,770	550	3.58	44.1	9.6	3.58E - 03	0.03	1.2E - 04	7.0E - 03	5.0E - 07	216	3.58E - 03	0.54	1.2E-04	1.6E - 01	9.0E - 07	18	3.6E-03	0.05	1.2E - 04	1.3E - 02	6.3E - 07
900-Foot Level North Pile	39,807	370	3.22	31.0	3.2	3.22E - 03	0.01	8.7E - 05	1.7E - 03	1.4E - 07	72	3.22E - 03	0.16	8.7E - 05	3.7E - 02	2.6E - 07	6	3.2E-03	0.01	8.7E - 05	3.1E - 03	1.8E - 07
900-Foot Level South Pile	5,292	90	4.18	46.9	3.2	4.18E - 03	0.01	3.2E - 05	6.1E - 04	1.6E - 07	72	4.18E - 03	0.21	3.2E - 05	1.4E - 02	2.8E - 07	6	4.2E-03	0.02	3.2E - 05	1.1E - 03	1.9E - 07
Open Pit		350	960.4	65.4	3.2	4.73E - 01	1.06	1.7E - 04	3.3E - 03	1.8E - 05	72	4.73E - 01	23.84	1.74E-04	7.4E - 02	2.9E - 05	6	4.7E-01	1.99	1.7E - 04	6.2E - 03	2.0E - 05
Pathway dose							**1.67**		**4.4E - 02**	**2.8E - 05**			**25.57**		**3.6E - 01**	**3.2E - 05**			**2.13**		**3.0E - 02**	**2.2E - 05**

1 MicroShield® calculated gamma exposure rate for 2-foot thick cover, 1-foot thick cover extrapolated for mine roads
2 RADON code calculated flux for 2-Foot thick onsite material cover

Table F-6. Calculated Dose/Risk – Mine Rock Alternative M-4- Consolidate OSA to 300-Foot Level; Consolidate 700-Foot and 900-Foot piles and mine roads in Open Pit; Cover with 2-foot thick onsite material[1]

					Dose/Risk to Site Visitor						Dose/Risk to Mineral Exploration Worker						Dose/Risk to Forest Service Worker					
	Pile Area (SF)	Longest Length (ft)	Gamma Exposure[2] Rate (uR/hr)	Radon Exit Flux[3] (pCi/m^2/sec)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (30 years)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (3 year)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose Factor	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (25 years)
OSA	0	0	0	0	134.4	0	0	0	0	0	144	0	0	0	0	0	12	0	0	0	0	0
300-Foot Level Mine Rock Pile	101,230	430	1.46	20.0	9.6	1.5E - 03	9.8E - 03	4.4E - 05	2.5E - 03	2.0E - 07	216	1.5E - 03	2.2E - 01	4.4E - 05	5.6E - 02	3.6E - 07	18	1.5E - 03	1.8E - 02	4.4E - 05	5.2E - 03	2.5E - 07
700-Foot Level Mine Rock Pile	0	0	0	0	9.6	0	0	0	0	0	216	0	0	0	0	0	18	0	0	0	0	0
900-Foot Level North Pile	0	0	0	0	3.2	0	0	0	0	0	72	0	0	0	0	0	6	0	0	0	0	0
900-Foot Level South Pile	0	0	0	0	3.2	0	0	0	0	0	72	0	0	0	0	0	6	0	0	0	0	0
Open Pit	26,704	410	3.22	31.2	3.2	3.2E - 03	7.2E - 03	9.8E - 05	1.8E - 03	1.5E - 07	72	3.2E - 03	1.6E - 01	9.8E - 05	4.1E - 02	2.6E -07	6	3.2E - 03	1.4E - 02	9.8E - 05	3.4E - 03	1.8E - 07
Pathway Dose							1.7E - 02		4.3E - 03	3.5E - 07			3.8E - 01		9.7E - 02	6.2E - 07			3.2E - 02		8.6E - 03	4.3E - 07

1 Gamma exposure and radon flux due to OSA consolidation determined by grading plan for 300-Foot Level Pile; Residual dose/risk assumed to be zero at removed mine rock piles; residual dose/risk would remain
2 MicroShield® calculated gamma exposure rate for 2-foot thick cover, 1-foot thick cover extrapolated for mine roads
3 RADON code calculated flux for 2-Foot thick onsite material cover

Table F-7. Calculated Dose/Risk – Mine Rock Alternative M-5 - Consolidate all piles to Open Pit Repository and cover with 2-foot thick on-site material[1]

					Dose/Risk to Site Visitor						Dose/Risk to Mineral Exploration Worker						Dose/Risk to Forest Service Worker					
	Pile Area (SF)	Longest Length (ft)	Gamma Exposure[2] Rate (uR/hr)	Radon Exit Flux[3] (pCi/m²/sec)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (30 years)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose (mrem/y)	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (3 year)	Exposure Time (hrs/year)	Direct Gamma Dose Rate (urem/hr)	Gamma Dose Factor	Radon Decay Product Conc. (WL)	Radon Dose (mrem/y)	Lifetime Risk (25 years)
OSA	0	0	0	0	134.4	0	0	0	0	0	144	0	0	0	0	0	12	0	0	0	0	0
300-Foot Level Mine Rock Pile	0	0	0	0	9.6	0	0	0	0	0	216	0	0	0	0	0	18	0	0	0	0	0
700-Foot Level Mine Rock Pile	0	0	0	0	9.6	0	0	0	0	0	216	0	0	0	0	0	18	0	0	0	0	0
900-Foot Level North Pile	0	0	0	0	3.2	0	0	0	0	0	72	0	0	0	0	0	6	0	0	0	0	0
900-Foot Level South Pile	0	0	0	0	3.2	0	0	0	0	0	72	0	0	0	0	0	6	0	0	0	0	0
Open Pit	115,576	410	1.46	16.2	3.2	1.5E - 03	3.3E - 03	5.1E - 05	8.8E - 04	6.7E - 08	72	1.5E - 03	7.4E - 02	4.7E - 05	2.0E - 02	1.2E - 07	6	1.5E - 03	6.1E - 03	4.7E - 05	1.6E - 03	8.3E - 08
Pathway Dose							3.3E - 03		8.8E - 04	6.7E - 08			7.4E - 02		2.0E - 02	1.2E - 07			6.1E - 03		1.6E - 03	8.3E - 08

1 Lowest Activity would be placed on top in Open Pit Repository; Material placement determined by grading plan with 300-Foot Level placed on top; Residual dose/risk assumed to be zero at removed mine rock piles; residual dose/risk would remain
2 MicroShield® calculated gamma exposure rate for 2-foot thick cover, 1-foot thick cover extrapolated for mine roads
3 RADON code calculated flux for 2-foot thick onsite material cover

Table F-8. Calculated Dose/Risk – Portal Alternatives

		300-Foot Level Portal	700-Foot Level Portal	900-Foot Level Portal	Air Ventilation Shaft	Open Pit		Radon Dose - Site Visitor (mrem/y)				Radon Dose - Mineral Exploration Worker				Radon Dose - Forest Service Worker			
	Alternative	Estimated Radon Decay Product Concentration (WL)	Estimated Radon Decay Product Concentration (WL)	Estimated Radon Decay Product Concentration (WL)	Estimated Radon Decay Product Concentration (WL)	Estimated Radon Decay Product Concentration (WL)	Average Radon Decay Product Concentration (WL) Note 3	Exposure Time (h/y)	Radon Decay Product Exposure (WLM/y)	Radon Dose (mrem/y)	Lifetime Risk (30 Years)	Exposure Time (h/y)	Radon Decay Product Exposure (WLM/y)	Radon Dose (mrem/y)	Lifetime Risk (1 year)	Exposure Time (h/y)	Radon Decay Product Exposure (WLM/y)	Radon Dose (mrem/y)	Lifetime Risk (25 Years)
1	No Action	0.291	0.023	0.163	0.039	See Mine Rock	0.129	28.0	0.021	21.2	3.2E - 04	648	0.492	492	7.4E - 04	54	0.041	41.0	5.1E - 04
2	300-Level Portal Gate (Note 1)	0.291	0.000	0.000	0.000	See Mine Rock	0.073	28.0	0.012	12.0	1.8E - 04	648	0.277	277	4.2E - 04	54	0.023	23.1	2.9E - 04
3	300-Foot Level Portal Backfill (Note 2)	0.291	0.000	0.000	0.000	See Mine Rock	0.073	28.0	0.012	12.0	1.8E - 04	648	0.277	277	4.2E - 04	54	0.023	23.1	2.9E - 04
4	300-Foot Level Portal Bulkhead	0.000	0.000	0.000	0.000	See Mine Rock	0.000	28.0	0.000	0.0	0.0E+00	648	0.000	0	0	54	0.000	0.0	0

1 Significant reduction in air flow, but reduction in radon exhalation indeterminable
2 Significant reduction in air flow and radon exhalation, but reduction in radon exhalation indeterminable
3 The site visitor, mineral exploration worker, and forest service worker were assumed to spend equal amounts of time per year at each location. Therefore, the average radon decay product concentration was multiplied by the total number of hours per year of exposure in the mined areas