REPORT

URANIUM MILL TAILINGS RADON FLUX CALCULATIONS

PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

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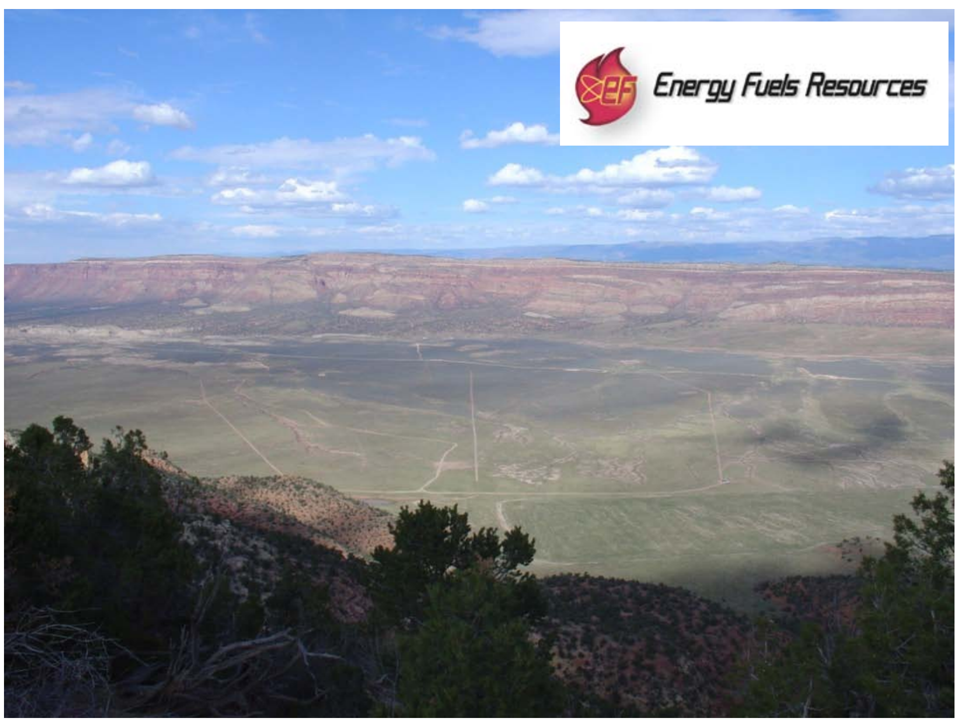

August 2010 **Project No. 073-81694.23**

EXECUTIVE SUMMARY

Energy Fuels Resources Corporation (EFRC) proposes to license, construct, and operate a conventional acid leach uranium and vanadium mill at the Piñon Ridge Property in western Montrose County, Colorado. The Piñon Ridge Mill includes an administration building, a 17-acre mill, a 30.5-acre tailings cell with phased expansion capacity to 91.5 acres, a 40-acre evaporation pond area with an expansion capacity to 80 acres, an approximately 6-acre ore storage pad, and access roads. The mill is designed to process ore containing uranium and vanadium produced from mines located within a reasonable haul distance on the Colorado Plateau.

Golder Associates Inc. (Golder) was commissioned by EFRC to evaluate the operations of the uranium mill tailings storage facility at the Piñon Ridge Mill in terms of the 20 pCi/m²s radon (Rn-222) flux standard that applies to uranium tailings facilities constructed prior to 1989. Although this flux standard does not apply to new facilities such as the Piñon Ridge Mill, it did play an inherent role in establishing the tailings disposal practices and maximum areas specified for new facilities under the U.S. Environmental Protection Agency (EPA) regulations found in 40 CFR 61 Subpart W, "National Emission Standards for Radon Emissions from Operating Mill Tailings" (EPA, 1998). EFRC had expressed a desire to maintain radon flux levels from the tailings to "As Low As Reasonably Achievable" (ALARA) levels, as required by State of Colorado and U.S. Nuclear Regulatory Commission (NRC) regulations. To achieve this goal, EFRC requested that Golder evaluate radon flux levels under a range of potential operating conditions.

The radon flux calculations presented in this report were conducted using the WISE Uranium Mill Tailings Radon Flux Calculator, as updated on November 23, 2009 (WISE, 2009). The results of these calculations show that the radon flux levels of the proposed uranium mill tailings facility at the Piñon Ridge Mill site will be less than 20 pCi/m²s under normal operating procedures whereby the tailings are maintained in a saturated state. Golder also assessed various unsaturated scenarios that could occur in the event of temporary equipment failure or during pre-closure operations when the water cover will be eliminated, and found that the radon flux remained less than 20 pCi/m²s under drying conditions with up to 20 percent of the tailings surface being unsaturated.

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1.0 INTRODUCTION

This report was prepared by Golder Associates Inc. (Golder) to assist Energy Fuels Resources Corporation (EFRC) in developing its operating plan for the Piñon Ridge tailings cells and evaporation ponds (EFRC, 2010). The average radon (Rn-222) flux levels for its proposed tailings cells were evaluated under normal operating conditions and under drying conditions where a portion of the tailings may lose saturation. The resulting flux levels were compared to the 20 pCi/m²s flux limit adopted for the much larger pre-1989 tailings facilities in 40 CFR 61 Subpart W, "National Emission Standards for Radon Emissions from Operating Mill Tailings" (EPA, 1998). This standard does not apply to the Piñon Ridge Mill per se, as the mill tailings facility meets the standard found in 40 CFR Subpart W 61.252 (b) (1) for facilities constructed after December 15, 1989 for phased disposal. This standard limits phased disposal to no more than two tailings impoundments in operation at any one time and limits the maximum size of the impoundments to 40 acres. However, EFRC plans to reduce radon flux levels to "As Low As Reasonably Achievable" (ALARA) levels, as defined in the Colorado Department of Public Health and Environment (CDPHE) and U.S. Nuclear Regulatory Commission (NRC) regulations by implementing tailings operating practices designed to limit radon flux. The 20 pCi/m²s flux level represents a convenient yardstick for evaluating tailings operating practices, as this flux rate was used by the U.S. Environmental Protection Agency (EPA) in its previous Subpart W rulemaking in assessing the associated health risks of both pre- and post-1989 tailings facilities.

The radon flux calculations in this report were conducted using the WISE Uranium Mill Tailings Radon Flux Calculator, as updated on November 23, 2009 (WISE, 2009). The results of these calculations show that the proposed uranium mill tailings facilities at the Piñon Ridge Mill site will produce substantially less than 20 pCi/m²s radon flux under normal operating conditions and procedures whereby the tailings are maintained in a saturated state. This report also assessed various unsaturated scenarios that could occur in the event of temporary equipment failure or during standby or pre-closure periods when water cover would be reduced and found that the 20 pCi/m²s flux level was not exceeded under drying conditions with up to 20 percent of the tailings surface being unsaturated.

2.0 SITE DESCRIPTION

EFRC proposes to license, construct, and operate a conventional acid leach uranium and vanadium mill at the Piñon Ridge Property in western Montrose County, Colorado. The property covers approximately 880 acres in the southeastern portion of Paradox Valley. The proposed Piñon Ridge Mill is located at 16910 Highway 90, approximately 7 miles east of Bedrock, Colorado, and 12 miles west of Naturita, Colorado. Figure 1 shows the location of the proposed project site.

The Piñon Ridge Mill is designed to process ore containing uranium and vanadium produced from mines located within a reasonable haul distance on the Colorado Plateau. The facility includes an administration building, a 17-acre mill, a 30.5-acre tailings cell with phased expansion capacity to 91.5 acres, a 40-acre evaporation pond area with an expansion capacity to 80 acres, an approximately 6-acre ore storage pad, and access roads. The phased expansion plan is designed to meet the standard found in 40 CFR Subpart W 61.252 (b) (1), as only two 30.5-acre tailings cells would be in operation at any one time. This would only occur for a relatively short transition period when the first cell is reaching its full capacity and a second cell is being put into service. The proposed uranium mill and tailings facilities at full build-out are shown in Figure 2.

The mill will initially process 500 tons of ore per day (tpd), but is designed to accommodate future expansion of production capacity to 1,000 tpd. The projected operating life of the facility is 40 years, operating 24 hours per day, 350 days per year at 500 tpd.

The ore to be processed at the mill contains elevated concentrations of natural uranium and its decay products. The average uranium content in the blended ore is 0.23 percent U_3O_8.

3.0 MILL TAILINGS RADON FLUX EVALUATION

3.1 Description of the Uranium Mill Tailings Radon Flux Calculator

The Uranium Mill Tailings Radon Flux Calculator evaluates the radon flux from a bare and/or water-covered uranium mill tailings storage area. The calculator is based on the modeling work of Nielson (Nielson and Rogers, 1986).

The model performs one-dimensional, steady-state radon diffusion calculations for various areas of the tailings deposit. For the submerged area, the model calculates the radon transport from the tailings through the impounded water to the top of the surface, and radon released from radium dissolved in the impounded water that covers the submerged tailings. It assumes that all radon reaching the top 1-meter (3.28 foot) layer of the water is released into the air, as well as all radon produced from dissolved radium in this top layer. The following areas are calculated in the model:

- Submerged Tailings Under Impounded Water. This area is primarily comprised of the smaller particle size material in the tailings ("slimes") which are preferentially accumulated in the center of the tailings storage facility as tailings are deposited. The submerged tailings consider two separate areas in the calculation:
  - Submerged area at a depth of 1 meter or less; and
  - Submerged area at greater than 1 meter.
- Saturated Beach. This area is located on the perimeter of the tailings storage facility and represents a mixture of particle size material ("slimes and sands") which deposits on the perimeter beaches. This area, while not covered with tailings water, will be wetted with recycled raffinate solution or tailings water to keep the tailings fully saturated. Keeping the tailings saturated in this manner minimizes the radon flux from the beach areas of the tailings cell.
- Unsaturated Zone. While it is the intent of EFRC to keep all beaches fully saturated, there may be some interim period where small areas of the tailings surface may become temporarily unsaturated due to mechanical failure of the water recycle system, or due to reduction in water cover during standby or pre-closure periods. Hence, calculations were performed to evaluate the maximum percentage of unsaturated tailings exposure that would still result in a radon flux level below 20 pCi/m^2s.

The various areas used for the radon flux calculations are shown in Figure 3.

3.2 Input Data

The physical and radiological properties of the uranium mill tailings that were input into the model are defined below. While the model allows for default parameters to be used, the most meaningful results for actual site conditions are obtained if site-specific data is used. Since the tailings facility has not been built and no actual tailings have been processed, data from other representative uranium mill sites has been used wherever possible together with sampling data for typical Salt Wash ores that will comprise the proposed feed to the Piñon Mill. The effective radon diffusion coefficients were obtained using methods developed by Nielson and Rogers (1986) and Rogers and Nielson (1991).

3.2.1 General Tailings Properties

This section provides discussion of the general tailings properties used in the radon flux modeling and the specific values used for the Piñon Ridge project.

3.2.1.1 Ra-226 Activity Concentration in the Uranium Tailings [pCi/g]

This input parameter is the overall activity concentration of radium-226 in the bulk tailings material. The value for the equilibrium concentration of radium-226 was calculated based on the average grade of the ore that will be processed. The average uranium content in the blended ore is expected to be 0.23 percent U_3O_8.

The activity of U-238 in the Piñon Ridge uranium tailings was evaluated as follows:

EQUATION 1

$$Activity = \left[\frac{0.0023(g_{U_3O_8})}{(g_{ore})}\right]\cdot\left[\frac{0.85(g_{U-238})}{(g_{U_3O_8})}\right]\cdot\left[\frac{330{,}000(pCi_{U-238})}{(g_{U-238})}\right] = 647\frac{(pCi_{U-238})}{(g_{ore})}$$

Assuming secular equilibrium in the ore between uranium-238 and radium-226, and that all radium goes into the tailings, the activity of radium-226 will be 647pCi/g.

3.2.1.2 Ra-226 Activity Ratio in Slimes vs. Sand

This input parameter estimates the ratio of radium-226 activity concentrations in the slimes fraction vs. the sand fraction of the tailings material. The radium-226 activity concentrations typically increase with decreasing particle size and the slimes will contain a higher concentration of radium-226. A ratio of 4 has been used in the calculations, which corresponds to the value used by Nielson and Rogers (1986) in the development of the model.

3.2.1.3 Rn-222 Emanation Fraction in Slimes

This input parameter is the fraction of the total amount of radon-222 produced by radium decay that escapes from the solid fraction of the slimes tailings particles and gets into the pores of the material. The value depends on the tailings material and the moisture content. It varies over a range of 0.1 to 0.4 with typical values in the range of 0.2 to 0.3. Nielson and Rogers (1986) uses a value of 0.22 for the tailings slimes, and this value was used in the calculation for the Piñon Ridge project.

3.2.1.4 Rn-222 Emanation Fraction in Sand

This input parameter is the fraction of the total amount of radon-222 produced by radium decay that escapes from the solid fraction of the sand tailings particles and gets into the pores of the material. The value depends on the tailings material and the moisture content. This parameter typically varies over a range of 0.1 to 0.4. Nielson and Rogers (1986) uses a value of 0.15 for the tailings sands, and this value was used in the calculation for the Piñon Ridge project.

3.2.1.5 Fraction Passing #200 Mesh (75 µm)

This input parameter is the fraction by weight of the overall bulk tailings material passing a No. 200 mesh, corresponding to a particle diameter of 75 µm or less. Since a 75-µm particle diameter typically marks the sand/silt dividing line, this figure denominates the fraction that is not sand, or the fraction of combined silt and clay contents ("slimes").

The value used for this parameter is taken from data as reported in Golder (2008a). The fraction for the bulk tailings material passing the #200 mesh is 0.379 (i.e., 37.9 percent). This gradation is based on data obtained from processing of Salt Wash ores at the White Mesa Mill in Blanding, Utah.

3.2.1.6 Fraction of Pond Area with less than 1 m depth

This input parameter is the fraction of the pond area that has less than 1 meter of water cover. This fraction was determined graphically for various percentages of total water cover based on the projected slope of the underlying coarse and fine tailings. The tailings with less than 1 meter of water cover contribute to the radon flux of the facility.

3.2.1.7 Average Pond Depth for Areas greater than 1 m deep

This input parameter is the depth of the pond area that has greater than 1 meter of water cover. This depth was determined graphically for various percentages of total water cover based on the projected slope of the underlying coarse and fine tailings. The tailings with greater than 1 meter of water cover do not contribute to the radon flux of the facility.

3.2.1.8 Ra-226 Activity Concentration in Impounded Water [pCi/L]

This input parameter is the activity concentration of dissolved radium-226 in the impounded water covering the deposited tailings material. As previously discussed, the uranium content of the projected ore to be processed at the Piñon Ridge Mill has been determined to be 0.23 percent U_3O_8, which leads to a radium activity of 647 pCi/g (refer to Section 3.2.1.1). The specific Ra-226 content of the impounded water in equilibrium with the tailings material was estimated using the values previously established for a model mill in the U.S. Nuclear Regulatory Commission (NRC) NUREG-0706 “Final Generic EIS on Uranium Milling” (NRC, 1980; Table 5.3). This document lists an activity level of 250 pCi/L Ra-226 for tailings solution at the model mill based on an activity level of 280 pCi/g Ra-226 in the ore. Scaling up to the expected higher uranium and radium activity levels in the Piñon Ridge ore of 647 pCi/g, the calculated radium activity level of the tailings solution in equilibrium with the tailings is 581 pCi/L.

3.2.1.9 Effective Stagnant Water Transport Coefficient [m^2/s]

This parameter describes radon transport in water. The established value for this parameter is 3×10^{-7} m^2/s, as determined by Nielson and Rogers (1986).

3.2.2 Zone-Specific Tailings Properties

The following parameters describe the specific properties of each tailings area: (i) the area submerged under impounded water; (ii) the saturated beach area; and (iii) the unsaturated area.

3.2.2.1 Surface Area [m²]

This parameter is the surface area for a given type of tailings. A calculation was made for each of the three areas in the tailings cell: the submerged area, the saturated area, and the unsaturated area. If no tailings exist in any particular area, then a value of zero (0) is entered and the area is discarded. The calculations were based on a tailings cell area of approximately 30.5 acres (120,365 m^2).

3.2.2.2 Bulk Density [g/cm³]

Each area of the tailing cell will have specific bulk density properties due to the nature of the deposition of tailings in the tailings cell. As reported in the tailings settlement report (Golder, 2010), the average dry density of tailings after initial settlement with release of water to the tailings pool is expected to be 79.2 pounds per cubic foot (pcf), or 1.27 grams per cubic centimeters (g/cm^3). The submerged, saturated, and unsaturated areas in the tailings cell will each have different dry densities depending on the amount of slimes and sands in these areas.

For the submerged area, which is mostly comprised of finer particle material ("slimes"), a bulk density value of 70 pcf was used. This corresponds to the expected average density for the material that will collect in the central part of the tailings cell, which will be submerged for most of the time while the tailings cell is being filled. This corresponds to a dry bulk density of 1.12 g/cm^3. For the saturated transition area, which is comprised mostly of sandy material with some amount of slimes, an average bulk density value of 80 pcf was used. This corresponded to a dry bulk density of 1.28 g/cm^3. For the sandy beach material, a bulk density of 90 pcf was used, which corresponds to a dry bulk density of 1.44 g/cm^3.

These dry density determinations were made after reviewing the available physical parameter information for the Atlas Moab tailings area (Golder, 2005), which indicated that the tailings density ranged from 50.2 pcf to 88.6 pcf for the slimes to a range of 81 to 106 pcf for the sand materials. The Piñon Ridge Mill tailings facility is expected to achieve higher densities because dewatering will be facilitated by the barge-mounted pump-back system and the tailings cell underdrain system. It is important to note that the dry density of 70 to 90 pcf for the Piñon Ridge tailings applies only to the near-surface tailings that are contributing to the radon flux. Tailings at depth will have substantially higher densities due to consolidation. The tailings density will also increase further after placement of the soil cover during cell closure.

3.2.2.3 Porosity

The porosity (n) of the tailings material is the ratio of the pore volume (air- and water-filled) to the total volume of the tailings. This value was calculated using the following relationship:

EQUATION 2

$$n = \frac{e}{1+e}$$

where e is the void ratio. Limited data on void ratio is available for existing tailings facilities. The data from the Moab tailings area showed that the void ratio for the finer particle material ("slimes") was 1.35 using the same criteria for densification modifications that were used for the determination of the dry bulk densities. This corresponds to a porosity of 0.57 for the slimes. This value, which was input into the model, is higher than the default value used in the model and is considerably more conservative (i.e., a higher porosity results in a higher radon flux).

For the average tailings material in the saturated area and unsaturated area of the tailings cell, a void ratio of 0.65 was used based on data from the Moab tailings area, which resulted in a porosity of 0.39. The model uses a default value of porosity of 0.4 for all areas of the tailings cell.

3.2.2.4 Moisture Content [dry wt %]

During the majority of operations, the tailings will either be submerged or fully saturated. The only area where percent moisture needs to be specified in the model is the unsaturated area. The moisture content of unsaturated tailings was assumed to be 15 percent, which is a relatively conservative estimate. By comparison, the moisture content in the unsaturated Atlas tailings ranged from approximately 21 percent to 28 percent when measured in the early 1980s (Golder, 2005).

3.2.2.5 Fraction Passing No. 200 Mesh (75 µm)

The fraction of material passing the No. 200 mesh provides an indication of the particle size of the material. Since 75 µm (the opening size of the No. 200 mesh) typically marks the dividing line between silts/clays ("slimes") and sands, each of the zones in the tailings cell will have different characteristics for this parameter. The average amount of fines passing a No. 200 mesh in the tailings discharge has been estimated to be 0.379 (Golder, 2008a). An estimate of the distribution of these fines through the various areas of the tailings cell was made based on a material balance calculation. Assuming that the tailings cell consists of 33.3% submerged fines, 33.3% transitional sands/fines and 33.3% sandy material, the fraction passing through the No. 200 mesh would be 0.72, 0.36 and 0.05 respectively. These proportions are roughly based on the percentages of fines observed in the Atlas Tailings Impoundment of 0.95, 0.45, and 0.21 for slimes, sand/slimes, and sands, respectively (Golder, 2005). However, the Atlas Mill processed ores from several different formations (using both acid and alkaline leach processes) and the resultant tailings contained more fines than the proposed Salt Wash ores.

The model uses a default distribution for minus No. 200 mesh tailings of 0.5, 0.3 and 0.0 for the three areas. Because the model has a higher default value for fines passing a No. 200 mesh in all of the tailings (i.e., 0.40) than the Salt Wash ores (0.379), it is apparent that the model assumes a proportionately larger area of slimes. This large slime area was common at historic tailings impoundments, which were typically 100 acres or more in size and the tailings were discharged from only a few points. This resulted in greater segregation between finer and coarser particles and a larger slime area. The smaller Piñon Ridge tailings cells will have multiple discharge points around the perimeter of each cell that is expected to result in the concentration of finer tailings within the center of each cell and in the development of a larger and more uniform transitional area between the slimes and sands.

3.2.2.6 Rn-222 Effective Diffusion Coefficient [m²/s]

The effective diffusion coefficient (De) for radon-222 is defined from Fick's equation as the ratio of the diffusive flux density of radon activity across the pore area to the gradient of the radon activity concentration in the pore or interstitial space. The diffusion coefficient in porous media is a property of the diffusing species, the pore structure, the type of fluids present in the pores, the adsorption properties of the solid matrix, the fluid saturations, and temperature. The Radon Flux Calculator Model calculates this value from the correlations from Nielson and Rogers (1986) using porosity and moisture content. The model also allows the input of experimental radon diffusion coefficients or coefficients obtained from more reliable sources.

The effective radon diffusivity values in porous media can vary over a wide range of values depending on the porosity of the material and particularly on its degree of water saturation. In a fully saturated soil material, the radon diffusion coefficient may be as low as 10^{-10} m²/s and, at the upper limit, the diffusion coefficient for air of 1.1×10^{-5} m²/s. Typically, the effective diffusion coefficient of radon in unconsolidated soil material with varying moisture content ranges from 10^{-6} m²/s to 10^{-10} m²/s. While the radon flux model uses an existing correlation to determine the effective radon diffusion coefficient, the user is encouraged to input experimentally determined effective diffusion coefficients or other more reliable diffusion coefficient information to increase the accuracy of the calculation.

Subsequent to the correlations that were used in developing the radon flux model, Rogers and Nielson (1991) have conducted additional correlations and proposed an updated correlation for the effective diffusion coefficient, D_e, as follows:

EQUATION 3

$$D_e = D_o p_t \exp(-6 p_t R_s - 6 R_s^{14 p_t})$$

where D_o (equal to 1.1×10^{-5} m²/s) is the radon diffusivity in open air, p_t is the total soil porosity, and R_s is the water saturation in the soil (or the fraction of the pore space filled with water, also called the saturation ratio).

This correlation has also been used in the latest User's Manual for RESRAD modeling (Yu et al., 2001) and in the support documentation for the modeling impacts on radioactive soils (Yu et al., 2003).

Calculations to determine the effective radon diffusion coefficients were made using this updated correlation. For example, the calculation of D_e for the case of saturated tailings (i.e., R_s = 1) having a total porosity (p_t) of 0.39 is as follows:

EQUATION 4

$$D_e = (1.1x10^{-5}\ m^2/s)\exp((-6)\cdot(0.39)\cdot(1)-(6)\cdot(1)^{(14\cdot 0.39)}) = 1.03x10^{-9}\ m^2/s$$

4.0 RADON FLUX MODELING RESULTS

4.1 Mill Tailings Operational Scenarios

Details of the design and operation of the proposed 30.5-acre tailings facility are given in Golder (2008b). The evaluation of radon flux from various operational scenarios from initial filling of the tailings cell to full capacity has been calculated for the following cases:

- Case 1: Initial Fill - 100% water cover;
- Case 2: Partial Fill - 80% water cover;
- Case 3: Partial Fill - 50% water cover;
- Case 4: Partial Fill - 20% water cover; and
- Case 5: Final Fill - 0% water cover.

Typically, the tailings cell will operate with 20 to 80 percent water cover with the smaller water cover occurring during the summer evaporation season and the larger water cover occurring in the winter. One hundred percent water cover would normally occur only during the initial filling of the cell when the area of tailings deposition is much smaller, or after a very large precipitation event. Zero percent water cover would normally occur only during the pre-closure period when the tailings solution is removed to achieve final deposition grades and allow for the start of closure activities (EFRC, 2010).

For each of the scenarios, it is assumed that the tailings will be deposited uniformly on the tailings beaches around the tailings cell perimeter, and that all of the surface area of the tailings cell will contain tailings. This represents a point in the operation of the tailings facility when the cell is nearing full capacity.

The proposed operating procedures for the filling and maintenance of the tailings facility dictates that the tailings will be kept saturated by applying tailings or raffinate solutions on the deposited tailings material. The raffinate is the barren process solution that is pumped to the evaporation ponds for disposal. Since water saturation will aid in the retardation of radon release, the normal mode of operation will be to keep the tailings wet at all times. The tailings facility will be considered to be in an operational mode from initial filling through the pre-closure steps described in the “Operating Plan, Tailings Cells and Evaporation Ponds” (EFRC, 2010). Once full, the tailings cell will be considered in closure mode and a radon and evapotranspiration cover will be placed over the tailings to permanently suppress radon flux in accordance with plans approved by the Radiation Control Program of the Colorado Department of Public Health and Environment (CDPHE).

Although EFRC plans to continuously keep the beach areas on the perimeter saturated during operations, there may be some interim period where a limited amount of the tailings surface may temporarily become unsaturated due to mechanical failure of the water recycle system, other unforeseen circumstances, or during the transition from operational to closure mode. While it is not the intent of EFRC to allow areas of unsaturated tailings to be exposed for any significant length of time, a series of model runs were performed which evaluated how much unsaturated tailings material could be allowed on an interim basis while still staying below 20 pCi/m²s of radon flux.

4.2 Radon Flux Model Calculation Results

The radon model was run for the various water cover scenarios outlined in Section 4.1. The results of these calculations are presented in Table 1 and Figure 4. The results indicate that the radon flux will be below 20 pCi/m²s for all scenarios. The radon flux generated for the case with 100 percent water cover is primarily attributable to the area with less than 1 meter of water cover. The model input parameters and data output are provided in Appendix A.

TABLE 1
RESULTS OF RADON FLUX MODEL

Case	Water Cover (%)	Radon Flux (pCi/m²s)
1	100	2.62
2	80	3.27
3	50	5.05
4	20	6.79
5	0	7.44

Modeling of unsaturated tailings was also performed to determine how much unsaturated material could be exposed during operations should the solution application system be temporarily shut down for repairs or other reasons. These results are shown in Table 2 for the worst case of zero percent water cover. Other percentages of water cover of course would show allowable unsaturated tailings areas in excess of the values in Table 2. The percentages calculated were of the saturated material rather than the whole of the tailings area. As can be seen from this table, the radon flux for all cases shows that some degree of unsaturated tailings can be allowed while still remaining below 20 pCi/m²s of radon flux.

TABLE 2
RADON FLUX WITH UNSATURATED TAILINGS EXPOSURE

Case	Water Cover (%)	Unsaturated Tailings (%)	Radon Flux (pCi/m²s)
1	0	5	10.57
2	0	10	13.70
3	0	20	19.95

The details of these calculations are provided in Appendix B.

4.3 Atmospheric Radon Concentrations

The results of radon flux values for the tailings facility cannot readily be converted to airborne radon concentrations due to the need for meteorological modeling and determination of where the airborne concentrations would be measured. EPA has estimated the maximum radon air concentration at the edge of a uranium tailings cell (WISE, 2009; EPA, 1983). Based on these estimates, and assuming a maximum radon flux at the surface of the tailings cell of 20 pCi/m^{2}sec, the maximum radon in the air would be approximately 0.28 pCi/l. Since the tailings cells will typically have a radon flux well below 20 pCi/m^{2}sec, the air concentration of radon near the Piñon Ridge tailings cells is expected to be proportionately lower.

The report "Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill" (Two Lines, 2009) also provides insight on the potential radon doses resulting from the ore stockpile, tailings cells, and mill emissions. This report is included in EFRC's Radioactive Materials License Application to the Radiation Control Program of CDPHE. This study was conducted using the MILDOS Area model, which includes material properties, emission rates, and site-specific meteorological data as model inputs. The study projected that radon doses at the property's fence line from all sources would range from 1.2 to 9.0 millirems per year (mrem/yr), and the nearest residents to the mill would receive a dose of less than 1 mrem/year. The study conservatively assumed that one tailings cell had reached capacity and a second tailings cell was in the initial stages of operation.

5.0 CONCLUSIONS

Golder was commissioned by EFRC to evaluate the operations of the uranium mill tailings storage facility at the Piñon Ridge Mill in terms of radon flux. The evaluation focused on identifying the flux levels produced during normal operations whereby tailings would be maintained in a saturated state with varying levels of water cover depending on the season and stage of operations. Operating flux levels were compared to the 20 pCi/m^2s flux limit established by the U.S. Environmental Protection Agency (EPA) in 40 CFR 61 Subpart W, "National Emission Standards for Radon Emissions from Operating Mill Tailings" (EPA, 1998) for pre-1989 tailings impoundments. The evaluation also looked at the flux levels that would occur as tailings lose some level of saturation due to drying conditions.

The radon flux calculations presented in this report were conducted using the WISE Uranium Mill Tailings Radon Flux Calculator, as updated on November 23, 2009 (WISE, 2009). The results of the radon flux modeling calculations demonstrate that the proposed normal mode of operation will maintain radon flux levels well below 20 pCi/m^2s. The modeling has also shown that some fraction of the tailings deposition can be unsaturated while still maintaining flux levels below 20 pCi/m^2s. This situation could occur as a result of equipment breakdown or during the transition from operational to closure mode.

6.0 USE OF THIS REPORT

This report has been prepared exclusively for the use of Energy Fuels Resources Corporation (EFRC) for specific application to the Piñon Ridge Project. The analyses reported herein were performed in accordance with accepted practices. No third-party engineer or consultant shall be entitled to rely on any of the information, conclusions, or opinions contained in this report without the written approval of Golder and EFRC.

Golder sincerely appreciates the opportunity to support EFRC on the Piñon Ridge Project. Please contact the undersigned with any questions or comments on the information contained in this report.

Respectfully submitted,

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7.0 REFERENCES

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FIGURES

LEGEND

- Property Boundary
- Town
- Interstate
- Highway
- Major Road
- Local Road
- National Park or Forest
- State
- County
- Stream
- Intermittent Stream
- Dam
- Reservoir

REFERENCES

Base Data: ESRI, 2009.
Imagery: ESRI API, Assorted Dates.
Projection: StatePlane, Colorado South, NAD83, Feet.

N

10 5 0 10 MILES

SCALE 1:500,000
WHEN PRODUCED AT SIZE 11X17IN

PROJECT

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

TITLE

SITE LOCATION MAP

Golder Associates
Denver, Colorado

PROJECT No.		073-81694	FILE No.	11x17_SiteLoc.mxd
DESIGN	AJR	08/04/2010	SCALE AS SHOWN	REV 0
GIS	AJR	08/04/2010		
CHECK	SS	08/04/2010	FIGURE 1	
REVIEW	KFM	08/04/2010		

Map Document: M:\Pinonridge\ArcMap\RadonFluxCalc\11x17_SiteLoc.mxd / Modified 8/4/2010 3:12:01 PM / Plotted 8/4/2010 3:12:01 PM by AReither

Dwg Name: N:\07\073-81694_E RADON FLUX\07381694E001.dwg
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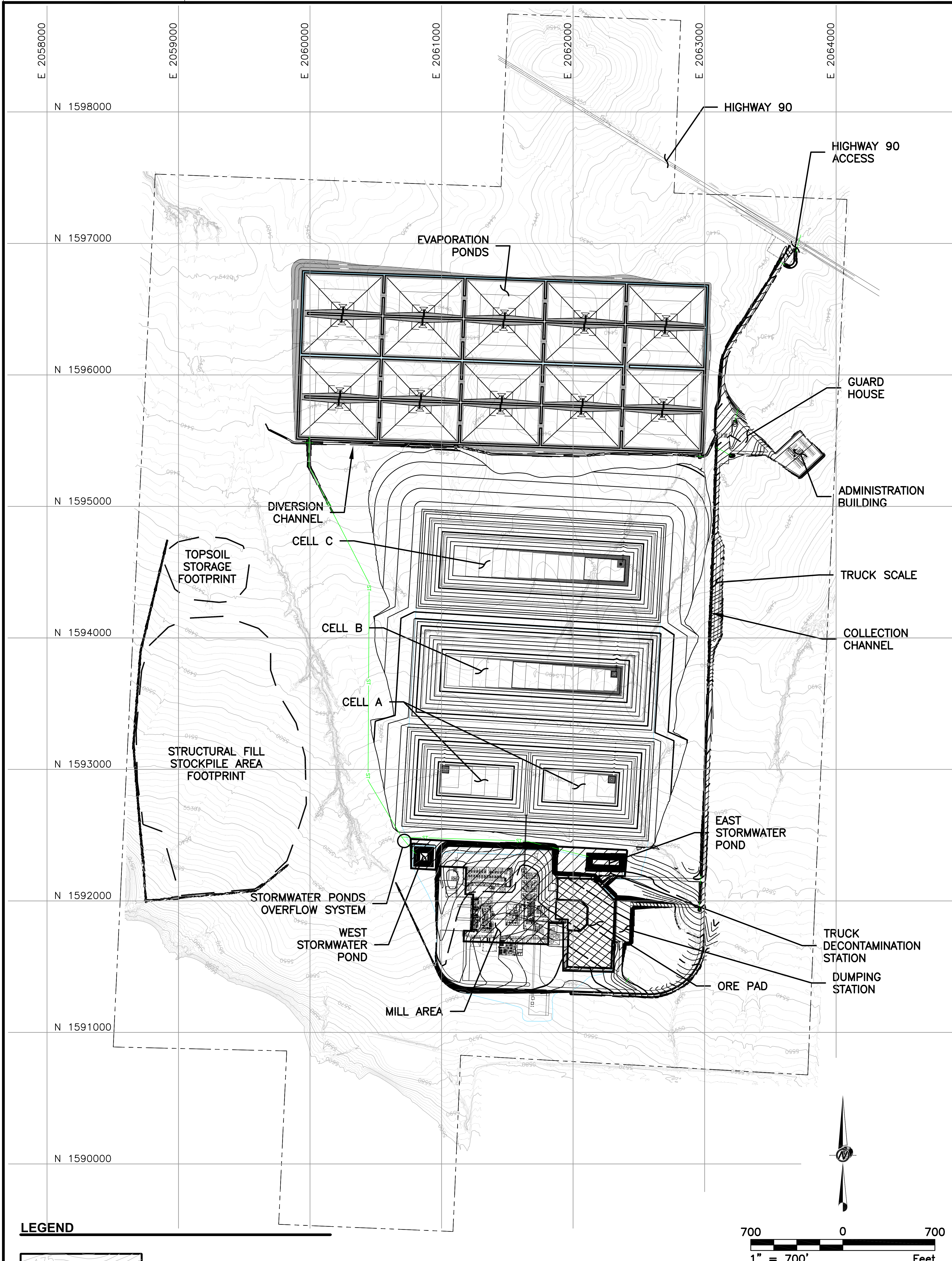
Last Update: Aug 04, 2010 10:20 By: NRosenthal
Last Plot: Aug 04, 2010 13:12 By: dsaunders



LEGEND

175 / 150	EXISTING GROUND TOPOGRAPHY
175 / 150	PROPOSED GRADES
	PROJECT BOUNDARY
ST	STORMWATER PONDS OVERFLOW SYSTEM
	STOCKPILE AREA FOOTPRINTS

PROJ.

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

TITLE

SITE FACILITIES MAP
FULL BUILD-OUT

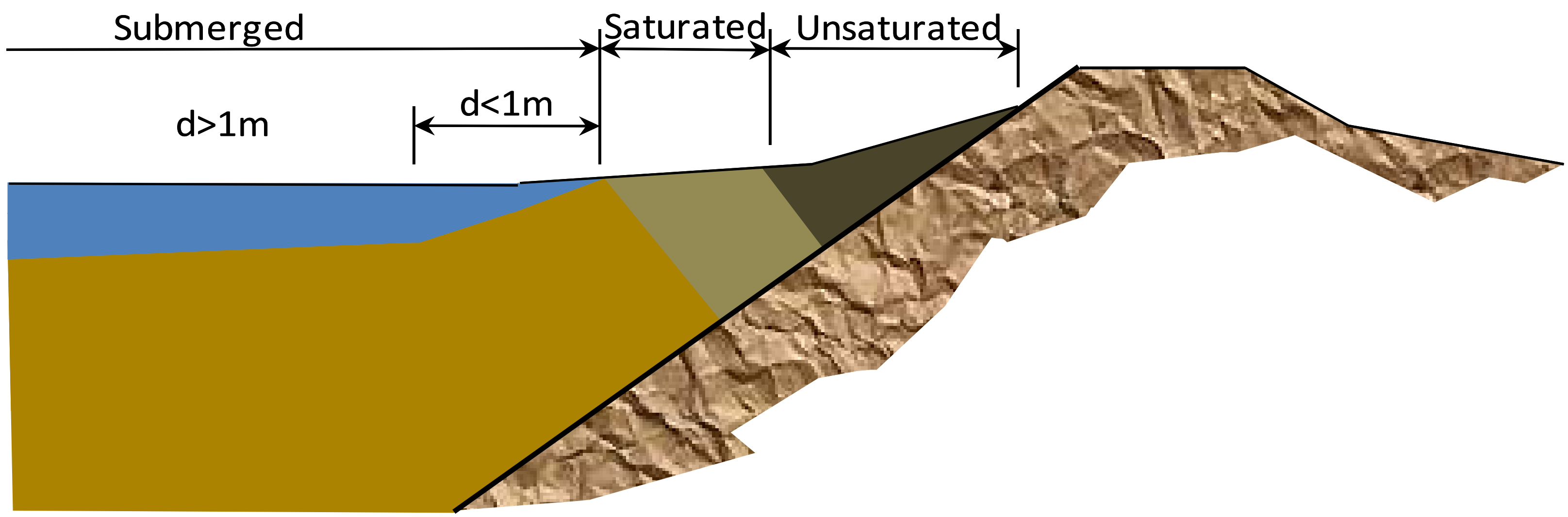
Golder Associates
DENVER, COLORADO

PROJECT No.		073-81694
DESIGN	SPS	08/02/10
CADD	NKR	08/02/10
CHECK	SPS	08/02/10
REVIEW	KFM	08/02/10

FILE No. 07381694E001
SCALE AS SHOWN REV. A

FIGURE 2

Plot Time: 08/04/10 13:12



Golder Associates

Denver, Colorado

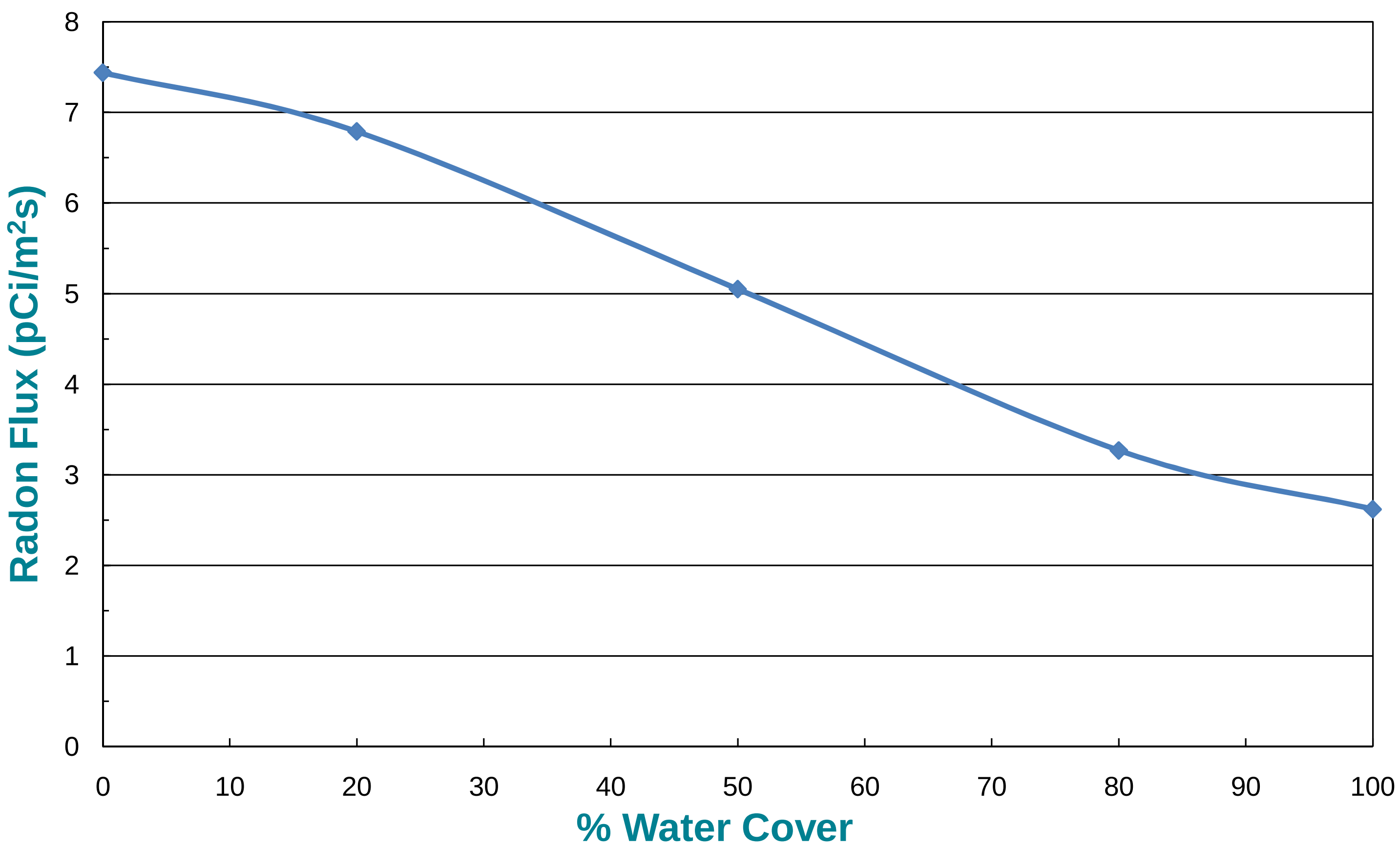
TITLE

Tailings Zonation Model Assumptions

CLIENT/PROJECT

ENERGY FUELS RESOURCES CORP.
PIÑON RIDGE PROJECT

DRAWN	KFM	DATE	Jul-10	JOB NO.	073-81694.0002
CHECKED	ET	SCALE	NTS	DWG. NO.	N/A
REVIEWED	ET	FILE NO.	TailingsZonationFigure.xls	FIGURE NO.	3



Golder Associates
Denver, Colorado

TITLE
Radon Flux vs. Percent Water Cover

CLIENT/PROJECT
ENERGY FUELS RESOURCES CORP.
PIÑON RIDGE PROJECT

DRAWN	ET	DATE	Aug-10	JOB NO.	073-81694.0023
CHECKED	KFM	SCALE	NTS	DWG. NO.	N/A
REVIEWED	ET	FILE NO.	07381694 RadonFluxCalc Fig4.xls	FIGURE NO.	4

APPENDIX A

DETAILS OF RADON FLUX CALCULATIONS FOR SATURATED AND SUBMERGED TAILINGS

Uranium Mill Tailings Radon Flux Calculations

Input Data / 0% Water Cover / 0% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	1	0	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	0	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	120365	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	0	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
7.44

Uranium Mill Tailings Radon Flux Calculations

Input Data / 20% Water Cover / 0% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	0.358	1.83	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	24073	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	96292	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	0	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
6.79

Uranium Mill Tailings Radon Flux Calculations

Input Data / 50% Water Cover / 0% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	0.19	2.43	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	60182	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	60182	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	0	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
5.05

Input Data / 80% Water Cover / 0% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	0.142	2.9	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	96292	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	24073	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	0	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
3.27

Uranium Mill Tailings Radon Flux Calculations

Input Data / 100% Water Cover / 0% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	0.2	3.05	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	120365	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	0	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	0	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
2.62

APPENDIX B

DETAILS OF RADON FLUX CALCULATIONS FOR ALLOWABLE UNSATURATED TAILINGS EXPOSURE

Uranium Mill Tailings Radon Flux Calculations

Input Data / 0% Water Cover / 5% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	1	0	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	0	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	114347	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	6018	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
10.57

Uranium Mill Tailings Radon Flux Calculations

Input Data / 0% Water Cover / 10% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	1	0	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	0	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	108329	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	12036	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
13.7

Golder Associates

Uranium Mill Tailings Radon Flux Calculations

Input Data / 0% Water Cover / 20% Unsaturated

Tailings Data

Ra - 226 Activity Concentrations in Tailings (pCi/g)	Ra - 226 Activity Ratio in slimes vs. sand	Ra - 222 Emanation Fraction in slimes	Ra - 222 Emanation Fraction in sand	Fraction Passing #200 Mesh (75 µm)	Fraction of Pond Area with less than 1 m deep	Average Pond Depth for Areas Greater than 1 m deep	Ra - 226 Activity Concentration in Ponding Water (pCi/l)	Effective Stagnant Water Transport coefficient (m^2/s)
647	4	0.22	0.15	0.379	1	0	578	3.00E-07

Zone - Specific Tailings Properties

Tailings Zone	Surface Area (m^2)	Bulk Density (g/cm^3)	Porosity	Moisture Contents (dry wt_%)	Fraction Passing #200 Mesh (75 µm)	Rn - 222 Effective Diffusion Coefficient (m^2/s)
Submerged	0	1.12	0.57	Saturated	0.72	5.08E-10
Saturated	96292	1.28	0.39	Saturated	0.36	1.03E-09
Unsaturated	24073	1.44	0.39	15	0.05	3.53E-05

Radon Flux Results pCi/m^2s
19.95