BASELINE RADIOLOGICAL INVESTIGATION REPORT

Rev. 0 **Date: July 29, 2009**

IN SUPPORT OF THE APPLICATION FOR A LICENSE FOR SOURCE MATERIAL MILLING

PIÑON RIDGE URANIUM MILL
Montrose County, Colorado

Submitted to:

Radiation Management Unit
Colorado Department of Public Health and Environment

Prepared for:

Energy Fuels Resources
44 Union Blvd., Suite 600
Lakewood, Colorado 80228

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Project No. 83088
DCN 83088.5.L-ALB08RP001

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ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AMS	Air Monitoring Station
CDPHE	Colorado Department of Public Health and the Environment
CFR	Code of Federal Regulations
cm	centimeters
EFR	Energy Fuels Resources (Corporation)
EPA	U.S. Environmental Protection Agency
ERG	Environmental Restoration Group
GIS	Geographic Information System
GPS	Global Positioning System
LLD	Lower Limit of Detection
μR/hr	microRoentgens per hour
m	meter
MDL	Method Detection Limit
mg/kg	milligrams per kilogram
mrem/yr	millirem per year
n	sample number
NaI	Sodium Iodide (detector)
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NVLAP	National Voluntary Laboratory Accreditation Program
OSL	Optically stimulated luminescence
Pb-210	Lead-210
pCi/g	picocuries per gram
PIC	Pressurized Ion Chamber
Po-210	Polonium-210
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
Ra-226	Radium-226
RER	Relative Error Ratio
RPD	Relative Percent Difference
Th-230	Thorium-230

Acronyms and Abbreviations (cont.)

Th-232	Thorium-232
UCL	upper confidence limit
U-nat	Natural Uranium
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

1.0 INTRODUCTION

Energy Fuels Resources Corporation (EFR) proposes to license, construct, and operate a conventional acid leach uranium and vanadium mill at the Piñon Ridge Mill site (the "Site") in western Montrose County, Colorado. Site facilities will include an administration building, a 17-acre mill, tailing ponds totaling 90 acres, a 40-acre evaporation pond (expandable to 80 acres), a 6-acre ore storage pad, and an access road. The mill will process ore produced from mines within a reasonable truck-hauling distance. The mill will process up to 500 tons of ore per day but is designed to accommodate subsequent expanded production capacity of up to 1,000 tons per day. The expected operating life of the mill is 20 to 40 years, depending on the production rate.

The Piñon Ridge Mill is subject to regulation by the State of Colorado, and the mill license (Radioactive Source Material License) will be issued and administered by the Colorado Department of Public Health and Environment (CDPHE). The activities described in this document were performed as part of the baseline characterization required for the Environmental Report (ER) in accordance with Section 3.8.8, Part 3, 6 *Colorado Code of Regulations* (CCR) 1007-1. This work was performed by Environmental Restoration Group (ERG) under contract to Kleinfelder in accordance with the Baseline Radiological Investigation Work Plan dated September 19, 2007, herein referred to as the Work Plan (ERG, 2007). The Work Plan was reviewed by CDPHE in October, 2007 and the agency's comments were incorporated into the investigation protocol where appropriate.

1.1 Description of the Project

The investigation documented herein was conducted for the EFR Piñon Ridge Project to license and construct a uranium mill in the Paradox Valley at 16910 Highway 90, approximately 12 miles west of Naturita, in Montrose County, Colorado. The Site's legal description is the Southwest ¼ of the Southeast ¼ of Section 5, all of Section 8, the North ¼ of Section 17, and the Southeast ¼ of the Northwest ¼ of Section 17, Township 46 North, Range 17 West, of the New Mexico Principal Base and Meridian. The Site is located on both the Davis Mesa Quadrangle and Bull Canyon Quadrangle 1:24,000 United States Geological Survey (USGS) topographic/geologic maps. Figure 1.1 shows the site layout and geographic setting of the Piñon Ridge property.

1.2 Purpose and Scope

The investigation documented herein provides baseline radiological data for surface soil (0 -5 and 0-15 centimeters [cm]), subsurface soils to a depth of 1 meter (m), vegetation, radon flux, ambient radon, and exposure rates representative of the Piñon Ridge site. Field investigations, sample collection, and other quality-impacting work performed during the Fall 2007 Baseline Field Investigation were conducted in accordance with the applicable ERG standard operating procedures referenced in Section 3.1 of the Work Plan and in accordance with Kleinfelder's Health and Safety Program and the project-specific Health and Safety Plan.

1.3 Organization and Contents

Following this introduction, Section 2 summarizes the scope of the investigation and identifies any deviations from the Work Plan. Section 3 documents the results of the gamma survey and associated predictions of exposure rates and radium-226 (Ra-226) concentrations in surface soil. Section 4 documents the analytical results for soil samples collected at biased, random, and air monitoring station (AMS) locations. Section 5 discusses associated data quality issues. Section 6 presents the results of ambient radon concentration and radon flux measurements. Section 7 presents the results of exposure rate measurements using optically stimulated luminescence (OSL) dosimeters. Section 8 documents the results of vegetation sampling. Section 9 presents the summary and conclusions. References are provided in Section 10.

To facilitate review, the bulk of the information in this report is provided in the tables (within the body of the document) and figures (separate tabbed section).

2.0 BASELINE FIELD INVESTIGATION SUMMARY AND SCOPE

2.1 Overall Scope of Project

Baseline radiological field investigations consisted of the following activities:

- A GPS-based gamma survey conducted at 50 to 100 m transects spanning the proposed property;
- Surface soil sampling (0-15 cm) at 80 randomly selected and biased locations. Biased samples were concentrated in the proposed tailings area, drainages, and at locations exhibiting elevated gamma readings;
- Subsurface soil sampling: two samples at each of five locations with depth intervals of 15-30 and 30-100 cm;
- Shallow (0-5 cm) surface soil sampling at all AMS locations;
- Vegetation sampling at all AMS locations;
- Radon flux measurements;
- Exposure rate measurements; and
- Ambient radon concentration measurements.

Table 2.1 summarizes the scope of the field program and identifies any deviations from the Work Plan (ERG, 2007), as discussed below.

2.2 Deviations from October 2007 Work Plan

In general, the work was performed in accordance with the Work Plan (ERG, 2007). However, some modifications were made. For example, some of the initially proposed soil sample locations were changed (see Section 4). In some cases this was because the planned location was off the site boundary or a physical feature (e.g., presence of water) prevented sample collection. Two additional biased samples were collected in a western area exhibiting some of the highest levels of radioactivity. As such, two of the planned random samples (PRR-37 and PRR-42) were not collected in the northern area of the site.

Although the Work Plan specified that one beef sample would be provided by a local rancher whose cattle graze the area, this activity was not performed by ERG. Rather, F. Ward Whicker of Colorado State University was contracted directly by EFR to perform sampling of beef as well as other available local fauna. The results of this sampling effort are presented in “Baseline Survey of Radionuclides in Animal Tissues at the Proposed Piñon Ridge Millsite” (Whicker, 2008).

2.3 Future Work

The scope addressed in the Work Plan is complete. No follow-up activities are planned.

Table 2.1 Summary of Baseline Radiological Investigation Scope

Survey Method/Endpoint	Baseline Investigation Scope	Parameters Evaluated
Gamma Survey	18- inch high bare detector gamma readings coupled with x- and y- coordinates taken every second moving along 50 to 100 m transects at ≤1.5 ms per second. Surveys were made over the entire site along 34 transects.	Used to estimate exposure rates, surface soil Ra-226 concentrations, and to identify additional areas for biased sampling.
Biased Soil Sampling	Biased samples at 34 locations shown on Figures 4.1 and 4.2. Note that PRB-33 and PRB-34 were not planned but were added during the field investigation due to elevated gamma readings in this area. Five of the 34 locations were sampled at depth (15-30 cm and 30-100 cm).	Ra-226 for most samples; Th-230, U-Nat, Pb-210, for a subset (N=5 locations, 2 at depth)
Random Soil Sampling	Random samples at 46 locations (Figure 4.1). PRR-37 and PRR-42 were not collected (replaced by addition of PRB-33 and PRB-34 noted above). All random samples were surface (0-15 cm) samples.	Ra-226 for most samples; Th-230, U-Nat, Pb-210, for a subset (N=5)
Exposure and External Dose Rate Monitoring	As indicated in the Work Plan, external dose rates were assessed using Optically Stimulated Luminescence (OSL) dosimeters at the five AMSs. However, for this report, exposure rate determinations are based on Pressurized Ion Chamber (PIC) measurements. Given the strong correlation between the PIC and associated gamma survey measurements, ERG considers the interpolated exposure rates documented herein to be reliable estimates.	External Dose and Exposure Rates
Soil and Vegetation Sampling at Air Monitoring Stations	Five locations: three onsite (AMS-01, AMS-02, and AMS-03) and two located approximately 3 miles offsite (AMS-04 to the northwest and AMS-05 to the southeast). Given the diurnal nature of winds, at various times these stations would be representative of downwind and upwind locations.	Ra-226, Th-230, U-Nat, Pb-210, and Po-210
Radon Measurements	Radon flux measurements at nine locations (coinciding with biased soil samples). Ambient radon concentrations were also measured at the 5 AMSs using passive track etch detectors.	Rn-222

3.0 GPS-BASED GAMMA (DIRECT RADIATION) SURVEYS

This section documents the results of the baseline direct radiation (gamma) survey of the Piñon Ridge property conducted in October 2007. Based on these results, exposure rates representative of the Piñon Ridge property were derived. The findings discussed in this section are reflected largely in the supporting figures; the text is limited to a discussion of overall trends and salient findings.

3.1 GPS Survey Methods

A GPS-based gamma survey was conducted over the Piñon Ridge property between October 16 and October 22, 2007. The survey was conducted using bare 2x2 sodium iodide (NaI) detectors, each of which was coupled to a ratemeter/scaler (set in ratemeter mode) and a Trimble Pro XRS GPS Receiver with Trimble TSCe Datalogger. Survey transects were spaced at approximately 100 m intervals over much of the site, as shown on Figure 3.1. In the southern portion of the site coinciding with the mill area, the survey density was increased, with transects set at approximately 50 m. The survey density in this area was increased to define the limits of elevated radioactivity identified in the initial 100 m transects. In accordance with the Work Plan, transects were surveyed at a speed between 2 and 5 feet per second with x- and y-coordinates and gamma count rates recorded every second. The survey coordinate system used was NAD 83, Colorado South in feet. The coordinates obtained from the GPS system were spatially corrected using base station COOP_CORS, MC04, CO located in Grand Junction, Colorado. The detector height was held relatively constant at approximately 18 inches above ground surface. Field personnel walked while carrying needed equipment in backpacks.

While walking the southern most transects, field personnel noticed that the site boundary, loaded on the Trimble TSCe Datalogger from files obtained from Kleinfelder, extended on to a fenced soil pile area and beyond a fence line on the eastern boundary of the site. Field personnel contacted a Kleinfelder representative on-site to determine if this boundary was accurate. The field personnel were instructed by the Kleinfelder representative to use the fence line as the eastern boundary and to extend the transect lines on the western boundary. Field personnel observed what appeared to be survey stakes delineating the western boundary. These stakes were used as guides for the western extent of the survey boundary.

3.2 Derivation of Direct Gamma Exposure Rates Based on PIC Correlation

Results of the direct radiation measurements collected using the 2x2 NaI detectors are shown on Figures 3.1 and 3.2. One-minute integrated counts from this detector were correlated to site-specific exposure rate measurements made with a Pressurized Ion Chamber (PIC) at twelve locations. Figure 3.1 shows the October 2007 gamma survey results and the PIC locations that formed the basis for the exposure rate derivation. Figure 3.2 maps the exposure rates interpolated based on the gamma survey point readings using ArcGIS spatial analyst software. In these figures, the gamma survey results are expressed as exposure rates to allow a more meaningful context for interpretation than the relative magnitude of individual gamma readings (with corresponding units of counts per minute [cpm]). Gamma readings were converted to exposure rates (expressed in units of microRoentgens per hour [µR/hr]) using the PIC data and correlation equation documented in Figure 3.3 (see discussion on following pages).

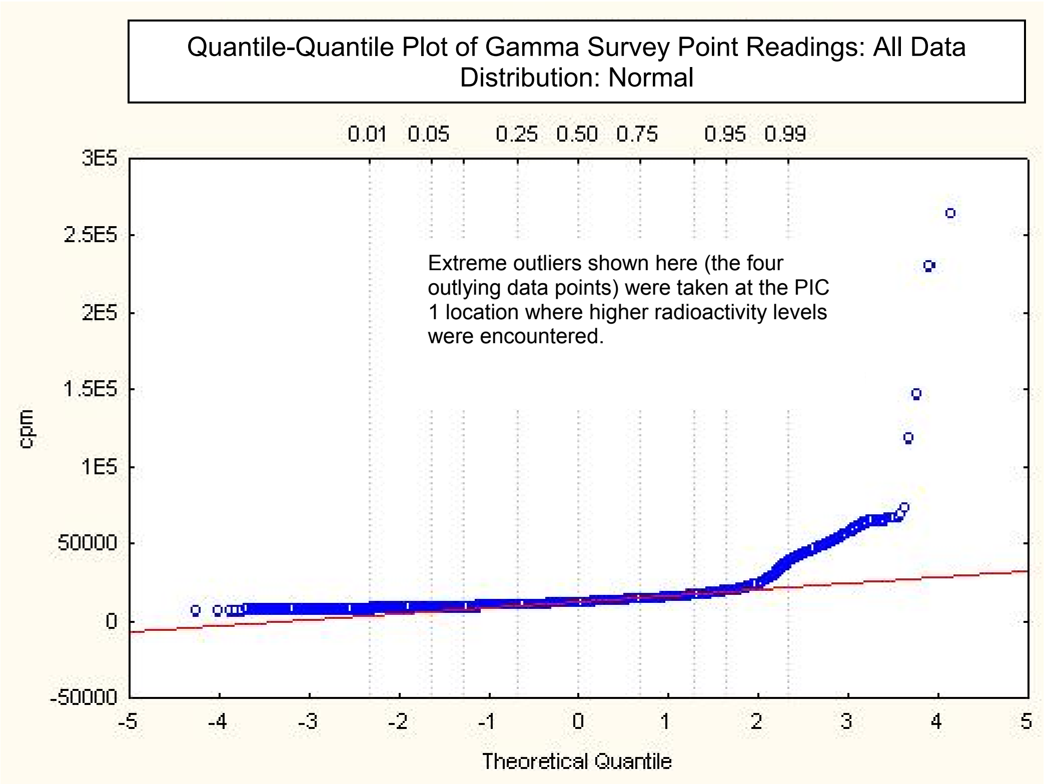
Note that two additional PIC locations (locations 12 and 13), beyond those originally planned, were added during the field program given elevated radioactivity exhibited in a localized area in the southwestern portion of the site. These were added to ensure that the regression analysis incorporated the range of readings observed on site.

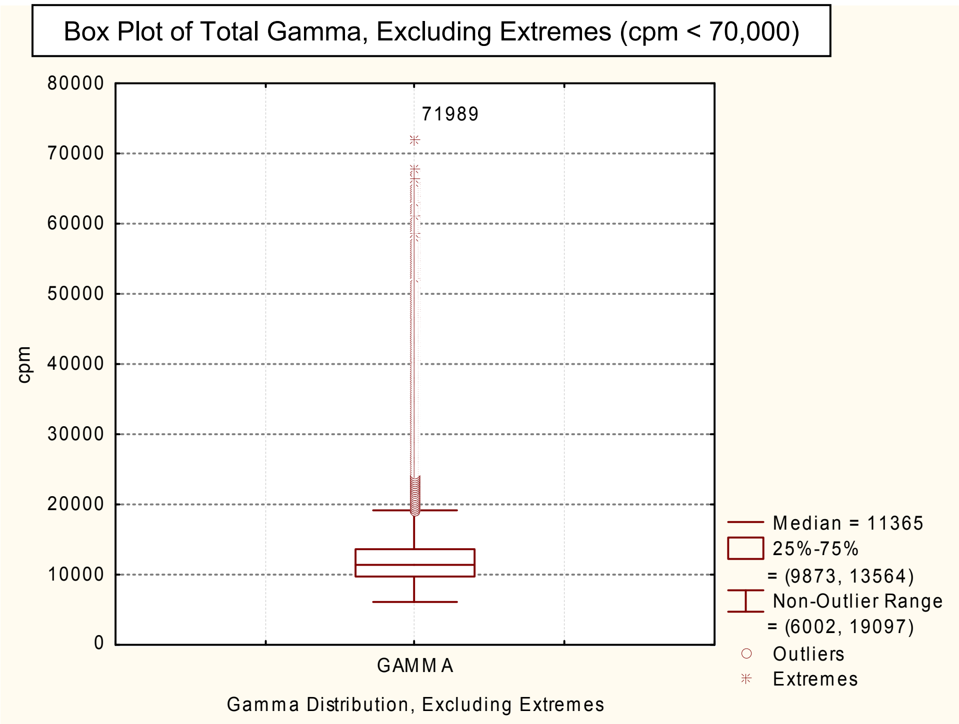
Before discussing the mapped exposure rates provided in Figures 3.1 and 3.2, initial discussion of the overall raw gamma distribution is warranted. This discussion is based on Illustration 3.1, provided on the following page.

Illustration 3.1 provides a condensed view of the gamma data and is intended as a prelude to the more detailed trends presented in Figures 3.1 through 3.4. The distribution of these points is illustrated using a quantile-quantile plot which assumes an underlying normal distribution. The most elevated readings (>100,000 cpm) shown in the quantile-quantile plot coincide with PIC location 1, where a localized area of higher radioactivity was encountered. This radiological anomaly may be attributable to alluvial fan deposits containing, in part, detritus originating in the uranium bearing Salt Wash member of the Morrison formation to the south. Two subpopulations in the data set are apparent when the extreme outliers from PIC 1 location are excluded. The box plot shown in the lower portion of Illustration 3.1 was developed excluding these extreme data points (i.e., for gamma readings less than 70,000 cpm). This plot demonstrates that the majority of gamma readings were below 20,000 cpm or 19,097 cpm, the non-outlier range of the data set.

The gamma measurements shown in the preceding illustrations were converted to exposure rates using the correlation equation documented in Figure 3.3. Plotting of the data from the PIC and NaI detectors yielded a strong linear correlation, with an r^2 of 0.99. Note that the data from PIC 1 (extreme outliers shown in Illustration 3.1) were not used to establish the correlation.

Illustration 3.1 Piñon Ridge Gamma Survey Point Distribution





3.3 Discussion of Findings

Based on the gamma survey measurements discussed above and using the correlation documented in Figure 3.3, the gamma survey of the Piñon Ridge site yielded median and average exposure rates of 14.2 and 14.9 μR/hr. Excluding the outlier measurements plotted above (coinciding primarily with PIC location 1), individual rates ranged between 11 and 19 μR/hr. Summary statistics are provided in Table 3.1 along with the corresponding gamma count rate.

Table 3.1 Statistical Summary of Gamma Data and Exposure Rate Measurements

Estimator/Endpoint	Gamma Data (cpm)	Exposure Rate (μR/hr)
Mean	**12,488**	**14.9**
Standard Error	20.8	0.01
Standard Deviation	5,321	3.2
Median	**11,365**	**14.2**
Mode	9,648	13.2
Range	258,193	154.9
Minimum	6,002	11.0
Maximum	264,195	165.93
Count	65,354	65,354

The summary above reflects the distribution of the raw gamma measurements demonstrated in the preceding box plot, with additional characteristics as follows:

Lower quartile or 25th percentile = 13.3 μR/hr
75th percentile = 15.5 μR/hr
Non-Outlier Range = 11.0 - 18.9 μR/hr

In cases where data are variable and/or where localized areas exhibit different characteristics from the majority of the site, the value of summary statistics can be limited. Thus, mapping of the data provided in Figures 3.1 and 3.2 is essential to characterizing trends. Figure 3.1 plots the discrete exposure rate measurements points converted from the gamma survey transect data (using the equation in Figure 3.3). Figure 3.2 presents an interpolation of exposure rates, created using ArcMap GIS Spatial Analyst and 3-D Analyst extensions. Using the latter's geostatistical techniques, point features were converted to a raster file and then averaged to create a single value for that cell.

Based on the data plotted in Figures 3.1 and 3.2, the following conclusions are drawn:

- The majority of the site exhibits exposure rate data points ranging between 11 and 20 μR/hr, coinciding closely with the summary statistics provided above for non-outlier ranges. The lower range or subpopulation of readings, ranging from 11 to 14 μR/hr, occurs in the northern portion of the site, coinciding with lower elevation areas.

- Readings between 14 and 20 µR/hr, corresponding to the range between the median and the non-outlier range, are found in the majority of the rest of the site (comprising approximately 40 percent of the site area), and appear to coincide with western and eastern drainages (see Figure 3.2).

- Elevated levels of radioactivity, as characterized by gamma readings greater than 20,000 cpm and estimated exposure rates greater than 20 µR/hr, appear to be limited to three areas:

    1) An area in the southern portion of the site (south of the proposed mill area), located just north of and adjacent to the offsite topsoil pile (see Figure 3.2). The approximate center of this area is located at 2061345.351 (easting) and 1591443.987 (northing). The interpolated exposure rates in this area range from 15.0 – 28.0 µR/hr.

    2) An area in the southwestern portion of the site, near the reach of the western drainage. This area is characterized by sparse vegetation (more evident in Site Layout, Figure 1.1), topsoil is present at depths exceeding 1 cm, and surficial deposits of fine-grained material appear to exist. The approximate center of this area is located at 2059711.097 (easting) and 1592152.881 (northing). The interpolated exposure rates in this area range from 15.2 – 44.4 µR/hr.

    3) Isolated points in the upper reaches of the eastern drainage, which are much more localized and less extensive than those noted above.

- Patterns of slightly elevated radioactivity are also apparent in the three site drainages (note darker patterns in Figure 3.2), where exposure rates range from approximately 15 to 17 µR/hr.

Based on the above information, it is clear that the southern quarter of the site exhibits radiological anomalies from natural and possibly historic anthropogenic sources within the area. The natural source of the elevated radioactivity in the southern portion of the site originates from erosion of the Salt Wash member of the Morrison formation, which outcrops along the flank of the mesa south of the site. The Salt Wash member is the uranium ore host for the nearby uranium mines. This natural source is evident by the elevated radioactivity within the drainages, especially in the extreme southern portion of the site where alluvial fans contain predominantly pebbles and cobbles of conglomeratic sandstone and sandstone with small clay galls. This detritus can be traced back to the exposed Morrison and Burro Canyon formations located further up the mesa.

Potential historic anthropogenic sources within the area include:

- Runoff and windblown dust from former ore stockpiles and existing waste rock dumps at the underground uranium mines located south of the site. These mining activities could have increased erosion and contributed higher levels of radioactivity (especially from the ore stockpiles) to the drainages.

- Runoff from the topsoil stockpile placed in an 80-acre parcel just south of the site in 1980 from an open pit uranium mining operation. This topsoil was removed from the area to the east where the overburden from the open pit was ultimately placed. The topsoil was placed in a series of thin lifts and reseeded for eventual use in reclamation. The area stripped of the topsoil contained several drainages, which likely contained alluvial materials from the mesa to the south with higher radiation levels similar to those observed at the site. The open pit was not mined down completely to the ore zone (i.e., a 20-foot layer of barren rock was left over the ore), so it is unlikely that that windblown dust from this open pit mining contributed to higher radioactivity levels in the area.

The following section documents the methods used to convert the gamma measurements to corresponding surface soil Ra-226 concentrations based on the gamma readings taken at the soil sample locations. Given that the basis for the soil Ra-226 predictions is the same as that discussed above for exposure rates, the trends discussed above are paralleled in Figures 3.4 and 3.5.

3.4 Surface Soil Ra-226 Estimates Based on Gamma-Soil Radium Correlation

To estimate Ra-226 concentrations corresponding to each of the gamma survey points shown in Figure 3.1, a gamma-soil radium correlation was established using the surface soil analytical results documented in Section 4 for all biased and random soil sample locations where gamma measurements were taken (n=79). One-minute integrated direct radiation measurements were collected at each of these locations, using the same radiation detection equipment used in the GPS gamma survey. These gamma survey point data were then correlated to soil Ra-226 concentrations as discussed below. The final correlation equation for the Piñon Ridge site was derived using a non-linear piecewise regression equation with a breakpoint, defined below:

For cpm < 14,447:
Ra-226 = (cpm * 0.000120) – 0.614224

For cpm ≥ 14,447:
Ra-226 = (cpm * 0.000631) – 7.3271

The derivation is discussed in Section 3.5. Using these equations, soil Ra-226 concentrations were estimated for each discrete gamma survey measurement datum. Figure 3.4 plots the discrete estimated soil Ra-226 concentrations. These data were then interpolated as reflected in Figure 3.5 using geostatistical natural neighbor estimation methods. As expected, these figures demonstrate the same spatial trends discussed above for exposure rates.

Estimated soil Ra-226 concentrations over most of the site based on the gamma measurements average approximately 1 pCi/g and range from <0.75 pCi/g to 1.25 pCi/g (based on the bins shown in Figure 3.5). Elevated areas, with estimated soil Ra-226 concentrations exceeding 1.25 pCi/g, correspond to the areas defined in Section 3.3 (i.e., the southern/southeastern portion of the site and portions of the western drainage). Although the extent of elevated areas shown in Figure 3.5 may appear to be greater than those mapped in Figure 3.2 for exposure rates, these two figures do reflect different endpoints (and units). Also, the color symbols used to define magnitude classes for each of these figures are also somewhat different and not directly comparable. Overall, the spatial trends exhibited in Figures 3.1 through 3.5 yield the same conclusions (i.e., that the southern quarter of the site exhibits radiological anomalies within the drainage areas from natural and possibly historic anthropogenic sources located on the mesa to the south).

3.5 Documentation Supporting Derivation of Gamma-Soil Radium Correlation

To derive the site-wide gamma-soil radium correlation used as the basis for the soil Ra-226 values plotted in Figures 3.4 and 3.5, a number of iterations using linear correlation methods were initially employed. For example, initial attempts used all data, followed by permutations using truncated data sets that excluded anomalous or outlying data. Although in some cases yielding fairly good r^2 values (e.g., greater than 0.8), residuals (i.e., predicted minus observed Ra-226 concentrations) were poor. Average residuals in all cases were negative (indicating a tendency to underestimate soil Ra-226 concentrations), and the sum of residuals ranged from -8 to -73, again indicating an overall tendency to under-predict surface soil Ra-226 content, especially for higher magnitude gamma readings. Definition of subsets did not yield any compelling results; in fact, correlations were sometimes weaker and residuals greater than those derived for the original linear equation using all data points. Ultimately, linear estimation methods were not technically defensible, as resulting surface soil Ra-226 concentrations would be unacceptably underestimated.

Given the above, non-linear estimation methods were utilized and, as documented below and in Appendix A, yielded defensible soil Ra-226 concentration predictions. The final correlation equation for the Piñon Ridge site was derived using a non-linear piecewise regression equation with a breakpoint, defined above in Section 3.4 (one equation for gamma readings below 14447 cpm, and an alternate one with a different slope for readings equal to or above that breakpoint).

The corresponding r^2 of 0.93 was strong, accounting for 0.93 or 93 percent of the variance in the data set. The corresponding average residual (again, predicted Ra-226 minus observed) is 0.16 pCi/g, indicating a slight tendency to overestimate soil Ra-226 concentrations. Documentation supporting the latter findings is provided in Appendix A. Appendix A, Table A.1 lists all observed and predicted values, sorted on ascending gamma count. Tables A.2 and A.3 present the same information, but sorted on ascending residual (i.e., under-predictions to over-predictions) and soil sample ID, respectively. Although relative percent differences (RPDs) calculated for the observed vs. predicted values were generally poor (i.e., greater than 20%), this is due to the fact that most soil Ra-226 was measured at or close to the method detection limit (MDL of <1 pCig). At these low magnitudes, even small differences in concentrations yield rather large RPDs.

It is important to acknowledge that discrepancies between measured soil Ra-226 concentrations reported by the laboratory and corresponding Ra-226 concentrations estimated by gamma surveys are inevitable in a characterization survey of this nature and magnitude, given the heterogeneity of the site (at least in some areas) and differing detector-source geometry at various sample/survey locations.

4.0 BASELINE RADIOLOGICAL INVESTIGATION SOIL SAMPLING

This section presents the results of the baseline soil sampling conducted in October 2007. Sample types included biased and random samples; soil samples were also collected at each of the five AMS locations. Section 4.1 summarizes the soil sampling field approach, scope, and analytical methods. Section 4.2 discusses the results obtained for Ra-226, the focus of the baseline soil sampling program. Sections 4.3 and 4.4 address results for samples collected at depth and other radiological parameters, respectively. Section 4.5 distills the latter findings, summarizing the overall statistical trends and baseline radiological characteristics exhibited at the Piñon Ridge site. The laboratory analytical reports for the soil analyses are provided in Appendix B-1.

4.1 Sampling Strategy and Approach

The soil sampling strategy for the Piñon Ridge site consisted of biased and random sampling at the 80 locations shown in Figure 4.1. Biased samples were collected at 34 locations. Initial placement was focused on the proposed process areas (especially the mill area), drainages, and areas where potential offsite impacts from nearby mines would be expected to accumulate. Additional locations were determined based on the gamma survey results (i.e., at locations exhibiting elevated radioactivity). Five of the 34 biased locations, two within the proposed mill area, two within the proposed evaporation pond area, and one within the tailings area were sampled at depth (15-30 cm and 30-100 cm). Random samples were collected at the 46 locations shown in Figure 4.1 in accordance with the Work Plan strategy. The number of and types of analytes for the surface and sub-surface soil samples were based on requirements in USNRC Regulatory Guide 4.14, Revision 1, *Radiological Effluent and Environmental Monitoring at Uranium Mills,* (NRC, 1980). The following tables summarize the Piñon Ridge baseline soil sampling program (Table 4.1) and list the sample location coordinates (Table 4.2).

Table 4.1. Piñon Ridge Baseline Soil Sampling Strategy and Scope

Sample Type	No. of Locations	Locations with Expanded Suite	No. of QA/QC Samples	No. of Locations Sampled at Depth
Biased Samples	34 (n = 44, excluding duplicates)	5 locations, 8 samples (some collected at depth)	9 (20.5%)	5 at 0-15 cm, 15-30 cm, and 30-100 cm
Random Samples	46	5	10 (21.7%)	None.
AMS Samples	5	5	1 (20%)	None. All were shallow (0-5 cm) samples.

Table 4.2. Sample Location Coordinates

Sample Location	Northing*	Easting*	Description
AMS-01	1598134.80	2061694.00	Air Monitoring Station
AMS-02	1591332.00	2061694.00	Air Monitoring Station
AMS-03	1592510.00	2058836.00	Air Monitoring Station
AMS-04	1607598.63	2045886.23	Air Monitoring Station
AMS-05	1582304.12	2076567.58	Air Monitoring Station
PRB-01	1591619.20	2059564.40	Biased, Surface Only
PRB-02	1591837.80	2061455.90	Biased, Surface and Subsurface
PRB-03	1590840.00	2060609.80	Biased, Surface Only
PRB-04	1590965.20	2063302.80	Biased, Surface Only
PRB-05	1592572.50	2063491.10	Biased, Surface Only
PRB-06	1590011.51	2061084.14	Biased, Surface Only
PRB-07	1591919.40	2058878.80	Biased, Surface Only
PRB-08	1590894.18	2061079.08	Biased, Surface Only
PRB-09	1592129.40	2062092.30	Biased, Surface and Subsurface
PRB-10	1590524.54	2061102.84	Biased, Surface Only
PRB-11	1591001.90	2060091.60	Biased, Surface Only
PRB-12	1594217.59	2063932.92	Biased, Surface Only
PRB-13	1594143.40	2061081.00	Biased, Surface and Rn Flux
PRB-14	1594004.80	2062293.50	Biased, Surface and Rn Flux
PRB-15	1595897.60	2063334.20	Biased, Surface Only
PRB-16	1592803.80	2062488.80	Biased, Surface and Rn Flux
PRB-17	1593552.10	2061649.50	Biased, Surface and Rn Flux
PRB-18	1592922.30	2061969.70	Biased, Surface and Rn Flux
PRB-19	1593606.90	2062401.10	Biased, Surface and Rn Flux
PRB-20	1593532.00	2061231.10	Biased, Surface and Rn Flux
PRB-21	1593962.10	2061280.50	Biased, Surface and Rn Flux
PRB-22	1593802.60	2061653.10	Biased, Surface Only
PRB-23	1593057.40	2061217.70	Biased, Surface and Rn Flux
PRB-24	1596062.00	2061313.80	Biased, Surface and Subsurface
PRB-25	1595749.30	2062554.90	Biased, Surface and Subsurface
PRB-26	1594694.80	2061817.20	Biased, Surface and Subsurface
PRB-27	1597108.50	2063593.30	Biased, Surface Only
PRB-28	1598072.90	2061827.40	Biased, Surface Only
PRB-29	1598249.50	2062180.60	Biased, Surface Only
PRB-30	1592329.20	2060451.30	Biased, Surface Only
PRB-31	1593960.60	2059995.60	Biased, Surface Only
PRB-32	1597285.10	2059015.60	Biased, Surface Only
PRB-33	1591942.24	2059532.91	Biased, Surface Only
PRB-34	1591881.97	2059486.99	Biased, Surface Only
PRR-01	1589878.80	2060509.10	Random, Surface Only

Table 4.2. Sample Location Coordinates (Continued)

Sample Location	Northing*	Easting*	Description
PRR-02	1590711.80	2060990.00	Random, Surface Only
PRR-03	1591544.80	2059547.20	Random, Surface Only
PRR-04	1591544.80	2060509.10	Random, Surface Only
PRR-05	1591544.80	2061471.00	Random, Surface Only
PRR-06	1591544.80	2062432.80	Random, Surface Only
PRR-07	1591544.80	2063394.70	Random, Surface Only
PRR-08	1592377.90	2059066.20	Random, Surface Only
PRR-09	1592377.90	2060028.10	Random, Surface Only
PRR-10	1592377.90	2060990.00	Random, Surface Only
PRR-11	1592377.90	2061951.90	Random, Surface Only
PRR-12	1592377.90	2062913.80	Random, Surface Only
PRR-13	1592385.49	2063853.20	Random, Surface Only
PRR-14	1593210.90	2059547.20	Random, Surface Only
PRR-15	1593210.90	2060509.10	Random, Surface Only
PRR-16	1593210.90	2061471.00	Random, Surface Only
PRR-17	1593210.90	2062432.80	Random, Surface Only
PRR-18	1593210.90	2063394.70	Random, Surface Only
PRR-19	1594043.90	2059066.20	Random, Surface Only
PRR-20	1594043.90	2060028.10	Random, Surface Only
PRR-21	1594043.90	2060990.00	Random, Surface Only
PRR-22	1594043.90	2061951.90	Random, Surface Only
PRR-23	1594043.90	2062913.80	Random, Surface Only
PRR-24	1594043.90	2063875.70	Random, Surface Only
PRR-25	1594876.90	2059547.20	Random, Surface Only
PRR-26	1594876.90	2060509.10	Random, Surface Only
PRR-27	1594876.90	2061471.00	Random, Surface Only
PRR-28	1594876.90	2062432.80	Random, Surface Only
PRR-29	1594876.90	2063394.70	Random, Surface Only
PRR-30	1595709.90	2059066.20	Random, Surface Only
PRR-31	1595709.90	2060028.10	Random, Surface Only
PRR-32	1595709.90	2060990.00	Random, Surface Only
PRR-33	1595709.90	2061951.90	Random, Surface Only
PRR-34	1595709.90	2062913.80	Random, Surface Only
PRR-35	1595709.90	2063875.70	Random, Surface Only
PRR-36	1596542.90	2059547.20	Random, Surface Only
PRR-38	1596542.95	2061470.95	Random, Surface Only
PRR-39	1596542.95	2062432.84	Random, Surface Only
PRR-40	1596542.95	2063394.73	Random, Surface Only
PRR-41	1597375.96	2059066.24	Random, Surface Only
PRR-43	1597376.00	2060990.00	Random, Surface Only

Table 4.2. Sample Location Coordinates (Concluded)

Sample Location	Northing*	Easting*	Description
PRR-44	1597376.00	2061951.90	Random, Surface Only
PRR-45	1597376.00	2062913.80	Random, Surface Only
PRR-46	1597376.00	2063875.70	Random, Surface Only
PRR-47	1598209.00	2061471.00	Random, Surface Only
PRR-48	1598209.00	2062432.80	Random, Surface Only

Notes:* NAD 1983 Colorado South, feet.

As discussed in Section 2, several minor modifications were made to the initially planned sample numbers and locations. For example, biased samples PRB-33 and PRB-34 were not planned but were added during the field investigation due to elevated gamma readings in this area (see elevated area in western portion of site coinciding with PIC locations 4, 5, 12, and 13). Given the addition of the latter two biased samples, two random samples (PRR-37 and PRR-42) initially planned for the northern site transect area were not collected (see Figure 4.1).

In addition to the biased and random samples described above, shallow (0-5 cm) surface soil samples were collected at the five AMS locations; onsite AMS stations are shown on Figure 4.1. Two AMS samples (AMS-04 and AMS-05) were collected offsite, approximately 3 miles northwest and southeast of the site, respectively. Given the diurnal nature of winds, at various times these stations would be representative of downwind and upwind locations. Corresponding soil sample results represent a pre-operational baseline to compare soil samples collected at the same location and depth during the operational phase of the mill.

In accordance with the Work Plan, the majority of baseline soil samples were analyzed for Ra-226 only. A small subset was analyzed for an extended suite of analytical parameters, consisting of Thorium-228 (not discussed in this report), Thorium-230 (Th-230), Thorium-232 (Th-232), Natural Uranium (U-Nat), and Lead-210 (Pb-210). Corresponding analytical methods are summarized below:

Radium-226 (Ra-226)	EPA M903.1 (soil digestion method is EPA 3050B)
Thorium-230 (Th-230)	ESM 4506
Thorium-232 (Th-232)	ESM 4506
Uranium, total (U-Nat)	EPA M6020 ICP-MS
Lead-210 (Pb-210)	EPA 901.1 (initially analyzed using Eichrom, but this method yielded high MDLs)

4.2 Surface Soil (0-15 cm) Ra-226 Results

The following discussion is based largely upon the results and spatial distributions reflected in the supporting figures and tabular summaries. Figures 4.2 and 4.3 plot the Ra-226 results reported for biased and random locations, respectively. Figures 4.4 and 4.5 plot the combined surface soil Ra-226 concentration results overlying the interpolated exposure rate and Ra-226 estimates based on the gamma survey results.

Supporting tables are provided at the end of this document, following the figures. Table 4.3 documents the results of biased soil sampling. Table 4.4 presents the corresponding subsurface sample subset, discussed in Section 4.3. Tables 4.5 and 4.6 summarize results for the random and AMS samples, respectively. Table 4.7 presents the resulting summary statistics for Ra-226 concentrations in surface soil for all sample types.

Before discussing the spatial trends reflected in Figures 4.2 through 4.5, some discussion of the overall Ra-226 distributional characteristics is warranted. Illustration 4.1 presents box plots of surface soil Ra-226 concentrations, first categorized by sample type (biased vs. random vs. AMS), and then combined. For the reader not familiar with box plots, these plots are a non-parametrical graphical technique, showing the median, lower and upper quartiles (25^{th} and 75^{th} percentiles), non-outlier ranges, and outliers and extremes in the data set.

Illustration 4.1 demonstrates that most of the surface Ra-226 concentrations measured at the Piñon Ridge site are less than 2 pCi/g. Illustration 4.1a plots the surface Ra-226 results by sample type, i.e., biased (n=34) vs. random (n=46) vs. onsite AMS locations (n=3). Although initially one might expect distinct differences between the biased vs. random distributions, even when excluding outliers, this was not the case for most of the data set (i.e., excluding extremes). This is partly due to the fact that biased samples were concentrated in the proposed process areas (see Figures 4.1 and 4.2), which, with the exception of a localized southern portion of the mill area, exhibited fairly homogenous levels of radioactivity. Also, some random samples were co-located with biased samples.

At the same time, Illustration 4.1 shows that without a gamma survey driving the selection of biased sample points (e.g., PRB-33 and PRB-34) in the western elevated area with the highest soil Ra-226 concentrations of 33 and 34 pCi/g, respectively, and PRB-02 and PRB-10 in the southern elevated area), reliance on a random soil sampling program alone would not have allowed the identification of elevated areas of radioactivity at the site. Increased radiation levels observed in the site drainages (see Figure 4.5) would also not be apparent.

Given that no distinct differences between the biased, random, and AMS location distributions were apparent (again, with the necessary exception being the exclusion of outliers), all data were plotted together. Based on Illustration 4.1b, the median of the surface soil Ra-226 data set is 0.97 pCi/g, with a corresponding non-outlier range of 0.13 to 2.6 pCi/g. As indicated in Table 4.7 (summary statistics), the median is comparable to the mean of the data set excluding the outliers (0.98 pCi/g). Excluding outliers, the baseline data are approximately normally distributed, as demonstrated in Illustration 4.2.

The proceeding illustrations, the data plotted in Figures 4.2 through 4.5, the corresponding soil analytical results documented in Tables 4.3 through 4.6, and the summary statistics in 4.7 indicate that the spatial trends identified in Section 3 are also exhibited by the baseline soil sampling data set.

Illustration 4.1 Surface Soil Ra-226 Concentration Distributions

Illustration 4.1a. Distribution by Sample Type

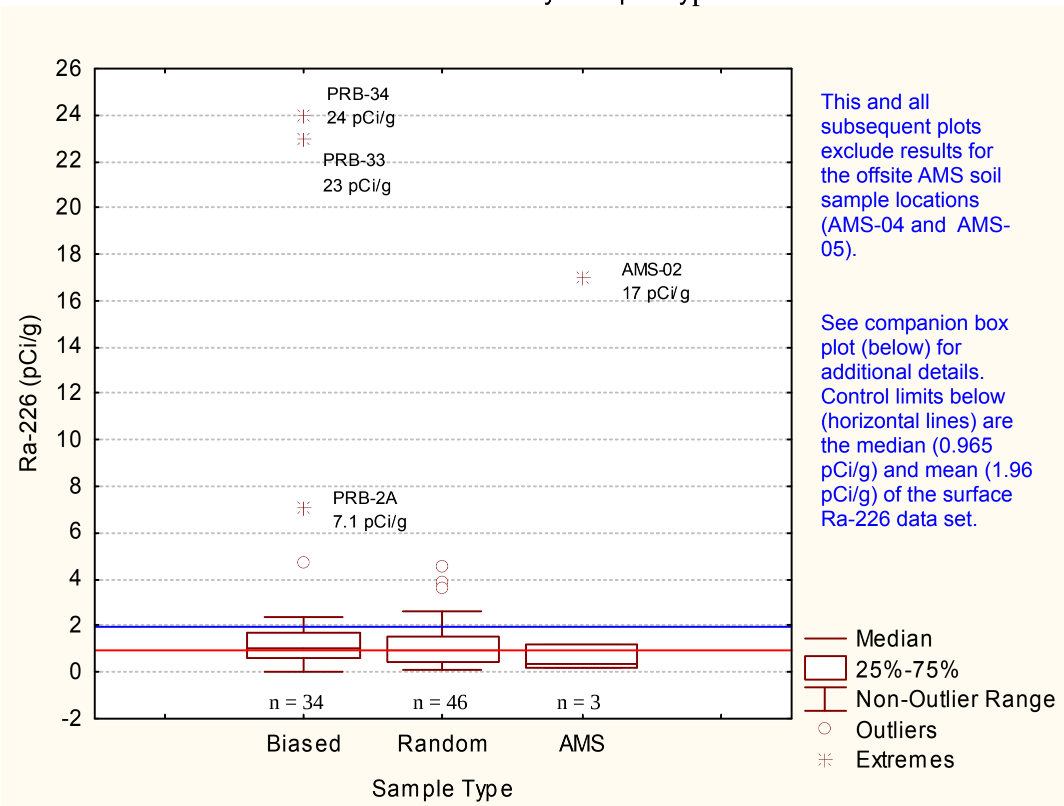


Illustration 4.1b. Distribution for all samples

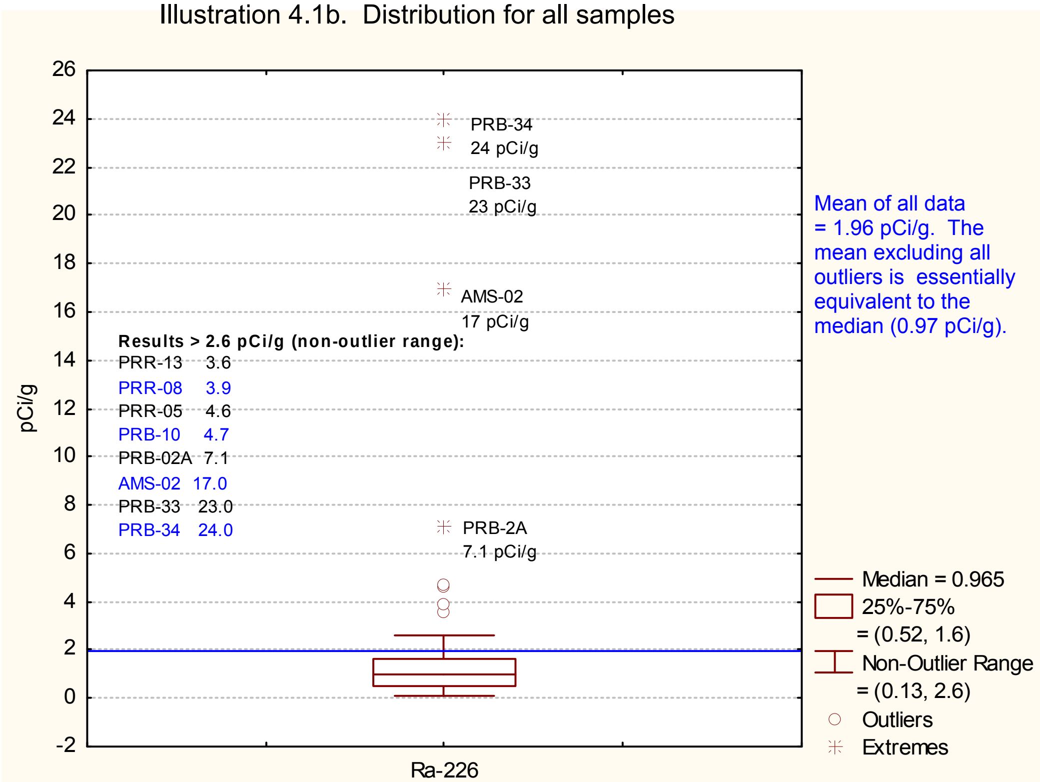
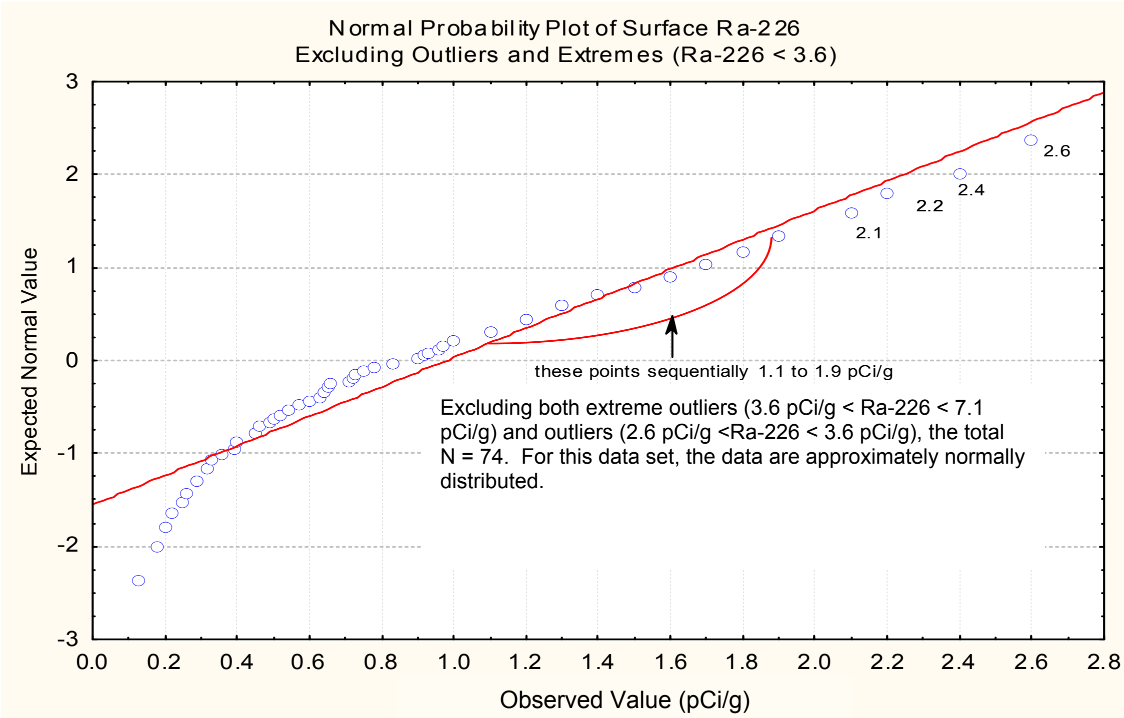


Illustration 4.2 Surface Soil Ra-226 Concentration Distribution



Although most of the site exhibits Ra-226 concentrations of approximately 1 pCi/g, areas in the southern portion of the site exhibit radiological anomalies from natural and potentially historic anthropogenic sources within the area. Additionally, as discussed in Section 3, slightly elevated levels of surface soil Ra-226 concentrations are apparent in all three major drainages—the western, central, and eastern drainage. This is apparent in Figure 4.5, as well as the other figures presenting gamma survey results.

4.3 Subsurface Soil Sampling Results

Table 4.4 summarizes the subset of biased samples that were collected at depth (PRB-02, PRB-9, PRB-24, PRB-25, and PRB-26). Samples collected at PRB-02 and PRB-09, which are located within the proposed mill area, had Ra-226 at concentrations greater than 1.0 pCi/g at all depths. However, there is no apparent trend with depth. The remaining sample locations, PRB-24 through PRB-26, are located within the proposed tailings cells and evaporation pond areas. Samples collected from these locations exhibited Ra-226 concentrations comparable to or lower than the majority of the site (< 1 pCi/g). Again, no trends with depth are evident in these samples.

4.4 Other Radiological Parameters

Table 4.8 summarizes the analytical results for the 18 samples (not including duplicates) analyzed for the extended suite of radiological parameters (biased, random, and AMS locations combined). Although the sample number isn't sufficient to allow any definitive conclusions to be drawn regarding distributional characteristics or trends of non-Ra-226 parameters, a positive linear relationship between Ra-226 concentrations and concentrations of Th-230, U-Nat, and Pb-210 is apparent.

Th-232 concentrations in the 18 samples range from 0.13 to 0.65 pCi/g and average 0.4 pCi/g. The low background values of Th-232 indicate no naturally enhanced mineralization of Th-232 in soils. Analysis of radium-228 need not be performed in this case.

4.5 Discussion

In summary, the results discussed above and shown in Figures 4.1 through 4.5 essentially parallel those shown in Figures 3.1 through 3.5. The majority of the site is characterized by surface Ra-226 concentrations $\leq$ 2.6 pCi/g, with a central tendency of 1 pCi/g. Areas in the southern portion of the site exhibit higher levels of radioactivity in drainage areas due to natural processes and possibly anthropogenic sources from nearby mines. Based on these findings, derivation of a single number or level that is representative of background conditions at the Piñon Ridge site is probably not appropriate. The background condition of the site would best be represented by the distribution of the observed data. Experience at other milling sites underscores the need for caution in characterizing background conditions for sites with naturally occurring radioactivity, as adherence to a single number (especially if a conservative estimator such as a mean is used) can have ramifications later (e.g., unnecessary cleanup and associated destruction of topsoil).[1]

[1] For example, in the NRC's review of Final Status Survey and background data for the Gas Hills site in Wyoming, for which closure is imminent, the staff concluded that “there is no statistical answer to the question of what is the most appropriate background value for this area.” (NRC 2001, available in public docket).

5.0 DATA QUALITY ASSESSMENT

This section briefly summarizes the results of the quality control (QC) samples collected for the baseline soil sampling program. As indicated in Table 4.1 and specified in Section 4.4 of the Work Plan, 20 percent of the soil samples collected were duplicated for QC purposes. The results of this QC effort are documented in Table 5.1, which lists the analytical results for each duplicate pair along with corresponding errors and lower limits of detection (LLDs). Table 5.2 documents associated comparisons, presenting the corresponding Replicate Error Ratio (RER) or RPD (in the case of U-nat) for each QC pair. These tables are provided at the end of this section.

Examination of the results provided in Table 5.1 indicates that, in general, there is close agreement in the analytical results reported for each duplicate pair collected for all parameters. Apparent anomalous results were reported for Th-230 for two sample pairs (PRR-46 and AMS-02); these results are highlighted in Table 5.1. Following re-evaluation of the data by the analytical laboratory, this discrepancy could not be resolved. Because duplicate results are generally comparable for the majority of QC samples collected and the other parameters for these two pairs of soil samples were within acceptable ranges, no request to re-analyze the samples were made.

Table 5.2 presents the corresponding RER and, in the case of U-nat, RPDs calculated for each duplicate pair. The calculation of RER and RPDs is a standard technique used to evaluate QC samples. Typically, an RER of < 2 and an RPD of <20 percent is used as a guideline in many data quality objective evaluations. This data set shows five cases where either the RER or RPD was greater than 2 and 20, respectively. Considering the low level of radioactivity observed in most of the QC pairs, the laboratory performance on blind duplicates is satisfactory. Table 5.3 presents summary statistics for reported values along with corresponding LLDs.

Table 5.1. Piñon Ridge QA-QC Comparison Results

Sample ID	Date	Lab ID	Ra-226 (pCi/g)	Ra-226 Error (+/-)	Th-230 (pCi/g)	Th-230 Error (+/-)	U-Nat (mg/kg)	Pb-210 (pCi/g)	Pb-210 Error (+/-)	Ra-226 LLD (pCi/g)	Th-230 LLD (pCi/g)
Biased Samples											
PRB-01	10/22/07	L65964-04	-0.01	0.1	0.10	0.4	0.62	0.17	1.0	0.35	0.62
PRB-01Q	10/22/07	L65960-05	0.38	0.2	0.56	0.5	0.50	0.21	1.0	0.63	0.27
PRB-13	10/19/07	L65964-09	2.2	0.31						0.44	
PRB-13Q	10/19/07	L65964-05	1.2	0.27						0.51	
PRB-22	10/23/07	L65966-02	1.8	0.24						0.36	
PRB-22Q	10/23/07	L65965-04	2.0	0.34						0.45	
PRB-24A	10/24/07	L65967-13	0.32	0.15						0.38	
PRB-24AQ	10/24/07	L65967-17	0.33	0.21						0.40	
PRB-25A	10/24/07	L65964-01	0.72	0.40						0.70	
PRB-25QA	10/24/07	L65967-12	0.57	0.19	0.39	0.43	0.85	0.43	2.0	0.40	0.23
PRB-25B	10/24/07	L65962-03	0.71	0.2	0.13	1.0	0.57	1.96	2.0	0.46	0.37
PRB-25QB	10/24/07	L65962-06	0.67	0.2	0.74	0.5	0.60	0.63	1.0	0.46	0.22
PRB-25C	10/24/07	L65962-07	0.46	0.2	0.60	0.5	0.60	0.25	2.0	0.53	0.23
PRB-25QC	10/24/07	L65961-05	0.52	0.1	-0.04	0.7	0.66	1.21	2.0	0.32	0.41
PRB-26A	10/24/07	L65967-09	0.52	0.15						0.41	
PRB-26AQ	10/24/07	L65967-16	0.33	0.18						0.5	
PRB-28	10/23/07	L65959-04	0.60	0.15						0.27	
PRB-28Q	10/23/07	L65965-09	0.43	0.21						0.44	
Random Samples											
PRR-06	10/22/07	L65959-12	1.0	0.19						0.31	
PRR-06Q	10/22/07	L65959-05	1.4	0.22						0.37	
PRR-10	10/22/07	L65966-10	2.1	0.25						0.32	
PRR-10Q	10/22/07	L65964-10	1.0	0.25						0.46	
PRR-15	10/23/07	L65965-14	1.9	0.30						0.43	
PRR-15Q	10/23/07	L65965-10	2.5	0.35						0.55	
PRR-20	10/23/07	L65964-07	1.9	0.39						0.73	
PRR-20Q	10/23/07	L65963-09	0.56	0.17						0.35	
PRR-24	10/23/07	L65959-02	1.3	0.22						0.33	
PRR-24Q	10/23/07	L65963-03	2.1	0.29						0.43	

Table 5.1. Piñon Ridge QA-QC Comparison Results (Cont.)

Sample ID	Date	Lab ID	Ra-226 (pCi/g)	Ra-226 Error (+/-)	Th-230 (pCi/g)	Th-230 Error (+/-)	U-Nat (mg/kg)	Pb-210 (pCi/g)	Pb-210 Error (+/-)	Ra-226 LLD (pCi/g)	Th-230 LLD (pCi/g)
PRR-29	10/23/07	L65965-08	0.45	0.18						0.45	
PRR-29Q	10/23/07	L65965-07	0.49	0.27						0.60	
PRR-34	10/23/07	L65965-03	0.29	0.20						0.44	
PRR-34Q	10/23/07	L65963-05	0.53	0.14						0.37	
PRR-38	10/24/07	L65962-01	0.54	0.18						0.42	
PRR-38Q	10/24/07	L65967-02	0.31	0.20						0.46	
PRR-43	10/24/07	L65962-05	0.26	0.19	0.53	0.45	1.26	1.24	1.0	0.59	0.60
PRR-43Q	10/24/07	L65967-04	0.48	0.15	0.12	0.35	0.73	1.20	1.0	0.39	0.53
PRR-46	10/23/07	L65963-04	0.92	0.22	1.0	0.47	1.65	2.06	1.0	0.39	0.54
PRR-46Q	10/23/07	L65965-05	0.84	0.21	20.0	1.6	1.65	2.85	1.0	0.41	0.62
AMS Soil Samples											
AMS-02	10/24/07	L65967-10	17.0	0.69	1.50	0.54	52.1	21.3	4.0	0.39	0.57
AMS-02Q	10/24/07	L65961-10	14.0	0.71	17	1.4	46.6	14.7	3.0	0.48	0.59

LLD Lower Limit of Detection

Anomalous QC results—applying to Th-230 only— are highlighted above. ERG requested that the laboratory re-evaluate their results. The analytical laboratory could not resolve the discrepancy. See discussion in Section 5.0.

For U-Nat, Method Detection Limits (MDLs), and Practical Quantitation Limits (PQLs) were all 0.05 mg/kg and 0.3 mg/kg, respectively.

Table 5.2. Piñon Ridge QA-QC Comparisons: RPD and RER Summary

Sample ID	Ra-226	Ra-226Q	RER	Th-230	Th-230Q	RER	U-Nat	U-NatQ	RPD	Pb-210	Pb-210Q	RER
PRB-01	-0.01	0.38	1.47	0.1	0.56	0.70	0.5	0.5	0%	0.17	0.21	0.03
PRB-13	2.2	1.2	1.80									
PRB-22	1.8	2.0	0.34									
PRB-24A	0.32	0.33	0.04									
PRB-25A	0.72	0.57	0.32									
PRB-25B	0.71	0.67	0.13	0.13	0.74	0.55	0.57	0.6	5%	1.96	0.63	0.59
PRB-25C	0.46	0.52	0.23	0.6	-0.04	0.77	0.6	0.66	10%	0.25	1.21	0.34
PRB-26A	0.52	0.33	0.75									
PRB-28	0.6	0.43	0.60									
PRR-06	1	1.4	1.03									
PRR-10	2.1	1.0	2.21									
PRR-15	1.9	2.5	0.91									
PRR-20	1.9	0.56	2.58									
PRR-24	1.3	2.1	1.54									
PRR-29	0.45	0.49	0.12									
PRR-34	0.29	0.53	0.92									
PRR-38	0.54	0.31	0.81									
PRR-43	0.26	0.48	0.86	0.53	0.12	1.14	1.26	0.73	53%	1.24	1.2	0.04
PRR-46	0.92	0.84	0.22	1.0	20	5.53	1.65	1.65	0%	2.06	2.85	0.52
AMS-02	17	14	0.87	1.5	17	5.22	52.10	46.6	11%	21.31	14.74	1.24

In this table, "Q" denotes the QA-QC counterpart listed in the preceding table for each sample location. RER corresponds to the Relative Error Ratio. RPD corresponds to the relative percent difference, which is derived by dividing the difference between the two results by the average result

Table 5.3. Descriptive Statistics for Radiological Parameters and Associated LLDs

Radionuclide	Valid N*	Mean	Minimum	Maximum	Std. Dev.
Ra-226	115	1.78	-0.01	24.00	3.63
Ra-226 LLD	115	0.44	0.25	0.93	0.11
Th-230	25	2.90	-0.05	20.00	5.21
Th-230 LLD	25	0.61	0.53	1.10	0.11
U-Nat	25	6.96	0.47	52.10	13.90
U-Nat LLD	115	0.05	0.05	0.05	0.00
Pb-210	25	3.50	0.17	21.31	4.93
Pb-210 LLD	25	1.04	1.00	2.00	0.20

LLD = Lower Limit of Detection, units in pCi/g except U-Nat, in mg/kg

Notes:* N includes duplicate samples.

6.0 RADON FLUX MEASUREMENTS AND AMBIENT AIR MONITORING

This section summarizes the results of pre-operational Radon-222 (Rn-222) flux measurements and ambient air monitoring conducted in accordance with Sections 4.6 and 4.7 of the September 2007 Work Plan. Field data and analytical results supporting the Radon-222 flux data are contained in Appendix C. Laboratory reports for ambient Radon-222 concentration measurements are contained in Appendix B-2.

6.1 Radon Flux Measurements

The Work Plan specified that three rounds of Rn-222 flux measurements would be taken to characterize pre-operational conditions in accordance with NRC Regulatory Guide (RG) 4.14. The following documents the results all three rounds of measurements taken in October 2007, April 2008, and July 2008.

Rn-222 emission rates were measured from nine locations within the proposed tailings area shown on Figure 4.1 (soil samples coinciding with Rn-222 flux measurements). Nine canisters were deployed in the Fall 2007, Spring 2008, and Summer 2008. These canisters were analyzed using U.S. Environmental Protection Agency (USEPA) Test Method 115, *Monitoring for Radon-222 Emissions*. Results are documented in the following table (Table 6.1). Sampling for all periods yielded an average flux of 1.7 picocuries per meter squared second (pCi/m^2-s). Radon-222 flux rates ranged between 0.41 and 3.78 pCi/m^2-s. These values are one to two orders of magnitude below the National Emissions Standards for Hazardous Air Pollutants (NESHAPS) requirements of 20 pCi/m^2-s specified in 10 CFR 40, Appendix A, Criterion 6. Although the latter requirement applies to tailings and thus is not directly germane to this characterization, it is useful as a context to demonstrate the relative magnitude of baseline radon flux levels measured in the central portion of the site.

Table 6.1. Pre-Operational Radon Flux Results Measurements

Soil Sample Location	Date Collected	Canister Number	Rn-222 Flux (pCi/m^2s)	Flux Error 1.00 S.D.	LLD (pCi/m^2s)	Ave. Flux (pCi/m^2s)
PRB-16	10/29/07	2	1.30	0.03	0.03	0.87
	4/24/08	46	0.41	0.05	0.2	
	7/14/08	203	0.90	0.05	0.1	
PRB-23	10/29/07	261	2.67	0.05	0.04	2.10
	4/24/08	22	1.54	0.06	0.2	
	7/14/08	101	2.08	0.06	0.1	
PRB-21	10/29/07	29	3.23	0.05	0.04	0.82
	4/24/08	261	2.12	0.06	0.2	
	7/14/08	62	3.16	0.06	0.1	
PRB-19	10/29/07	38	0.69	0.03	0.04	1.71
	4/24/08	64	0.68	0.05	0.2	
	7/14/08	89	1.10	0.05	0.1	
PRB-14	10/29/07	48	1.32	0.03	0.04	2.74
	4/24/08	39	1.74	0.06	0.2	
	7/14/08	2	2.07	0.05	0.1	
PRB-17	10/29/07	71	3.28	0.05	0.04	2.43
	4/24/08	47	2.60	0.06	0.2	
	7/14/08	45	2.34	0.06	0.1	
PRB-18	10/29/07	80	2.12	0.04	0.04	1.31
	4/24/08	66	1.19	0.06	0.2	
	7/14/08	64	0.64	0.05	0.1	
PRB-20	10/29/07	88	1.31	0.03	0.04	1.01
	4/24/08	94	0.74	0.05	0.2	
	7/14/08	98	0.98	0.05	0.1	
PRB-13	10/29/07	255	2.22	0.04	0.04	2.56
	4/24/08	29	1.68	0.06	0.2	
	7/14/08	49	3.78	0.06	0.1	
average:			1.70			
minimum:			0.41			
maximum:			3.78			

Canisters deployed and analyzed using EPA Test Method 115.

6.2 Radon Ambient Air Monitoring

In accordance with the September 2007 Work Plan and NRC Regulatory Guide (RG) 4.14, passive track etch detectors were placed at each of the five AMS locations to measure Radon-222 air concentrations. Three AMS locations are on the site property. The remaining two locations are offsite and located upwind and downwind from the site. The Radon-222 measurements were collected for over a year, March 8, 2008 through July 1, 2009, with detectors exchanged quarterly.

The ambient radon monitoring results are listed in Table 6-2. Quarter 1 ambient radon concentrations ranged from 0.6 to 0.9, averaging 0.8 pCi/L. Quarter 2 ambient radon concentrations ranged from 1.7 to 1.9, averaging 1.8 pCi/L. Quarter 3 concentrations ranged from 1.6 to 3.2, averaging 2.0 pCi/L. Quarter 4 concentrations ranged from 3.3 to 4.1, averaging 3.7 pCi/L. Quarter 5 concentrations ranged from 0.7 to 1.3, averaging 0.9 pCi/L.

There appear to be no spatial trends in the data set, other than the levels are within the same order of magnitude across the AMS locations.

In terms of effluent concentration comparison as suggested by NRC RG 4.14, the measured values exceed the 10 CFR 20 value of 0.1 pCi/L for radon-222 with progeny present. However, on average the measured values are within the range, albeit on the high end, of reported worldwide ambient background radon concentrations, 0.027 to 2.7 pCi/L (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000).

Table 6-2. Baseline Radon Ambient Air Monitoring Measurements

Location	Starting Date	Ending Date	Radon-222 Conc. (pCi/L)	Error ± (pCi/L)	Percent Effluent Conc.	Average Rn-222 Conc. (pCi/L)	Standard Deviation of Average (pCi/L)	Minimum Rn-222 Conc. (pCi/L)	Maximum Rn-222 Conc. (pCi/L)
AMS-1	3/8/08	7/1/08	0.9	-	900	1.9	1.2	0.9	3.8
	7/1/08	10/1/08	1.9	-	1900				
	10/1/08	1/1/09	1.8	-	1800				
	1/1/09	4/3/09	3.8	0.2	3800				
	4/3/09	7/1/09	0.9	0.9	900				
AMS-2	3/8/08	7/1/08	0.9	-	900	2.2	1.2	0.9	3.8
	7/1/08	10/1/08	1.9	-	1900				
	10/1/08	1/1/09	3.2	-	3200				
	1/1/09	4/3/09	3.8	0.2	3800				
	4/3/09	7/1/09	1.3	0.1	1300				
AMS-3	3/8/08	7/1/08	0.6	-	600	1.7	1.4	0.6	4.1
	7/1/08	10/1/08	1.7	-	1700				
	10/1/08	1/1/09	1.6	-	1600				
	1/1/09	4/3/09	4.1	0.2	4100				
	4/3/09	7/1/09	0.7	0.8	700				
AMS-4	3/8/08	7/1/08	0.9	-	900	1.8	1.1	0.9	3.6
	7/1/08	10/1/08	1.7	-	1700				
	10/1/08	1/1/09	1.7	-	1700				
	1/1/09	4/3/09	3.6	0.2	3600				
	4/3/09	7/1/09	0.9	0.1	900				
AMS-5	3/8/08	7/1/08	0.8	-	800	1.9	1.0	0.8	3.3
	7/1/08	10/1/08	1.8	-	1800				
	10/1/08	1/1/09	1.8	-	1800				
	1/1/09	4/3/09	3.3	0.2	3300				
	4/3/09	7/1/09	0.9	0.1	900				

7.0 EXPOSURE RATE MONITORING

This section summarizes the environmental dose rate measurements at the AMS locations using OSL dosimeters. The measurements were collected in accordance with Section 4.8 of the September 2007 Work Plan. Laboratory reports for dose rate measurements using OSL dosimeters are contained in Appendix B-3.

7.1 Methods

In accordance with the Work Plan and NRC RG 4.14., OSL dosimeters were placed at each of the five air monitoring locations to measure external ionizing radiation exposure. These exposure measurements were collected for a year with dosimeters exchanged quarterly by EFR personnel. The dosimeters were provided and analyzed by Landauer, Inc., a National Voluntary Laboratory Accreditation Program (NVLAP) certified laboratory.

7.2 Results

Ambient exposure rates were determined for four periods, using OSL dosimeters supplied and analyzed by Landauer, Inc. The monitoring periods were: 3rd Quarter 2008 through 2nd Quarter 2009.

The dosimeters were deployed at each of the 5 AMS locations. EFR personnel managed the dosimeter exchanges as well as performed the analysis to correct AMS site dosimeter responses for the control dosimeter responses.

The ambient gamma dose rate monitoring results are listed in Table 7-1. Assuming a µR/hr to µrem/hr conversion of 1, the ambient gamma dose rate monitoring results are consistent with the exposure rate results presented in Section 3.0 above. The ranges of observed gamma dose rates are 11.6 to 14.5 µrem/hr and 11 to 19 µR/hr as measured using the OSLs and PIC (via correlation of gamma count rates), respectively. All dose rates are within the average worldwide exposures to natural radiation sources comprised of cosmic radiation, cosmogenic radionuclides, and external terrestrial radiation reported in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Report to the General Assembly, Sources and Effects of Ionizing Radiation, Annex B. The typical ranges of average worldwide exposures reported in this reference document are to 60 to 160 millirem per year (mrem/yr).

Table 7-1. Control Corrected Ambient Gamma Dose Rates using OSL Dosimeters

Location	Period (Quarter)	Dose (mrem)	Average Dose per Monitoring Period (mrem)	Projected Annual Dose (mrem)
AMS-01	3rd QTR 2008	27.0	25.5	101.8
	4th QTR 2008	23.2		
	1st QTR 2009	24.3		
	2nd QTR 2009	27.3		
AMS-02	3rd QTR 2008	36.2	31.8	127.2
	4th QTR 2008	30.1		
	1st QTR 2009	31.1		
	2nd QTR 2009	29.8		
AMS-03	3rd QTR 2008	30.0*	30.2	120.8
	4th QTR 2008	30.1		
	1st QTR 2009	30.0		
	2nd QTR 2009	30.7		
AMS-04	3rd QTR 2008	31.2	28.4	113.4
	4th QTR 2008	25.5		
	1st QTR 2009	27.0		
	2nd QTR 2009	29.7		
AMS-05	3rd QTR 2008	34.0	31.3	125.1
	4th QTR 2008	30.1		
	1st QTR 2009	28.8		
	2nd QTR 2009	32.2		

Notes:* Dosimeter was damaged during processing; result is an estimated value from the laboratory.

8.0 VEGETATION SAMPLING

This section documents the results of vegetation sampling conducted for the baseline radiological characterization. Samples were collected in the Fall of 2007, and Spring and Summer of 2008 which are reflective of the typical growing seasons at the site.

8.1 Sampling Methods and Analytes

In accordance with the Work Plan and NRC Regulatory Guide (RG) 4.14, one vegetation sample was collected at each of the five AMS locations during the sampling periods described above. Samples were collected using grass clippers or shears and placed in large plastic lawn bags, labeled appropriately, and stored in a laboratory-supplied cooler until transferred to the laboratory. Only vegetation available to and likely eaten by locally grazed livestock was collected. No segregation by common or genus/species names was performed. The samples were analyzed for Ra-226, Th-230, U-Nat, Pb-210, and Po-210 using the methods identified on Table 8.1.

8.2 Results

Table 8.1 presents the results of vegetation sampling. Ra-226 and Th-230 concentrations were detected at concentrations comparable to, and sometimes below the corresponding MDL. Ra-226 concentrations ranged from 0.03 to 0.6 pCi/g; those for Th-230 from –0.2 to 1.2 pCi/g. U-Nat concentrations ranged from 0.08 to 2.41 mg/kg (equivalent to 0.05 to 1.6 pCi/g. Pb-210 and Po-210 concentrations were somewhat higher. Pb-210 concentrations ranged from 1.4 to 6.6 pCi/g, with the maximum concentration measured at the onsite location AMS-02. Po-210 concentrations ranged from 0.2 to 4.3 pCi/g. The maximum Po-210 concentration was measured at offsite location AMS-04.

Comparison with corresponding soil sample results yields no apparent relationship. Radionuclide concentrations were highest in onsite soil sample AMS-02, located in the southeastern portion of the site. The corresponding vegetation sample collected at this location actually had the lowest radionuclide concentrations of the five samples collected.

Table 8.1. Piñon Ridge Vegetation Sampling Results

Sample ID	Date Collected	Ra-226 (pCi/g)	Ra-226 Error (+/-)	Ra-226 LLD	Th-230 (pCi/g)	Th-230 Error (+/-)	Th-230 LLD	U-Nat (mg/kg)	U-Nat LLD	Pb-210 (pCi/g)	Pb-210 Error(+/-)	Pb-210 LLD	Po-210 (pCi/g)	Po-210 Error(+/-)	Po-210 LLD
AMS-01	10/24/07	0.37	0.23	0.55	0.21	0.4	0.59	0.11	0.05	3.9	0.50	0.5	1.67	0.32	0.02
	04/25/08	0.19	0.15	0.47	0.27	0.42	0.61	0.2	0.05	2.82	1	0.09	0.86	0.17	0.01
	07/15/08	0.15	0.11	0.28	0.03	0.38	0.25	U	0.05	3.5	1.7	3.6	1.69	0.30	0.02
AMS-02	10/24/07	0.04	0.16	0.43	-0.02	0.39	0.64	0.52	0.05	2.69	0.49	0.2	0.81	0.17	0.02
	04/25/08	0.53	0.26	0.55	1.2	0.52	0.59	0.65	0.05	5.54	1	0.08	2.07	0.36	0.02
	07/15/08	0.16	0.17	0.46	-0.2	0.45	0.77	0.09	0.05	3.2	1.8	3.9	0.34	0.08	0.013
AMS-03	10/24/07	0.28	0.26	0.47	-0.05	0.37	0.61	0.24	0.05	3.12	0.61	0.61	0.99	0.19	0.02
	04/25/08	0.31	0.24	0.64	0.42	0.48	0.67	0.11	0.05	6.63	1	0.11	1.65	0.30	0.01
	07/15/08	0.23	0.13	0.32	0.13	0.47	0.72	0.08	0.05	4	1.8	4.1	0.4	0.09	0.02
AMS-04	10/25/07	0.1	0.21	0.72	0.12	0.41	0.41	0.09	0.05	6.04	0.57	0.19	4.26	0.72	0.02
	04/25/08	0.54	0.19	0.41	0.4	0.46	0.65	0.63	0.05	3.01	1	0.1	2.50	0.44	0.01
	07/15/08	0.03	0.13	0.37	0.27	0.45	0.66	U	0.05	2	2	5	0.19	0.06	0.02
AMS-05	10/24/07	0.31	0.17	0.43	0.14	0.41	0.62	0.08	0.05	3.7	0.60	0.23	1.6	0.28	0.02
	04/25/08	0.59	0.16	0.41	1.1	0.55	0.65	2.41	0.05	4.81	1	0.09	2.00	0.34	0.01
	07/15/08	0.6	0.18	0.52	0.24	0.46	0.68	0.47	0.05	1.4	1.6	3.7	0.36	0.09	0.01

LLDs for U-Nat and Po-210 were all 0.05 mg/kg and 0.02 pCi/g, respectively.
U = Undetected in sample

Laboratory Analytical Methods, for Vegetation Samples:

Analyte	Method	Comment
Radium 226	M903.1	Digestion method was EPA method 3050B
Thorium 230	ESM 4506	Th-228 and Th-232 were also measured using this method; results are provided in the laboratory reports.
Uranium, total	M6020 ICP-MS	
Lead-210	EPA 901.1	Initially analyzed using Eichrom method, but because associated LLDs and errors were high, samples were reanalyzed.
Polonium-210	Alpha Spectroscopy	This analysis was subcontracted to Paragon Analytics in order to meet detection limits described in RG 4.14.

9.0 SUMMARY AND CONCLUSIONS

The results of the Piñon Ridge baseline field investigation documented herein indicate the following:

- The majority of the site exhibits exposure rate data points ranging between 11 and 20 μR/hr, coinciding closely with the summary statistics provided in Section 3 for non-outlier ranges. The lower range or subpopulation of readings ranging from 11 to 14 μR/hr occurs in the northern portion of the site, coinciding with lower elevation areas.

- Readings between 14 and 20 μR/hr, corresponding to the range between the median and the non-outlier range, are found in the majority of the rest of the site (comprising approximately 40 percent of the site area), and appear to coincide with western and eastern drainages (see Figure 3.2).

- Elevated levels of radioactivity, as characterized by gamma readings greater than 20,000 cpm and estimated exposure rates greater than 20 μR/hr, appear to be limited to three areas:

  1) An area in the southern portion of the site (south of the proposed mill area), located just north of and adjacent to the offsite topsoil pile (see Figure 3.2);

  2) An area in the southwestern portion of the site, near the reach of the western drainage. This area is characterized by sparse vegetation (more evident in Site Layout, Figure 1.1), topsoil is present at depths exceeding 1 cm, and surficial deposits of fine-grained material appear to exist.

  3) Isolated locations in the upper reaches of the eastern drainage, which were much more localized and less extensive than those noted above.

- Patterns of slightly elevated radioactivity are also apparent in the three site drainages (note darker patterns in Figure 3.2), where exposure rates range from approximately 15 to 17 μR/hr.

- The results based on surface soil sampling corroborate the findings discussed above regarding spatial trends of radioactivity at the site. The majority of the site is characterized by surface Ra-226 concentrations < 2.6 pCi/g, with a central tendency of 1 pCi/g. Areas in the southern portion of the site exhibit higher levels of radioactivity indicative of natural and possibly historic anthropogenic influences.

- Experience at other milling sites underscores the need for caution in characterizing background conditions, as adherence to a single number (especially if a conservative estimator such as a mean is used) can result in later unnecessary cleanup and/or habitat destruction. In the case of the Piñon Ridge site, most Ra-226 concentrations range between 0.5 and approximately 1 pCi/g, close to the detection limit in some cases. However, isolated areas of elevated Ra-226 (ranging up to 24 pCi/g based on sample results) do occur, coinciding with a former drainage in the southeastern portion of the site and a sparsely vegetated area coinciding with parts of the western drainage.

- Rn-222 flux rates ranged between 0.41 and 3.78 pCi/m^2-s within the footprint of the proposed tailings area. These values are well below the NESHAPS requirement of 20 pCi/m^2-s specified in 10 CFR 40, Appendix A, Criterion 6. Although the requirement applies to uranium mill tailings and thus is not directly germane to this characterization, it is useful as a context to demonstrate the magnitude of baseline radon flux levels measured at the site.

- Radionuclide concentrations in vegetation are near MDLs and do not correlate to radionuclide concentrations in soil for the same sample locations.

- "Baseline Survey of Radionuclides in Animal Tissues at the Proposed Piñon Ridge Millsite" (Whicker, 2008) summarizes radiological characteristics of animal tissues collected from the site and provides recommendations for future biological monitoring.

- Ambient radon-222 concentrations are within the expected ranges for this geographical area

In summary, it is clear that the drainage areas within the southern quarter of the site exhibit radiological anomalies from natural and possibly historic anthropogenic sources within the area. The natural source of the elevated radioactivity in the southern portion of the site originates from erosion of the Salt Wash member of the Morrison formation, which outcrops along the flank of the mesa south of the site. The Salt Wash member is the uranium ore host for the nearby uranium mines. Possible historic anthropogenic sources within the area include underground and surface uranium mining activities conducted in areas south of the site.

10.0 REFERENCES

Environmental Restoration Group (ERG). 2007. Work Plan for Energy Fuels Resource Corporation Uranium Mill Licensing Support Baseline Radiological Investigation. Kleinfelder Project No. 83088. September 19, 2007.

US Environmental Protection Agency, Test Method 115: Monitoring for Radon-222 Emissions.

US Nuclear Regulatory Commission (NRC). 1980. Regulatory Guide 4.14, Revision 1, *Radiological Effluent and Environmental Monitoring at Uranium Mills*.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000. UNSCEAR Report to the General Assembly, *Sources and Effects of Ionizing Radiation, Annex B.*

Whicker, F. Ward. 2008. Baseline Survey of Radionuclides in Animal Tissues at the Proposed Piñon Ridge Millsite. August 27, 2008.

Section 4 Tables
(Tables 4.3 – 4.8)

Table 4.3. Piñon Ridge Biased Soil Sampling Results

			Ra-226		Th-230		Th-232		U-Nat		Pb-210		LLDs (pCi/g)		
Sample ID	Depth (cm)	Date	pCi/g	Error (+/-)	pCi/g	Error (+/-)	pCi/g	Error (+/-)	mg/kg	pCi/g	pCi/g	Error (+/-)	Ra-226	Th-230	Th-232
PRB-01 *	0-15	10/22/07	-0.01	0.1	0.1	0.4	0.3	0.39	0.62	0.42	0.17	1.0	0.35	0.62	0.24
PRB-02A	0-15	10/22/07	7.1	0.4	8.20	1.1	0.65	0.46	18.7	12.7	7.31	2.0	0.25	0.65	0.25
PRB-02B	15-30	10/22/07	4.0	0.4	2.90	0.7	0.32	0.37	4.21	2.85	2.79	2.0	0.45	0.57	0.22
PRB-02C	30-100	10/22/07	1.4	0.3	1.50	0.6	0.4	0.38	2.42	1.64	1.70	2.0	0.38	0.53	0.22
PRB-03	0-15	10/22/07	0.64	0.2	0.96	0.5	0.13	0.35	1.94	1.31	2.98	2.0	0.46	0.59	0.22
PRB-04	0-15	10/22/07	1.7	0.3									0.57		
PRB-05	0-15	10/22/07	1.3	0.28									0.44		
PRB-06	0-15	10/22/07	0.18	0.13									0.38		
PRB-07	0-15	10/22/07	0.66	0.24									0.58		
PRB-08	0-15	10/22/07	0.22	0.16									0.45		
PRB-09A	0-15	10/22/07	1.5	0.25									0.45		
PRB-09B	15-30	10/22/07	3.5	0.35									0.36		
PRB-09C	30-100	10/22/07	1.2	0.23									0.39		
PRB-10	0-15	10/22/07	4.7	0.54	6.6	0.97	0.19	0.37	19.3	13.1	7.36	2.0	0.67	0.62	0.24
PRB-11	0-15	10/22/07	0.73	0.17									0.30		
PRB-12	0-15	10/23/07	1.3	0.22									0.38		
PRB-13*†	0-15	10/19/07	2.2	0.31									0.44		
PRB-14†	0-15	10/19/07	2.1	0.24									0.33		
PRB-15	0-15	10/23/07	0.78	0.18									0.36		
PRB-16†	0-15	10/19/07	0.9	0.19									0.41		
PRB-17†	0-15	10/19/07	1.7	0.24									0.38		
PRB-18†	0-15	10/19/07	2.4	0.37									0.52		
PRB-19†	0-15	10/19/07	0.64	0.24									0.50		
PRB-20†	0-15	10/19/07	0.49	0.13									0.26		
PRB-21†	0-15	10/19/07	1.2	0.24									0.44		
PRB-22*	0-15	10/23/07	1.8	0.24									0.36		
PRB-23†	0-15	10/19/07	1.6	0.44									0.93		

Shaded rows denote outlier results for surface Ra-226 (i.e., ≥ 3.6 pCi/g), given the distributional characteristics discussed in the text.
* Denotes that a corresponding QA/QC sample was collected (see Table 5.1 for results).
† Denotes co-located radon flux sample location.
For U-Nat, Method Detection Limits (MDLs) and Practical Quantitation Limits (PQLs) were all 0.05 and 0.3 mg/kg, respectively. All Pb-210 MDLs were 0.1 pCi/g.

Table 4.3. Piñon Ridge Biased Soil Sampling Results (Concluded)

			Ra-226		Th-230		Th-232		U-Nat		Pb-210		LLDs (pCi/g)		
Sample ID	Depth (cm)	Date	pCi/g	Error (+/-)	pCi/g	Error (+/-)	pCi/g	Error (+/-)	mg/kg	pCi/g	pCi/g	Error (+/-)	Ra-226	Th-230	Th-232
PRB-24A*	0-15	10/24/07	0.32	0.15									0.38		
PRB-24B	15-30	10/24/07	0.60	0.25									0.60		
PRB-24C	30-100	10/24/07	0.36	0.21									0.52		
PRB-25A*	0-15	10/24/07	0.72	0.4									0.70		
PRB-25B*	15-30	10/24/07	0.71	0.2	0.13	1.0	0.64	0.64	0.57	0.39	1.96	2.0	0.46	0.63	0.37
PRB-25C*	30-100	10/24/07	0.46	0.2	0.6	0.5	0.47	0.4	0.6	0.41	0.25	2.0	0.53	0.6	0.23
PRB-26A*	0-15	10/24/07	0.52	0.15									0.41		
PRB-26B	15-30	10/24/07	0.03	0.19									0.42		
PRB-26C	30-100	10/24/07	0.47	0.18									0.36		
PRB-27	0-15	10/23/07	0.54	0.18									0.39		
PRB-28*	0-15	10/23/07	0.60	0.15									0.27		
PRB-29	0-15	10/23/07	0.46	0.17									0.41		
PRB-30	0-15	10/22/07	1.1	0.26									0.54		
PRB-31	0-15	10/23/07	1.1	0.18									0.30		
PRB-32	0-15	10/23/07	0.97	0.21									0.38		
PRB-33	0-15	10/24/07	23	1.0									0.57		
PRB-34	0-15	10/24/07	24	0.9									0.45		

See Table 4.7 for corresponding summary statistics. Table 4.3 shows the subsurface soil subset; Table 4.8 combines the results for all samples (biased, random, and AMS locations combined) analyzed for the larger suite of radiological parameters (U-Nat, Th-230, Th-232, Pb-210, in addition to Ra-226).

Laboratory Analytical Methods:

Analyte	Method	Comment
Radium 226	EPA M903.1	
Thorium 230	ESM 4506	Th-228 and Th-232 also measured using this method; Th-228 results are provided in the laboratory reports.
Uranium, total	EPA M6020 ICP-MS	
Lead-210	EPA 901.1	Initially analyzed using Eichrom method, but because associated LLDs and errors were high, samples were reanalyzed.
Percent Solids	CLPSOW390, PART F, D	Results provided in laboratory reports.

Table 4.4. Piñon Ridge Biased Soil Sampling Results: Subsurface Sample Subset

Sample ID	Depth (cm)	Code	Date	Ra-226 (pCi/g)	Ra-226 Error (+/-)	Th-230 (pCi/g)	Th-230 Error (+/-)	U-Nat (mg/kg)	U-Nat (pCi/g)	Pb-210 (pCi/g)	Pb-210 Error (+/-)	Ra-226 LLD (pCi/g)	Th-230 LLD (pCi/g)
PRB-02A	0-15		10/22/07	7.1	0.4	8.20	1.1	18.7	12.7	7.31	2.0	0.25	0.65
PRB-02B	15-30		10/22/07	4.0	0.4	2.90	0.7	4.21	2.85	2.79	2.0	0.45	0.57
PRB-02C	30-100		10/22/07	1.4	0.3	1.50	0.6	2.42	1.63	1.70	2.0	0.38	0.53
PRB-09A	0-15		10/22/07	1.5	0.25							0.45	
PRB-09B	15-30		10/22/07	3.5	0.35							0.36	
PRB-09C	30-100		10/22/07	1.2	0.23							0.39	
PRB-24A	0-15	*	10/24/07	0.32	0.15							0.38	
PRB-24B	15-30		10/24/07	0.60	0.25							0.60	
PRB-24C	30-100		10/24/07	0.36	0.21							0.52	
PRB-25A	0-15	*	10/24/07	0.72	0.4							0.7	
PRB-25B	15-30	*	10/24/07	0.71	0.2	0.13	1.0	0.57	0.39	1.96	2.0	0.46	0.63
PRB-25C	30-100	*	10/24/07	0.46	0.2	0.6	0.5	0.6	0.41	0.25	2.0	0.53	0.6
PRB-26A	0-15	*	10/24/07	0.52	0.15							0.41	
PRB-26B	15-30		10/24/07	0.03	0.19							0.42	
PRB-26C	30-100		10/24/07	0.47	0.18							0.36	

Notes: * Denotes that a corresponding QA/QC sample was collected (see Table 5.1 for results).

Table 4.5. Piñon Ridge Random Baseline Characterization Soil Sampling Results (all 0-15 cm)

		Ra-226		Th-230		Th-232		U-Nat		Pb-210		LLDs (pCi/g)		
Sample ID	Date	pCi/g	Error (+/-)	pCi/g	Error (+/-)	pCi/g	Error (+/-)	mg/kg	pCi/g	pCi/g	Error (+/-)	Ra-226	Th-230	Th-232
PRR-01	10/22/07	0.25	0.11									0.27		
PRR-02	10/22/07	1.4	0.23									0.38		
PRR-03	10/22/07	0.4	0.15	-0.02	0.34	0.41	0.37	0.57	0.39	1.64	2.0	0.30	0.55	0.21
PRR-04	10/22/07	0.4	0.15									0.30		
PRR-05	10/22/07	4.6	0.35									0.34		
PRR-06 *	10/22/07	1.0	0.19									0.31		
PRR-07	10/22/07	1.8	0.27									0.41		
PRR-08	10/22/07	3.9	0.34									0.36		
PRR-09	10/22/07	1.9	0.29									0.36		
PRR-10 *	10/22/07	2.1	0.25									0.32		
PRR-11	10/22/07	1.3	0.2									0.31		
PRR-12	10/22/07	0.93	0.26									0.53		
PRR-13	10/22/07	3.6	0.34									0.36		
PRR-14	10/23/07	2.6	0.39									0.55		
PRR-15 *	10/23/07	1.9	0.3									0.43		
PRR-16	10/23/07	1.1	0.27									0.57		
PRR-17	10/23/07	0.96	0.24									0.52		
PRR-18	10/23/07	0.63	0.16									0.3		
PRR-19	10/23/07	1.6	0.2									0.33		
PRR-20 *	10/23/07	1.9	0.39									0.73		
PRR-21	10/23/07	0.71	0.25									0.40		
PRR-22	10/23/07	1.6	0.27									0.45		
PRR-23	10/23/07	0.83	0.2									0.41		
PRR-24 *	10/23/07	1.3	0.22									0.33		
PRR-25	10/23/07	1.5	0.31	1.9	0.61	0.57	0.43	0.89	0.60	1.34	2.0	0.54	0.62	0.24
PRR-26	10/23/07	1.1	0.18									0.36		
PRR-27	10/24/07	1.2	0.24									0.46		

Shaded rows denote outlier results for surface Ra-226 (i.e., $\geq$ 3.6 pCi/g), given the distributional characteristics discussed in the text.
* Denotes that a corresponding QA/QC sample was collected (see Table 5.1 for results).
For U-Nat, Method Detection Limits (MDLs) and Practical Quantitation Limits (PQLs) were all 0.05 and 0.3 mg/kg, respectively. All Pb-210 LLDs were 0.1 pCi/g.

Table 4.5. Piñon Ridge Random Baseline Characterization Soil Sampling Results (Concluded)

		Ra-226		Th-230		Th-232		U-Nat		Pb-210		LLDs (pCi/g)		
Sample ID	Date	pCi/g	Error (+/-)	pCi/g	Error (+/-)	pCi/g	Error (+/-)	mg/kg	pCi/g	pCi/g	Error (+/-)	Ra-226	Th-230	Th-232
PRR-28	10/24/07	1.3	0.26									0.52		
PRR-29 *	10/23/07	0.45	0.18									0.45		
PRR-30	10/23/07	1.0	0.38									0.68		
PRR-31	10/23/07	0.83	0.22									0.39		
PRR-32	10/24/07	0.5	0.16									0.39		
PRR-33	10/24/07	0.45	0.15									0.42		
PRR-34 *	10/23/07	0.29	0.2									0.44		
PRR-35	10/23/07	0.13	0.2									0.43		
PRR-36	10/23/07	0.75	0.21									0.39		
PRR-38 *	10/24/07	0.54	0.18									0.42		
PRR-39	10/24/07	0.65	0.22	0.49	0.43	0.41	0.39	0.66	0.45	1.71	2.0	0.49	0.58	0.22
PRR-40	10/23/07	0.36	0.2									0.48		
PRR-41	10/23/07	0.57	0.17									0.37		
PRR-43 *	10/24/07	0.26	0.19	0.53	0.45	0.24	0.37	1.26	0.85	1.24	1.0	0.59	0.60	0.23
PRR-44	10/24/07	0.39	0.27									0.73		
PRR-45	10/23/07	0.33	0.17									0.40		
PRR-46 *	10/23/07	0.92	0.22	1.0	0.47	0.52	0.38	1.65	1.11	2.06	1.0	0.39	0.54	0.21
PRR-47	10/23/07	0.32	0.16									0.42		
PRR-48	10/23/07	0.29	0.22									0.43		

See Table 4.7 for corresponding summary statistics.

Laboratory Analytical Methods:

Analyte	Method	Comment
Radium 226	EPA M903.1	
Thorium 230	ESM 4506	Th-228 and Th-232 also measured using this method; results are provided in the laboratory reports.
Uranium, total	EPA M6020 ICP-MS	
Lead-210	EPA 901.1	Initially analyzed using Eichrom method, but because both LLDs and errors were high, samples were reanalyzed.
Percent Solids	CLPSOW390, PART F, D	Results provided in laboratory reports (Appendix _).

Table 4.6. Piñon Ridge Air Monitoring Station Soil Sampling Results

Sample ID	Date Collected	Ra-226 (pCi/g)	Ra-226 Error (+/-)	Th-230 (pCi/g)	Th-230 Error (+/-)	U-Nat (mg/kg)	U-Nat (pCi/g)	Pb-210 (pCi/g)	Pb-210 Error (+/-)	Ra-226 LLD (pCi/g)	Th-230 LLD (pCi/g)
AMS-01	10/24/07	0.2	0.17	0.47	0.46	1.14	0.77	1.82	1.0	0.34	0.63
AMS-02	10/24/07	17.00	0.69	1.50	0.54	52.10	35.3	21.31	4.0	0.39	0.57
AMS-03	10/24/07	1.2	0.36	6.5	0.94	14.1	9.55	7.35	2.0	0.68	0.59
AMS-04	10/25/07	0.21	0.25	-0.05	0.37	0.47	0.31	2.1	2.0	0.64	0.61
AMS-05	10/25/07	0.36	0.14	0.4	0.39	1.2	0.81	1.14	2.0	0.3	0.53

Table 4.7 Summary Statistics for Surface (0-15 cm) Soil Ra-226 Results: All Sample Types Combined

All Surface Data, Including AMS Onsite Locations

		Valid N	Mean	Lower 95% UCL	Upper 95% UCL	GM	Median	Minimum	Maximum	Lower Quartile	Upper Quartile
Ra-226, All Data		83	1.96	1.08	2.84	0.99	0.97	-0.01	24.00	0.52	1.60
Ra-226, exc. extreme outliers	Ra-226 < 7.1	79	1.15	0.94	1.35	0.86	0.93	0.13	4.70	0.50	1.50
exc all outliers	Ra-226 < 3.6	75	0.98	0.84	1.12	0.79	0.87	0.13	2.60	0.49	1.30
Biased Data											
Ra-226		34	2.70	0.74	4.66	1.19	1.10	-0.01	24.00	0.64	1.70
Ra-226	Ra-226 < 7.1	31	1.17	0.83	1.50	0.92	0.94	0.18	4.70	0.60	1.60
exc all outliers	Ra-226 < 3.6	30	1.05	0.81	1.28	0.87	0.90	0.18	2.40	0.60	1.50
Random Data											
Ra-226, all data		46	1.15	0.86	1.44	0.85	0.93	0.13	4.60	0.45	1.50
Ra-226, exc. extremes (n=0)	Ra-226 < 7.1	46	1.15	0.86	1.44	0.85	0.93	0.13	4.60	0.45	1.50
Ra-226, exc. outliers & extremes	Ra-226 < 3.6	43	0.95	0.76	1.13	0.76	0.83	0.13	2.60	0.40	1.30

GM = Geometric Mean

Table 4.8 Summary of Extended Suite Radiological Analysis for All Soil Samples Combined

			Ra-226		Th-230		Th-232		U-Nat		Pb-210		LLDs (pCi/g)		
Sample ID	Depth (cm)	Date	pCi/g	Error (+/-)	pCi/g	Error (+/-)	pCi/g	Error (+/-)	mg/kg	pCi/g	pCi/g	Error (+/-)	Ra-226	Th-230	Th-232
PRB-01*	0-15	10/22/07	-0.01	0.1	0.1	0.4	0.3	0.39	0.62	0.42	0.17	1.0	0.35	0.62	0.24
PRB-02A	0-15	10/22/07	7.1	0.4	8.20	1.1	0.65	0.46	18.7	12.7	7.31	2.0	0.25	0.65	0.25
PRB-02B	15-30	10/22/07	4.0	0.4	2.90	0.7	0.32	0.37	4.21	2.85	2.79	2.0	0.45	0.57	0.22
PRB-02C	30-100	10/22/07	1.4	0.3	1.50	0.6	0.4	0.38	2.42	1.63	1.70	2.0	0.38	0.53	0.22
PRB-03	0-15	10/22/07	0.64	0.2	0.96	0.5	0.13	0.35	1.94	1.31	2.98	2.0	0.46	0.59	0.22
PRB-10	0-15	10/22/07	4.7	0.54	6.6	0.97	0.19	0.37	19.3	13.1	7.36	2.0	0.67	0.62	0.24
PRB-25B*	15-30	10/24/07	0.71	0.2	0.13	1.0	0.64	0.64	0.57	0.39	1.96	2.0	0.46	0.63	0.37
PRB-25C*	30-100	10/24/07	0.46	0.2	0.6	0.5	0.47	0.4	0.6	0.41	0.25	2.0	0.53	0.6	0.23
PRR-03	0-15	10/22/07	0.4	0.15	-0.02	0.34	0.41	0.37	0.57	0.39	1.64	2.0	0.30	0.55	0.21
PRR-25	0-15	10/23/07	1.9	0.61	0.89	1.34	0.57	0.43	2.0	1.35	0.54	0.62	0.54	0.62	0.24
PRR-39	0-15	10/24/07	0.65	0.22	0.49	0.43	0.41	0.39	0.66	0.45	1.71	2.0	0.49	0.58	0.22
PRR-43*	0-15	10/24/07	0.26	0.19	0.53	0.45	0.24	0.37	1.26	0.85	1.24	1.0	0.59	0.60	0.23
PRR-46*	0-15	10/23/07	0.92	0.22	1.0	0.47	0.52	0.38	1.65	1.11	2.06	1.0	0.39	0.54	0.21
AMS-01	0-5	10/24/07	0.2	0.17	0.47	0.46	0.52	0.43	1.14	0.77	1.82	1.0	0.34	0.63	0.24
AMS-02*	0-5	10/24/07	17.00	0.69	1.50	0.54	0.53	0.4	52.10	35.3	21.31	4.0	0.39	0.57	0.22
AMS-03	0-5	10/24/07	1.2	0.36	6.5	0.94	0.34	0.38	14.1	9.55	7.35	2.0	0.68	0.59	0.23
AMS-04	0-5	10/25/07	0.21	0.25	-0.05	0.37	0.43	0.41	0.47	0.32	2.1	2.0	0.64	0.61	0.23
AMS-05	0-5	10/25/07	0.36	0.14	0.4	0.39	0.35	0.35	1.2	0.81	1.14	2.0	0.3	0.53	0.2
Summary Statistics															
Minimum			*-0.1*		*-0.05*		*0.13*		*0.47*	*0.32*	*0.17*				
Maximum			*17*		*8.20*		*0.65*		*52.10*	*35.30*	*21.31*				
Mean			*2.3*		*1.82*		*0.4*		*6.86*	*4.65*	*3.64*				
Std. Dev.			*4.1*		*2.55*		*0.1*		*12.90*	*8.74*	*4.98*				
Mean w/o max			*1.5*		*1.44*		*0.4*		*4.20*	*2.85*	*2.60*				
Std. Dev. w/o max			*2.0*		*2.05*		*0.1*		*6.43*	*4.36*	*3.42*				

Notes: * Denotes that a corresponding QA/QC sample was collected (see Table 5.1 for results).
Refer to the preceding table (Table 4.7) for Ra-226 summary statistics, as a summary based on the truncated data set above would not be reflective of the entire soil Ra-226 data set.
For U-Nat, Method Detection Limits (MDLs) and Practical Quantitation Limits (PQLs) were all 0.05 mg/kg and 0.3 mg/kg, respectively.

Figures

Appendix A

Gamma-PIC and Gamma-Soil Radium Correlation Documentation

Appendix B

Analytical Data

Appendix B-1

Laboratory Analytical Data
(Provided on CD)

Appendix B-2

Radon-222 Concentration Data
(Provided on CD)

Appendix B-3

Optically Stimulated Luminescent Dosimeter Data
(Provided on CD)

Appendix C

Radon Flux Measurement Documentation