POWERTECH (USA) INC.

APPENDIX J
BASELINE RADIOLOGICAL CHARACTERISTICS

1.1 Baseline Radiologic Characteristics

1.1.1 Introduction

This section provides baseline radiological data for surface soils (0-5 and 0-15 cm), subsurface soils to a depth of 1 meter, vegetation, locally grazed cattle, direct radiation, radon-222 in air; and radon-222 flux rates representative of the project property. The work was performed by Environmental Restoration Group (ERG) between August 2007 and July 2008.

Field investigations, sample collection, and other quality-related work performed were conducted in accordance with ARSD 74:29:11:02 (2) and applicable ERG standard operating procedures (SOPs), listed below:

- SOP .010 Radon Flux Canister Deployment
- SOP 1.05 Calibration of Scaler, Ratemeters
- SOP 1.22 Determining the Concentration of Airborne Radioactive Particles
- SOP 1.51 Correlation between Gamma-Ray Count Rate and Exposure Rate
- SOP 2.02 General Equipment Decontamination
- SOP 2.07 Function Check of Equipment
- SOP 2.09 Correlation between Gamma-Ray Measurements and Radium-226 in Soil
- SOP 3.02 Sample Control and Documentation
- SOP 5.01 Setup and Operation of Trimble Pro XRS GPS Receiver with Trimble TSCe Datalogger
- SOP 5.02 Download, Correction, and Export of GPS Survey Data
- SOP 5.06 Creating, Uploading, and Navigating to Waypoints
- SOP 7.08 Surface and Shallow Subsurface Soil Sampling
- SOP 7.09 Vegetation Sampling

The baseline radiological field investigation consisted of the following activities:

- A GPS-based gamma survey conducted at 100 to 500 m transects spanning the PAA.

- A second GPS-based gamma survey of two, collective land application areas conducted at 100 m transects.
- Collecting surface soil (0-15 cm) samples at 75 randomly selected and at five biased locations spanning the PAA.
- Collecting subsurface soil samples at nine randomly selected locations taken at depth intervals of 15-30 cm and 30-100 cm.
- Collecting surface (0-15 cm) and subsurface samples at the same depth intervals at 17 randomly selected locations in the land application areas.
- Collecting shallow (0-5 cm) surface soil samples at the eight Air Monitoring Stations (AMS).
- Vegetation sampling at each AMS during the summer, fall and spring.
- Air monitoring at one background and seven additional locations.
- Radon monitoring in air.
- Radon flux measurements at locations coinciding with the subsurface samples.
- Exposure rate monitoring, using a High Pressurized Ion Chamber (PIC) and thermoluminescent detectors (TLDs).
- Collecting three samples of locally grazed livestock.

Table 1.1-1 summarizes the scope of the field investigation. All samples were shipped under chain-of-custody to a National Environmental Accreditation Conference-certified laboratory, Energy Laboratories, in Rapid City, South Dakota.

The units reported in the body, tables, and figures related to this section vary. NRC Regulatory Guide 4.14, *Radiological Effluent and Environmental Monitoring at Uranium Mills*, has specific requirements for unit reporting in tables. For example, it recommends that radionuclide soil concentrations be reported in units of microcuries per gram (μCi/g). Where applicable, the tables adopt this unit. The main body of Section 1.1, however, adopts the unit picocuries per gram (pCi/g) for this parameter, as this unit is used more generally and consistently by the uranium industry and public.

Table 1.1-1: Summary of Baseline Radiological Investigation Scope

Task Method/Endpoint	Baseline Investigation Scope	Parameters Evaluated
A.GPS-Based Gamma Surveys	GPS-based unshielded gamma-ray readings along 100 or 500 meter transects at ≤1.5 meters per second. A second survey covered land application areas along 100 meter transects.	Serve as basis to estimate pre-operational gamma emissions from land areas and exposure rates, surface soil radium-226 concentrations, and identify areas for biased soil sampling.
B. Biased Soil Sampling	Biased samples at five locations, all collected from 0 to 15 cm	Radium-226 for all samples Thorium-230, natural uranium, lead-210 for 2 locations
C. Random Soil Sampling	Random samples at 75 locations Nine of the 75 locations were sampled at depth (15-30 cm and 30-100 cm) Ten duplicates at 0 to 15 cm. One duplicate each at 15 to 30 cm and 30 to 100 cm.	Radium-226 for all samples Thorium-230, natural uranium, lead-210 (8 from 0 to 15 cm and one each at 15 to 30 cm and 30 to 100 cm
D. Soil sampling in land application areas	Random samples at 17 locations, all but one of which were sampled at 0 to 15, 15 to 30 and 30 to 100 cm. Refusal was encountered at 45 cm in the exceptional location. One duplicate each at 0 to 5, 15 to 30, and 30 to 100 cm.	Radium-226, thorium-230, natural uranium, and lead-210 for all samples
E. Exposure Rate Monitoring	Exposure rate determinations based on TLD and PIC measurements. TLD measurements collected for four quarters.	Exposure rates
F. Soil and Vegetation Sampling at Air Monitoring Stations	Eight locations: seven onsite (AMS-01 through AMS-07) and one located approximately 1.9 miles west of the southwest corner of the permit area (AMS-BKG). Vegetation samples collected for four quarters.	Vegetation: radium-226, thorium-230, natural uranium, lead-210 and polonium-210 Soil: All of the above except polonium-210
G. Air Particulate Sampling	Eight locations: seven onsite (AMS-01 through AMS-07) and one located approximately 1.9 miles west of the southwest corner of the permit area (AMS-BKG). Air particulate samples collected for four quarters.	Air filters: radium-226, thorium-230, natural uranium, lead-210 and polonium-210
H. Radon in air	16 locations: eight AMS and eight additional locations. Radon in air measurements taken for four quarters.	Radon-222
I. Radon Flux Measurements	Radon flux measurements at nine locations (collected at the biased subsurface soil sample locations in Task C) in summer, fall, and spring.	Radon-222
I. Locally Grazed Livestock Sampling	Three samples collected from one locally grazing cow.	Radium-226, thorium-230, natural uranium, lead-210 and polonium-210

1.1.1.1 References

Code of Federal Regulations, 10 CFR 40, *"Appendix A, Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content"*.

USNRC, 1980, Regulatory Guide 4.14, "*Radiological Effluent and Environmental Monitoring at Uranium Mills, Revision 1",* U.S. Nuclear Regulatory Commission, April 25.

USNRC, 2003, *"Standard Review Plan for In Situ Leach Uranium Extraction License Applications",* U.S. Nuclear Regulatory Commission Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, June.

1.1.2 Gamma Survey

1.1.2.1 Methods

1.1.2.1.1 Baseline GPS-Based Gamma Surveys

A GPS-based gamma survey was conducted over the main and surface mine areas of the project from September 13-27, 2007 and completed on July 14, 2008. Unshielded Ludlum Model 44-10 2"x 2" sodium iodide (NaI) detectors were coupled to Ludlum Model 2221 ratemeter/scalers (set in ratemeter mode) and a Trimble Pro XRS GPS Receiver with Trimble TSCe Datalogger. Survey transects were spaced at approximately 500-m intervals in the main project area and 100 m in the surface mine area. The transect spacing was reduced in the surface mine area in anticipation of finding a greater variation in gamma-ray emissions, due to historical mining in the area. The survey speed was maintained between 2 and 5 feet per second with x- and y-coordinates and gamma-ray count rates recorded every second. The detector height was held relatively constant at approximately 18 inches above ground surface. Depending on the terrain, field personnel surveyed using ATVs or by walking with the equipment in backpacks.

A second GPS-based gamma survey was conducted over the land application areas from July 17-19, 2008, using the Ludlum gamma-ray detection system described above with the same response characteristics as used in the initial survey. The scanning speed and detection height were unchanged from the initial survey and the transect spacing was 100 m.

The areas subject to GPS-based gamma surveys are shown on Figure 1.1-1.

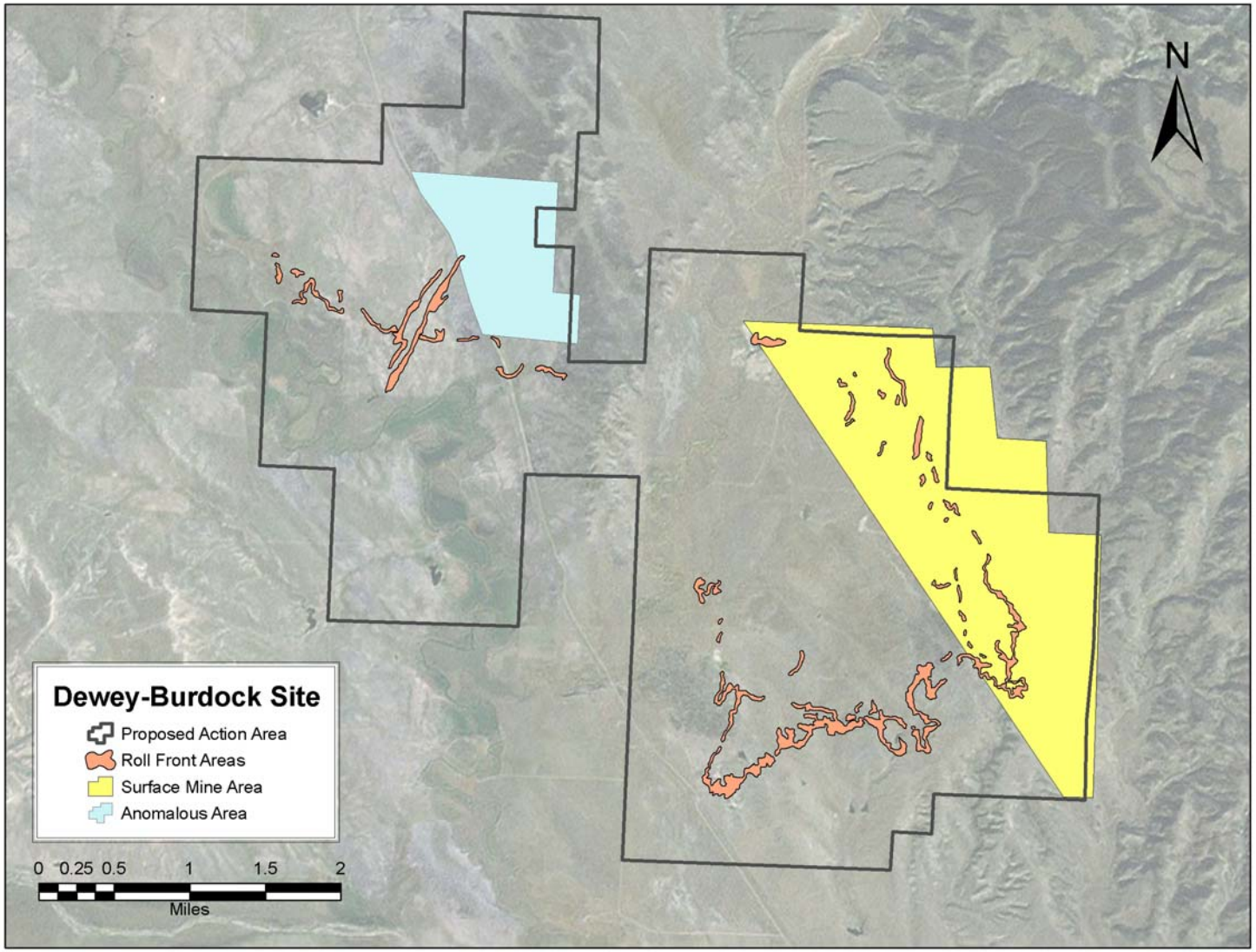

Figure 1.1-1: Areas Subject to GPS-Based Gamma Surveys

1.1.2.1.2 Cross-Calibration of Sodium Iodide Detectors and a High-Pressure Ionization Chamber

Both the sodium iodide detector and PIC measure gamma radiation. The sodium iodide detection system measures the rate that the gamma rays interact with the detector in counts per minute (cpm), has a lower sensitivity than the PIC and is energy dependent. The PIC is a highly accurate ionization chamber for measuring exposure rate in micoRoentgens per hour (µR/h) but requires a longer count time. The PIC was used because it measures exposure rates directly and is considered a primary standard by NIST, when calibrated. The PIC measures gamma, X-rays, and cosmic radiation without discrimination. It is highly stable, relatively energy independent, and serves as an excellent tool to calibrate other survey equipment to measure exposure rates. Because of its portability and shorter measurement times, the sodium iodide detector is more efficient than the PIC for use in large area surveys. By performing the large area gamma surveys with sodium iodide detectors, then developing a correlation between the two instruments, exposure rates derived from the sodium iodide measurements can represent site wide gamma emissions from surface soils.

Powertech (USA) collected 12 co-located static gamma counts and exposure rate measurements to develop the correlation between gamma counts and exposure rates. The locations were biased towards areas where gamma shine was not relatively high; that is, where gamma count rates remained relatively constant at 18 in, 1 m, and 2 m above ground surface. In addition, locations were chosen to encompass most of the range of sodium iodide detector readings observed in the GPS-based gamma surveys. The sodium iodide measurements were taken using one of the 2-inch by 2-inch sodium iodide detectors that were used in the baseline gamma survey. A 1-minute integrated count was taken at each of the 12 locations with the detector suspended at 18 in. above the ground surface. Exposure rate measurements were then collected at a 1-m height at each location, directly above the location where the sodium iodide detector was held. Exposure rates were determined after 20-minute integrated counts. The PIC and gross gamma measurements were performed on July 14 to 16, 2008 at the locations shown on Figure 1.1-2.

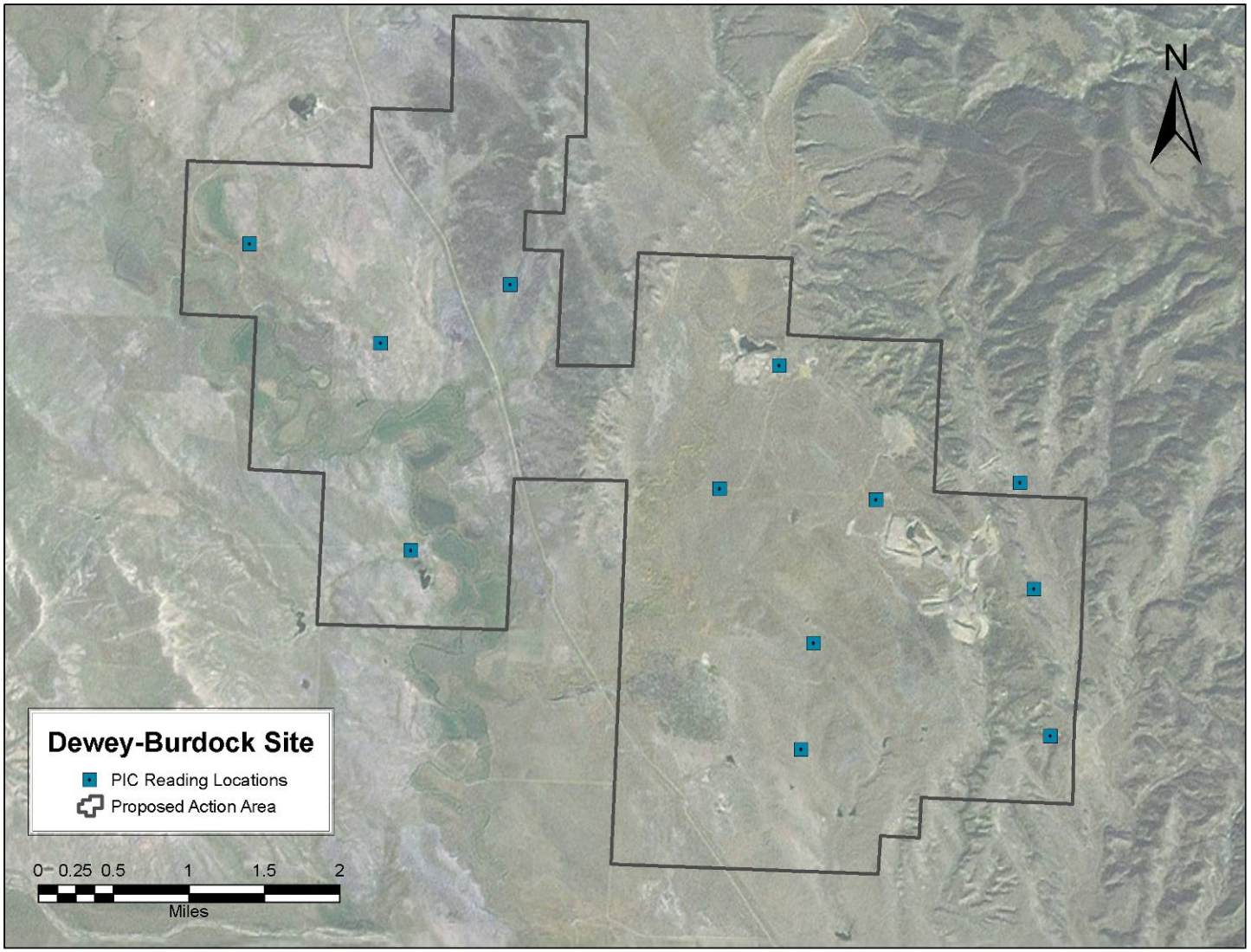

Figure 1.1-2: Locations of High Pressure Ion Chamber and Sodium Iodide Detector Measurements

1.1.2.1.3 Gamma/Radium-226 Correlation Grids

To estimate site-wide radium-226 concentrations at each of the GPS-based gamma survey points, a correlation was established by performing a regression between the surface soil analytical results for radium-226 in the 80 surface (0 to 15 cm) soil samples and one-minute integrated direct radiation measurements collected at each of these locations prior to sample collection. The measurements were collected with the same Ludlum 44-10/2221 2-in by 2-in sodium iodide gamma detection systems used in the GPS-based gamma survey.

The correlation was used to translate each of the gamma-ray count rates obtained in the GPS-based survey to predicted radium-226 concentrations. ArcView GIS then was used to generate average predicted radium-226 concentrations in 700 by 700 ft grid blocks covering the site.

1.1.2.1.4 Data Quality Assurances/Quality Control

All survey instruments were calibrated. The function of survey instruments was checked at the beginning and end of each work day using a National Institute of Standards and Technology-traceable cesium-137 source. Calibration Sheets and function check data are provided in Appendix A of Appendix 1.1-A.

1.1.2.2 Gamma Survey Results

1.1.2.2.1 Baseline Gamma Survey Results

The gamma-ray count rate data obtained in the initial survey were first evaluated as an entire set and then subdivided into the main permit (the entire data set less the surface mine area) and surface mine areas.

The observed gamma-ray count rates are presented as colors representing ranges of counts in Figure 1.1-3. Three areas are shown on the figure: the main permit and surface mine areas, and an area of anomalous gamma-ray count rates located in the northern portion of the main project area.

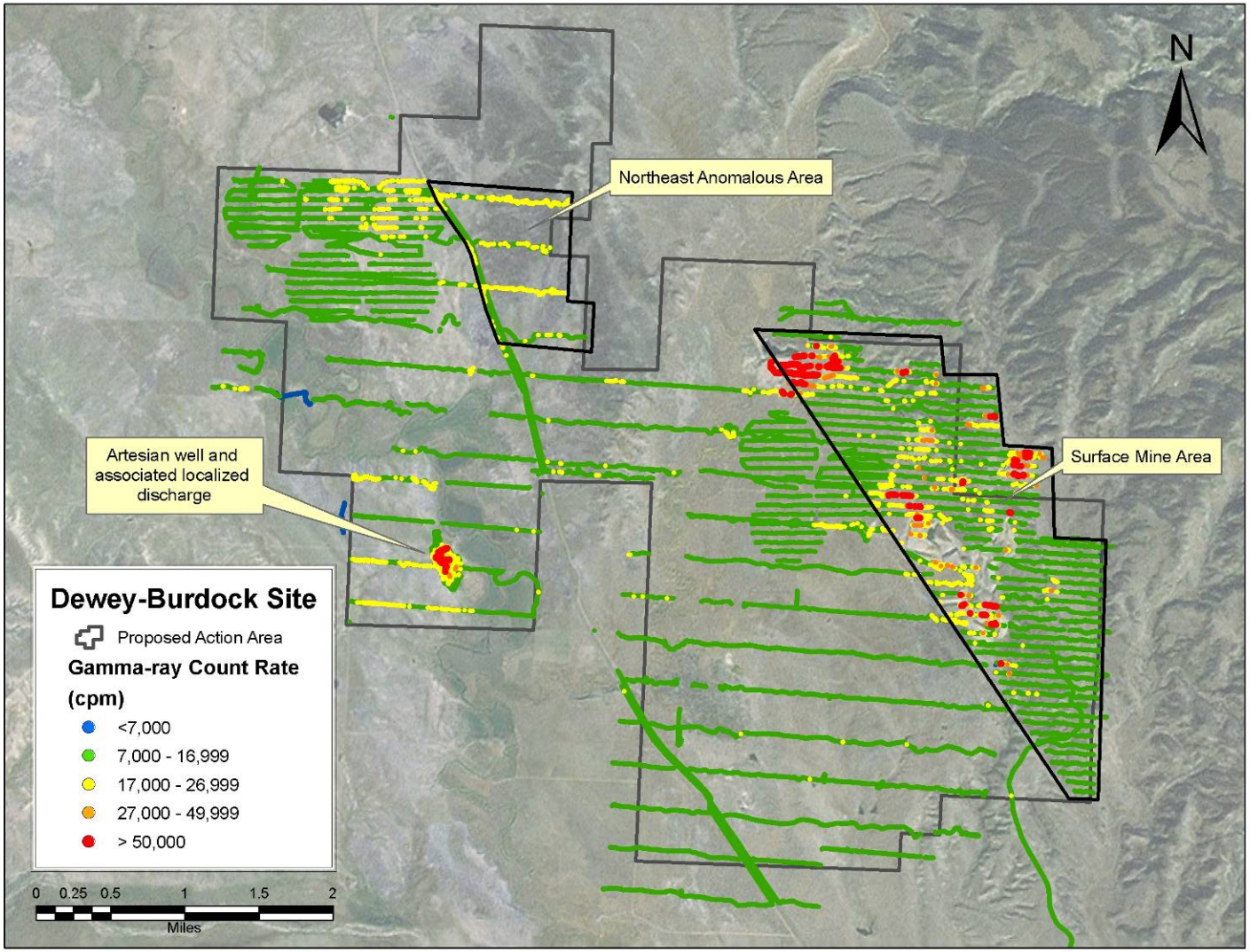

Figure 1.1-3: Gamma-Ray Count Rates Obtained During Initial GPS-Based Gamma Survey

None of the data sets: the entire permit area, and gamma data obtained in the main permit and surface mine areas are normally, lognormal, or exponentially distributed. Furthermore, normalizing data transformations were conducted and the transformed data did not follow standard distributions. For these reasons, data analysis and summaries were performed using non-parametric statistical methods, which are less sensitive to extreme observations typical of skewed data distributions.

The median and interquartile range (IQR) are non-parametric measures of central tendency and variability, respectively. The IQR is the difference between the first (Q1) and third (Q3) quartiles, i.e., 25 and 75 percent of the data area less than Q1 and Q3, respectively. Any datum that is outside the range of 1.5 times the IQR lower than Q1 and 1.5 times the IQR higher than Q3 is considered an outlier. Extreme outliers, or extremes, are those exceeding three times the IQR to the left and right from the first and third quartiles respectively (Ott and Longnecker, 2001).

The summary statistics of the GPS-based gamma-ray survey are listed in Table 1.1-2. The median of the gamma-ray count rates for the overall data set was 12,687 counts per minute (cpm). Field personnel collected 157,075 readings ranging from 5,550 to 460,485 cpm.

Table 1.1-2: Statistical Summary of Gamma-Ray Count Rates in Entire Data Set, Main Permit and Surface Mine Areas

	Gamma-Ray Count Rate (cpm)		
Estimator/Endpoint	**Entire Data Set**	**Main Permit Area**	**Surface Mine Area**
Mean	15,025	13,073	16,823
Standard Deviation	17,095	2,995	23,377
Median	12,687	12,664	12,717
Mode	12,487 (n=53)	12,585 (n=35)	12,138 (n=31)
Minimum	5,550	5,883	5,550
Maximum	460,485	171,243	460,485
Q1	11,395	11,598	11,125
Q3	14,437	14,137	14,783
IQR	3,042	2,539	3,658
No. of Counts	157,075	75,345	81,757

Notes:
Entire data set does not include gamma-ray counts obtained along the eastern haul road. In addition, the sum of the counts in the main permit and surface mine areas is 27 counts greater than the counts in the entire data set, due to an overlap in counts within the two shapes placed as a layer in ArcView GIS to select the data sets. .

Main Project Area

As shown in Table 1.1-2, the median gamma-ray count rate for the main project area data set was 12,664 cpm for 71,148 observations. The count rates ranged from 5,883 to 171,243 cpm. Low outliers in the main project area data set, count rates below 7,790 cpm, appear to be limited to two clusters. High outliers in the data set, count rates exceeding 17,946 cpm, appear to be limited to an approximately 600-acre located at the north end of the main project area. The area is identified as an anomalous area on Figure 1.1-1.

Approximately 0.1 and 2 percent of the gamma-ray count rates observed in the main project area are comprised of low and high outliers, respectively.

The majority of high outliers are located in the north section of the main project area. The distribution of these anomalous gamma-ray count rate data is unknown. The count rates ranged from 8,863 to 22,130 cpm and the median was 15,503 cpm.

Surface Mine Area

In the surface mine area, the gamma-ray count rates ranged from 5,550 to 460,485 cpm and the median was 12,717 cpm. In general, clusters of higher readings are associated with un-reclaimed open pit uranium mines, waste rock, rocky outcrops, and drainages in the surface mine area. Approximately 0.004 and 9 percent of the gamma-ray count rates observed in the surface mine area are low and high outliers, respectively.

Discussion

As indicated above, there is sufficient evidence for the variances in the main permit and surface mine area gamma-ray count rates being distinct and thus represent distinct data populations. The variances in the main permit anomalous area are also distinct.

It is clear that the surface mine area in the eastern quarter of the site exhibits radiological impacts from historic and/or current anthropogenic activities within the area. In addition, gamma-ray count rates in the anomalous north area also are clearly distinct from those in the wider main permit area. The precise sources of the differences are not relevant in the context of this investigation since they are part of the baseline or background radiological characteristics of the site.

Land Application Areas

The summary statistics of the GPS-based gamma-ray survey of the project land application areas are listed in Table 1.1-3. The gamma-ray count rates obtained in the main permit area are listed in the table to facilitate comparison between the land application areas and the larger area in which they occur. The data are shown as ranges of count rates on Figure 1.1-4.

Gamma-ray count rates in the land application areas are similar to those obtained in the larger main permit area. In the Dewey land application area, the median of the gamma-ray count rates was 12,523 cpm. Field personnel collected 23,480 readings ranging from 6,798 to 20,422 cpm. In the smaller, Burdock land application area, the median of the gamma-ray count rates was 12,232 cpm. Field personnel collected 13,647 readings ranging from 8,498 to 24,248 cpm.

Table 1.1-3: Statistical Summary of Gamma-Ray Count Rates in Land Application Areas

	Gamma-Ray Count Rate (cpm)		
		Land Application Area	
Estimator/Endpoint	**Main Permit Area**	**Dewey**	**Burdock**
Mean	13,073	12,815	12,308
Standard Deviation	2,995	1,940	1,318
Median	12,664	12,523	12,232
Mode	12,585 (n=35)	11,778 (n=15)	12,266 (n=16)
Minimum	5,883	6,798	8,498
Maximum	171,243	20,422	24,248
Q1	11,598	11,437	11,504
Q3	14,137	13,993	12,958
IQR	2,539	2,556	1,454
No. of Counts	75,345	23,480	13,647

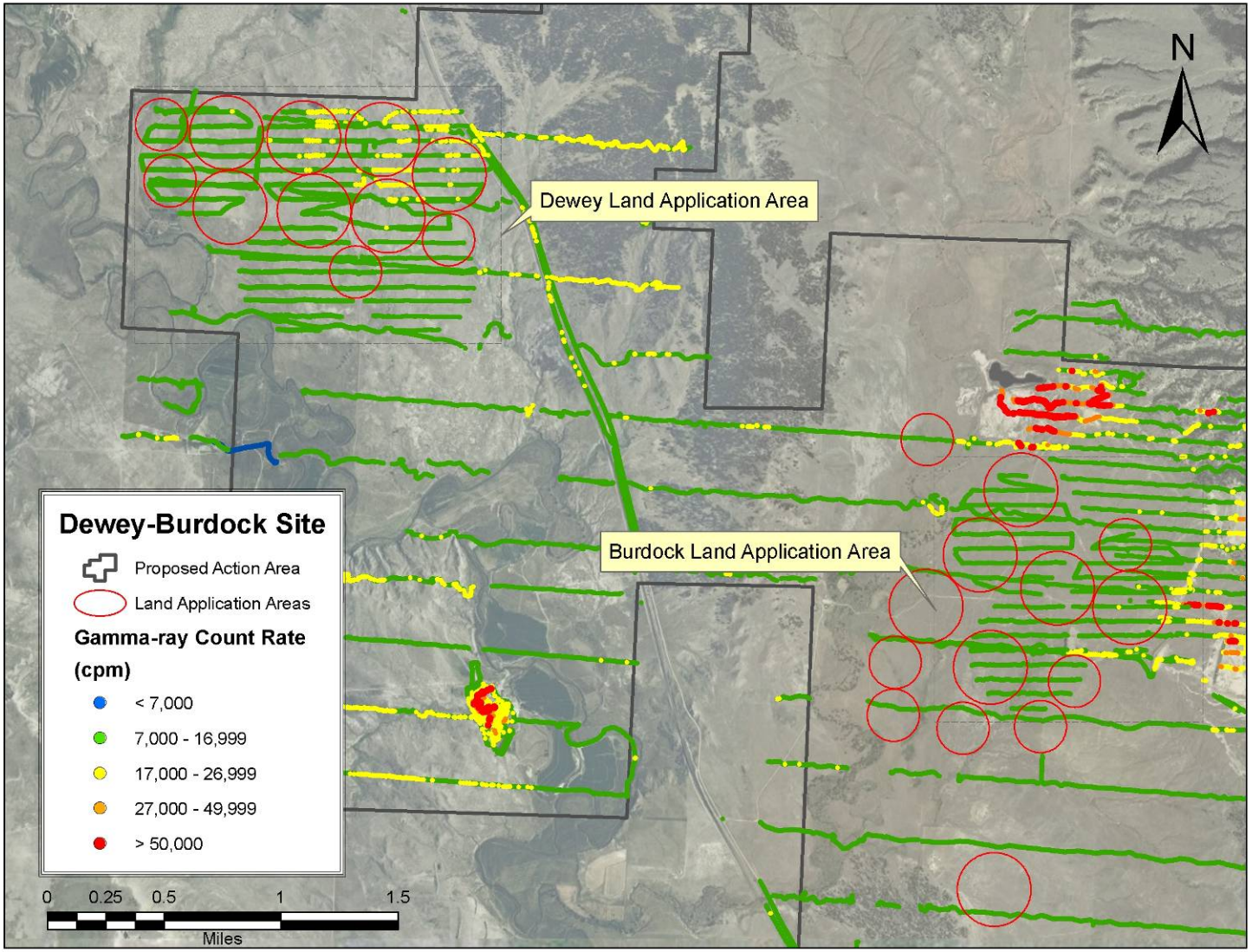

Figure 1.1-4: GPS-Based Gamma-Ray Count Rates in the Land Application Areas

1.1.2.2.2 Results of Cross-Calibration of Sodium Iodide Detectors and High-Pressure Ionization Chamber

The linear equation representing the correlation between exposure rates and gamma-ray count rates, determined using the PIC and average of the two sodium iodide detectors is:

Exposure Rate = 0.0007 x Gamma Count Rate + 2.02

where the exposure rate is in gross µR/hr and the gamma count rate is in gross cpm.

The linear regression model for the average is a good fit, with an R^2 of 0.96. Nearly all of the data align along the slope of the line, as shown in Figure 1.1-5. The correlations are similar for the individual sodium iodide detectors and not discussed further.

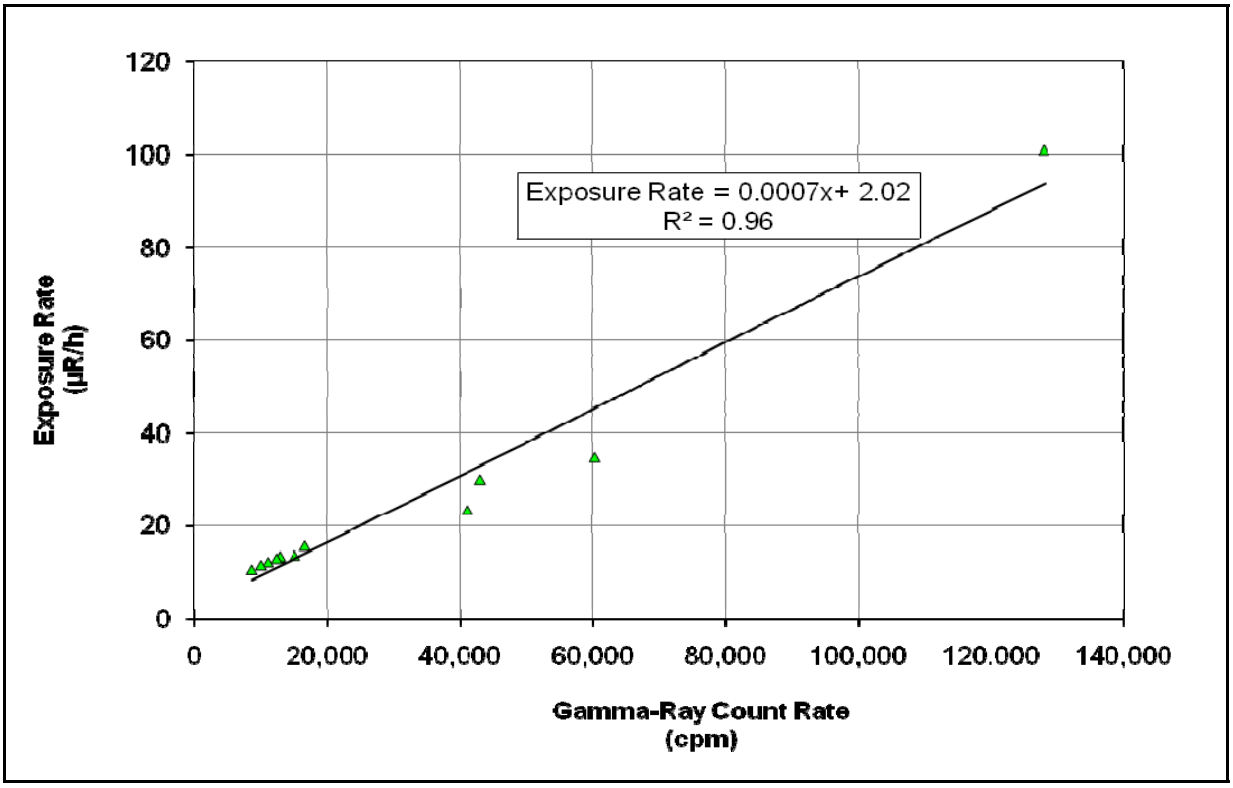

Figure 1.1-5: Linear Regression Model: Exposure Rates Correlated to Gamma-Ray Count Rates

The linear regression model predicts an average exposure rate of 10.9 µR/hr for the site. The range of predicted exposure rates is 5.9 to 324 µR/hr, based on the observed gamma-ray count rates at the site. The predicted site-wide exposure rates are shown as ranges of colors in 700 by 700 ft grid block averages on Figure 1.1-6.

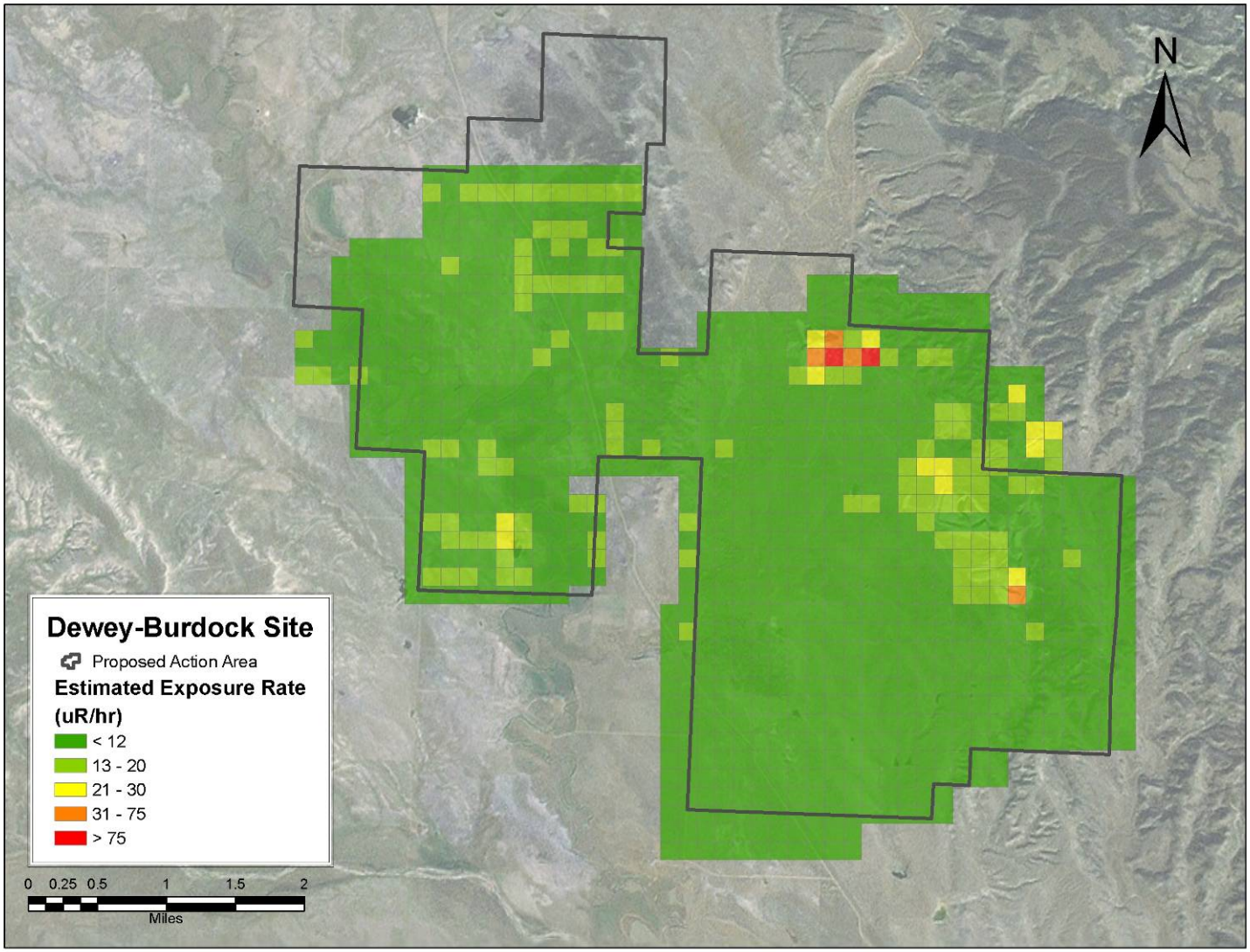

Figure 1.1-6: Predicted Site-Wide Exposure Rates, Grid Block Averages

1.1.2.2.3 Gamma-Ray Count Rate-Soil Ra-226 Concentration Correlation Grid Results

The relationship between gamma-ray count rates and radium-226 concentrations was determined to be appropriate after five outliers were removed from the set of 80 data points. The equation of the linear fit is:

$$Radium\text{-}226 = 1.9*10^{-4} \times Gamma\text{-}Ray\ Count\ Rate - 1.04$$

where the radium-226 concentration is in pCi/g and the gamma-ray count rate is in gross cpm.

This model has an R^2 of 0.43, with 0.43 accounting for 43 percent of the variance in the data set. Table 1.1-4 lists summary data for the predicted radium-226 concentrations in each of the major areas.

Of the 1,015 grid blocks covering the entire permit area, the majority (approximately 78 percent) of the interpolated surface radium-226 concentrations is less than 1.5 pCi/g. In the overall data set, the median predicted radium-226 concentration is 1.1 pCi/g and the range is 0.0 to 24.9 pCi/g. In the main permit area (excluding the anomalous area), the median predicted radium-226 concentration is 0.0 pCi/g and the range is 0.0 to 9.0 pCi/g. In the surface mine area, the median predicted radium-226 concentration is 1.5 pCi/g and the range is 0.0 to 24.9 pCi/g. In the anomalous portion of the main permit area, the median predicted radium-226 concentration is 1.4 pCi/g and the range is 0 to 2.3 pCi/g.

Table 1.1-4: Summary of Predicted Radium-226 Concentrations in Grid Blocks

		Predicted Radium-226 Concentration Based on Average of Counts Within Grid Block (pCi/g)					
Data Set	**No. of Grid Blocks**	**Median**	**Minimum**	**Maximum**	**Q1**	**Q3**	**IQR**
All Data	1,015	1.1	0	24.9	0	1.4	1.4
Surface Mine Area	171	1.5	0	24.9	1.1	1.8	0.7
Main Permit Area without Anomalous Area	791	1.0	0	9.0	0	1.3	1.3
Anomalous Area	53	1.4	0	2.3	0	1.8	1.8

1.1.2.2.4 Final Gamma Exposure Rate Mapping

As stated in Section 1.1.2.2.2, the linear regression model correlating sodium iodide detector readings to PIC measurements predicts a site-wide average exposure rate of 10.9 µR/hr. The range of predicted exposure rates is 5.9 to 324 µR/hr, based on the observed gamma-ray count rates at the site. As indicated on Figure 1.1-6, predicted exposure rates ranging from 21 to greater than 75 µR/hr occur in the open pit mine areas, near the artesian well and its localized discharge areas, and in rocky outcrop areas in the northwest corner of the surface mine area. Predicted exposure rates in the anomalous area in the northern portion of the main permit area range from less than 12 to 30 µR/hr.

1.1.2.2.5 Soil Ra-226 Concentration Mapping

Predicted radium-226 concentrations in soil are shown as grid block averages in Figure 1.1-7. It is important to acknowledge that discrepancies between measured soil radium-226 concentrations reported by the laboratory and corresponding radium-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.

At the same time, Figure 1.1-7 shows that without a gamma survey, reliance on a random soil sampling program alone would not have identified elevated areas of radioactivity at the site.

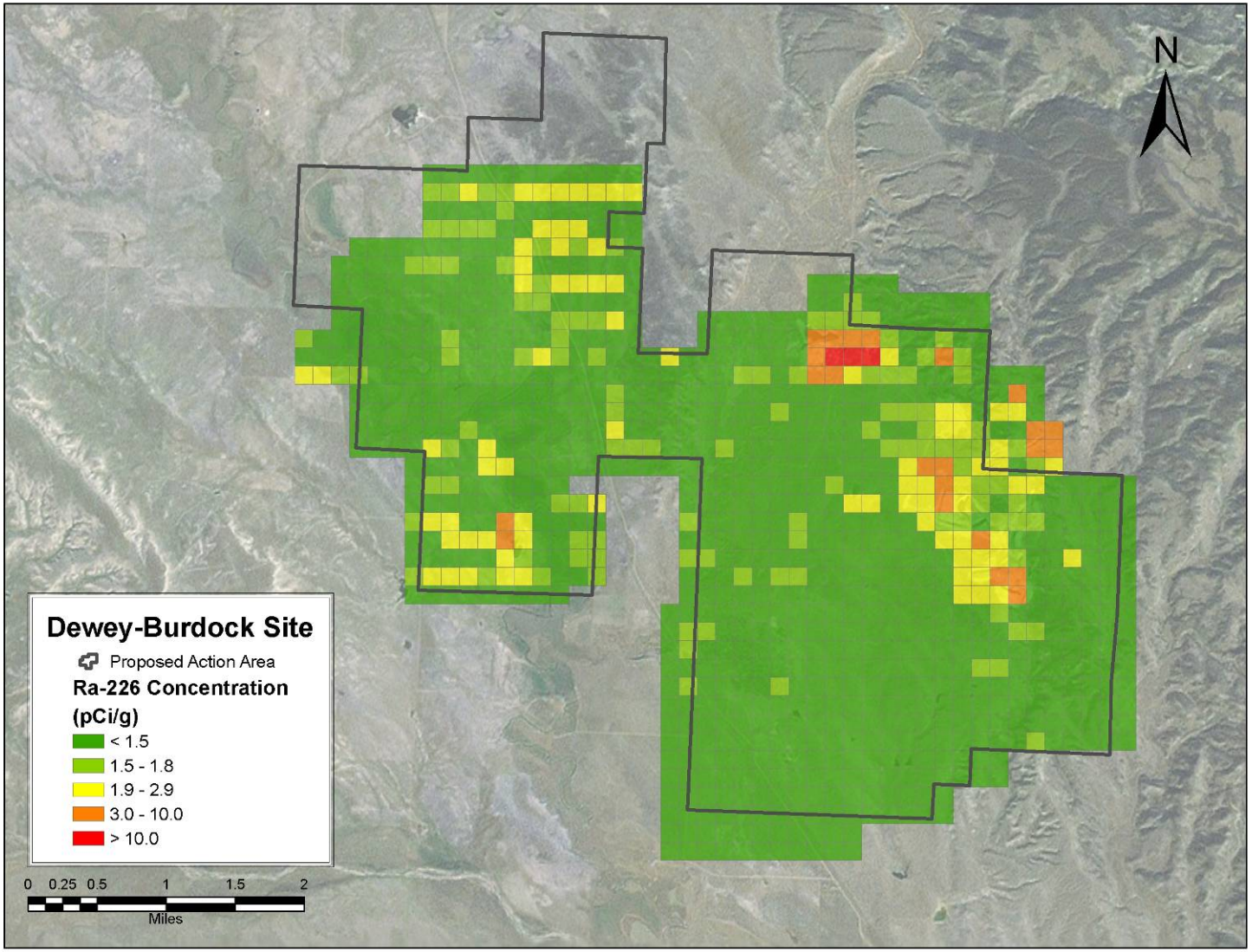

Figure 1.1-7: Predicted Site-Wide Radium-226 Concentrations, Grid Block Averages

1.1.3 Soil Sampling

1.1.3.1 Methods

1.1.3.1.1 Surface and Subsurface Soil Sampling

Two salient guidances were applied to the radiological characterization of the project site. The first is NUREG-1569 "Standard Review Plan (STR) for In Situ Leach Uranium Extraction License Applications (NRC 2003). NUREG-1569 identifies guidance in NRC Regulatory Guide 4.14 (Revision 1), "Radiological Effluent and Environmental Monitoring at Uranium Mills" (NRC 1980) as the acceptable criteria for pre-operational radiological baseline evaluations.

In the case of surface soil radiological characterization, sample placement prescribed by RG 4.14 may lead to insufficient characterization of the site. RG 4.14 states that soil sampling locations start at a point halfway between proposed tailings and process areas, and 0-5 cm samples are collected every 300 meters out to 1500 meters in eight compass directions (40 samples) and one at each air monitoring station. This prescribed spacing largely ignores potentially varying site features such as soil types, drainages, outcrops, and the affects of historical activities. In addition, the soil sampling depth of 0 to 5 cm does not coincide with applicable cleanup standards. The NUREG-1569 requirements include collecting 0-15 cm samples to be consistent with the radium-226 cleanup standard of 5 pCi/g above background for the 0-15 cm soil horizon (10 CFR 40, Appendix A, Criterion 6(6)).

RG 4.14 suggests the collection of 40 samples from 0 to 5 cm. NUREG-1569 suggest the collection of samples at 0 to 15 cm. To avoid any ambiguity in the interpretation of these guidance documents, Powertech (USA) chose to collect 80 samples at 0 to 15 cm and supplementing the sampling effort with Global Positioning System (GPS)-based gamma radiation surveys. The GPS-based surveys allow orders of magnitude more data to be obtained with a similar effort. Owners of uranium recovery sites that have or are undergoing decommissioning are finding that extensive baseline data are invaluable. In conjunction with soil sampling and analysis and cross-reference to PIC measurements, the GPS-based gamma surveys can be used to predict site-wide concentrations of gamma-emitting radionuclides and/or exposure rates. Spatial trends in gamma emissions (and radionuclide concentrations as surrogates) are also far more apparent through the use of GPS-based gamma surveys than soil sampling alone. As will be shown below, reliance on a random soil sampling program alone would not have identified elevated areas of radioactivity at the site.

Main Permit and Surface Mine Areas

The soil sampling strategy for the main permit and surface mine areas of the project site consisted of biased and random sampling at the eight AMS locations shown in Figure 1.1-8 (this figure also shows the locations of the radon flux and track etch detector measurements, discussed below) and 80 additional locations shown in Figure 1.1-9. Biased samples were collected at 5 of the 80 locations; the remainder was placed randomly, using Visual Sampling Plan (VSP), Version 5.0. The biased samples were obtained in the surface mine area and selected to bound the upper range of radionuclide concentrations. The five biased samples are not sufficient to characterize radium-226 concentrations in impacted areas.

The additional 80 surface soil samples were collected from 0 to 15 cm below ground surface. Seventy-one of these samples were collected using a hand shovel. A hand auger was used to collect samples at 0 to 15, 15 to 30, and 30 to 100 cm at nine of the 80 locations. All of the soil samples were analyzed for radium-226. Ten of the 80 samples were also analyzed for natural uranium, lead-210, and thorium-230. Thirteen duplicate samples were collected: 11 with the surface set and two with the subsurface set. All duplicate samples were analyzed for radium-226 while two were also analyzed for natural uranium, thorium-230, and lead-210. The analytes and corresponding analytical methods were:

- Radium-226 via gamma spectroscopy or radon emanation: EPA Methods 901.1 and 903.1, respectively. *Prescribed Procedures for Measurement of Radioactivity in Drinking Water* (EPA/600/4-80-032), August 1980. The majority of radium-226 analyses were performed using EPA Method 901.1.

- Thorium-230: EPA 907.0 *Prescribed Procedures for Measurement of Radioactivity in Drinking Water* (EPA/600/4-80-032), August 1980.

- Natural Uranium: EPA 6020 ICP-MS, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), June 2007.

- Lead-210: EPA 909.0M *Prescribed Procedures for Measurement of Radioactivity in Drinking Water* (EPA/600/4-80-032), 1980.

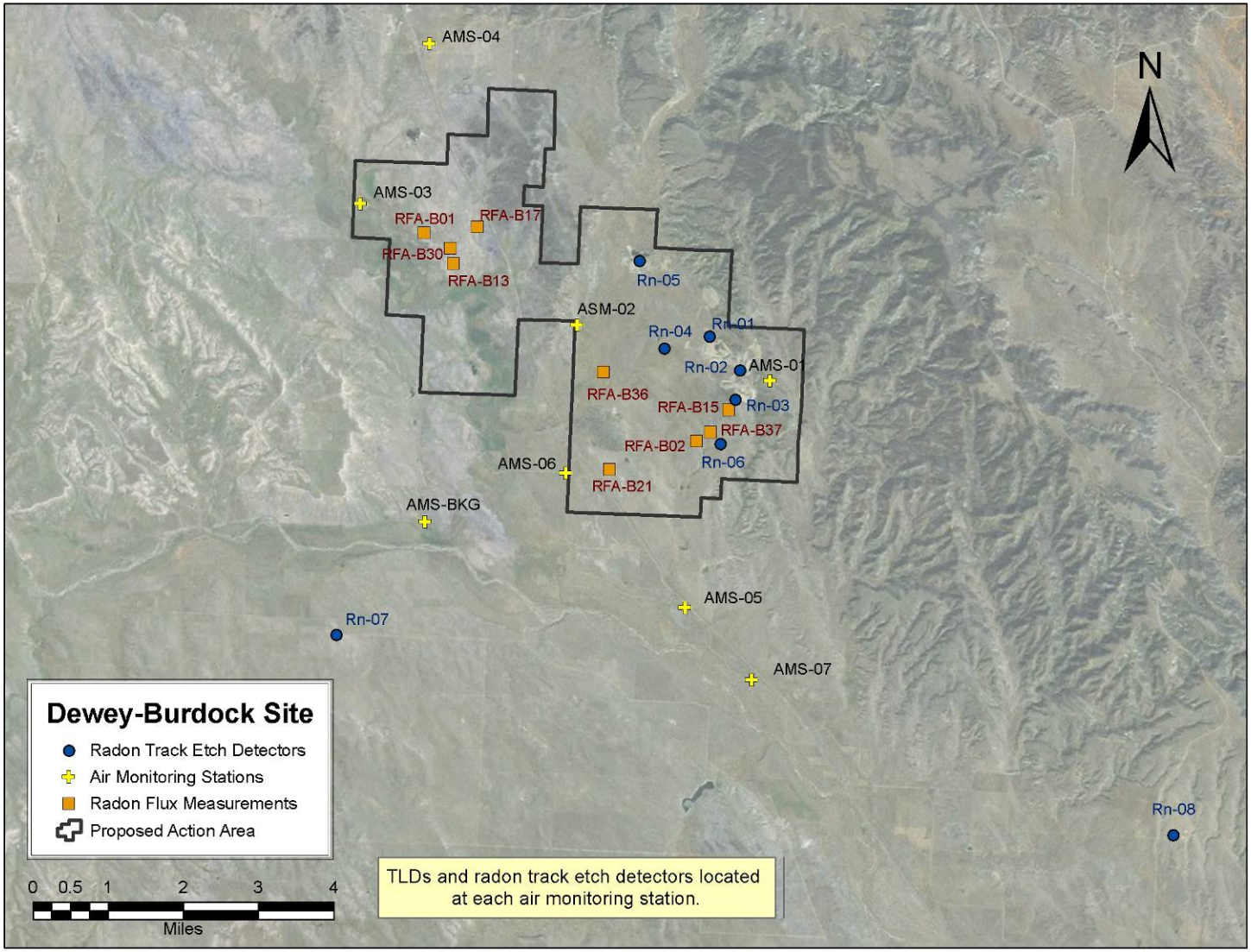

Figure 1.1-8: Air Monitoring Station, Ambient Radon, and Radon Flux Measurement Locations

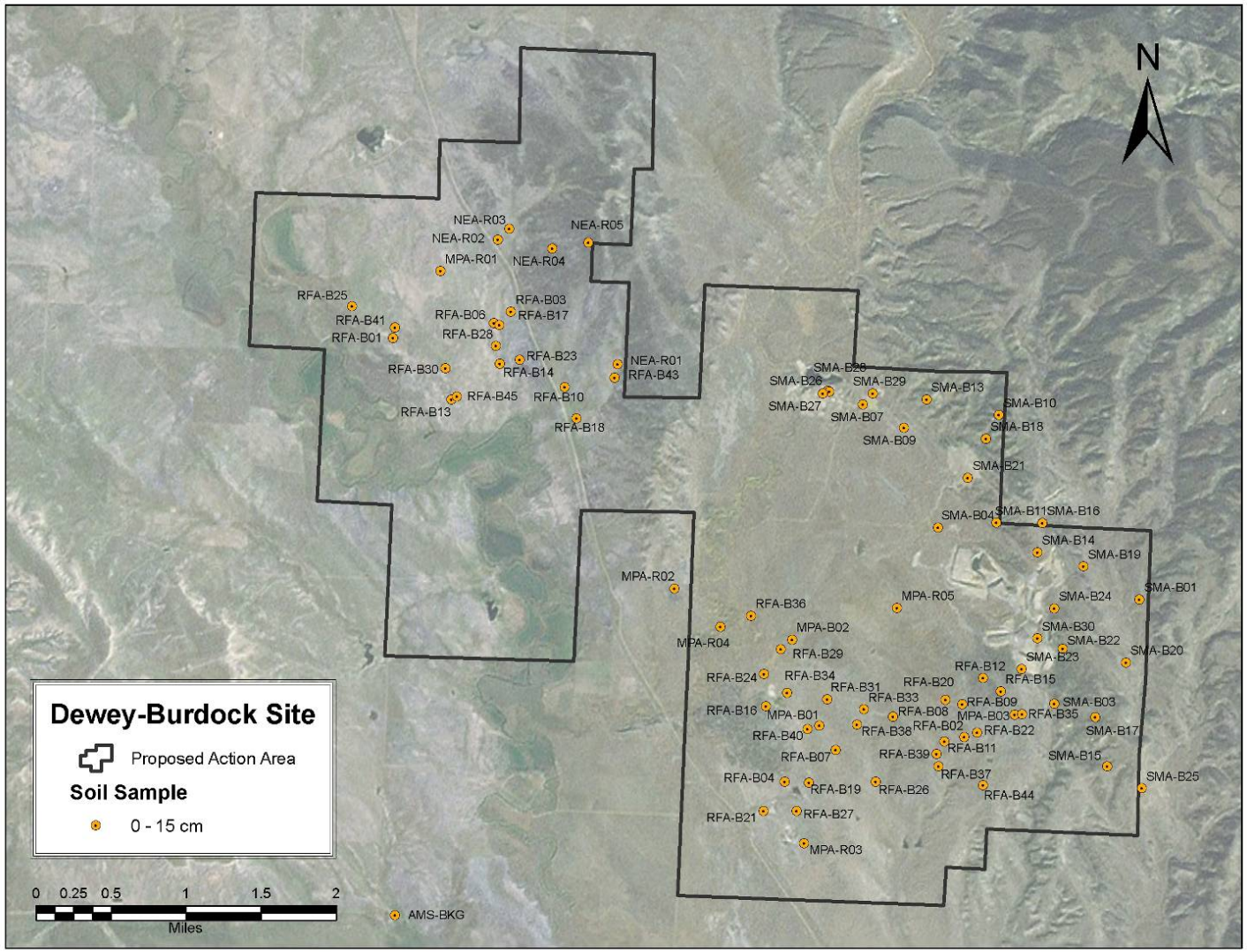

Figure 1.1-9: Surface Soil Sample Locations (80 Locations)

Land Application Areas

To characterize baseline radionuclide concentrations in soils in the land application areas, samples were collected at 17 locations, 10 in the northern and 7 in the southern area, from three intervals: 0 to 15, 15 to 30, and 30 to 100 cm. Refusal was encountered at 10 inches bgs in LAN-008 and the lower interval was not collected. The sample locations, selected randomly using VSP Version 5.0, are shown on Figure 1.1-10. The samples were analyzed for radium-226, natural uranium, thorium-230, and lead-210.

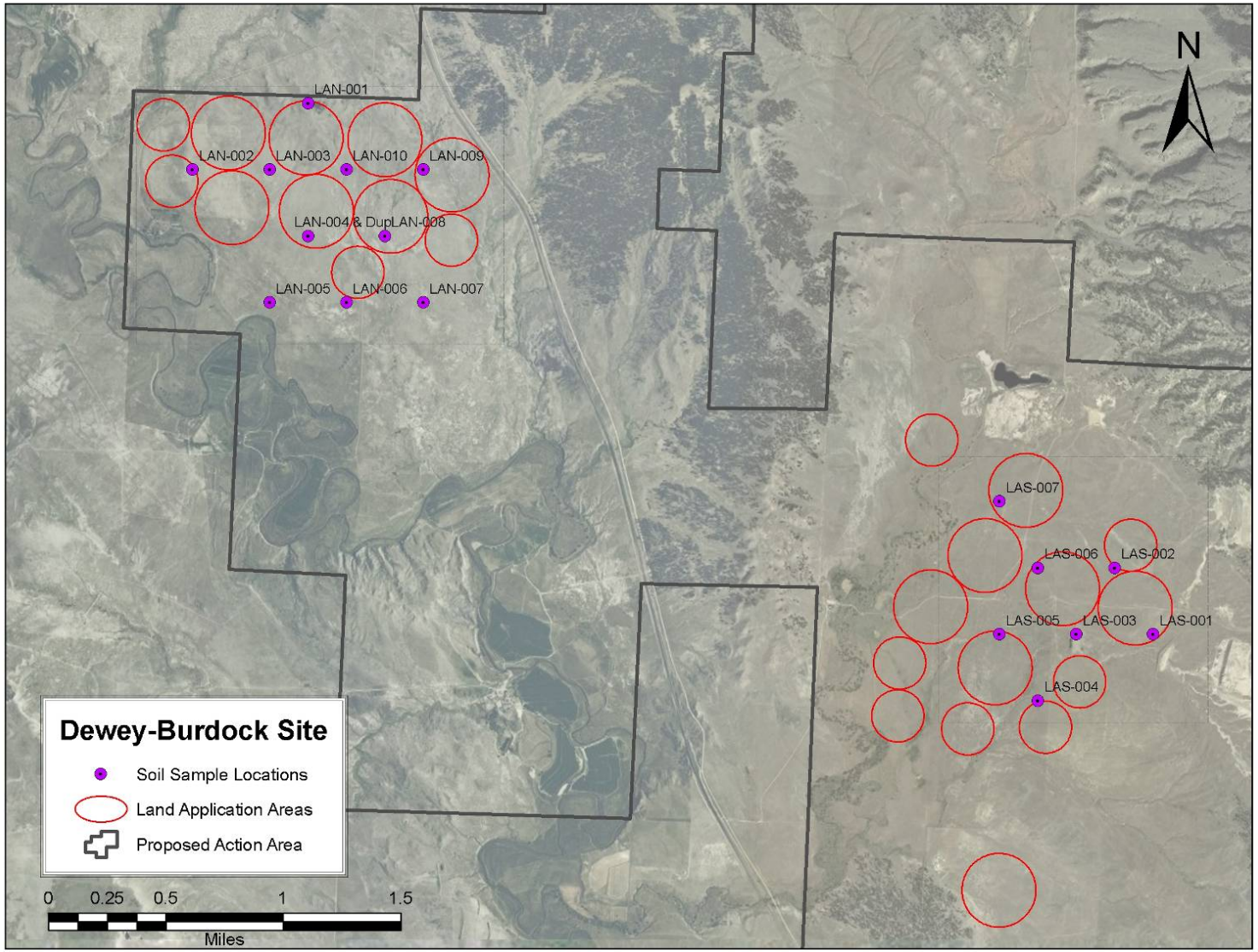

Figure 1.1-10: Soil Sample Locations in Land Application Areas

1.1.3.2 Soil Sampling Results

Table 1.1-5 presents the radium-226 concentrations in the soil samples collected in the main permit, surface mine, and land application areas. The results described in this section are those determined using only EPA Method 901.1. The laboratory analytical data reports are provided in Appendix B of Appendix 1.1-A.

Samples are identified as follows, with duplicates labeled as "dup":

- AMS: air monitoring station
- SMA: surface mine area
- MPA: main permit area
- NEA: northeast area
- RFA: roll front area
- LAN: land application area north (Dewey)
- LAS: land application south (Burdock)

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Table 1.1-5: Radionuclide Concentrations in All Soil Samples

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
AMS-1	9/27/2007	0-5	-	9.6E-07	2.0E-06	3.0E-07	4.0E-07	1.0E-07	1.4E-06	2.0E-07
AMS-2	9/27/2007	0-5	-	9.5E-07	3.0E-06	3.0E-07	5.0E-07	1.0E-07	1.1E-06	2.0E-07
AMS-3	9/27/2007	0-5	-	8.2E-07	2.0E-06	2.0E-07	4.0E-07	1.0E-07	1.5E-06	2.0E-07
AMS-4	9/27/2007	0-5	-	1.4E-06	2.0E-06	2.0E-07	8.0E-07	2.0E-07	1.5E-06	3.0E-07
AMS-5	9/27/2007	0-5	-	6.8E-07	2.0E-06	2.0E-07	6.0E-07	1.0E-07	1.3E-06	3.0E-07
AMS-6	9/27/2007	0-5	-	5.5E-07	1.0E-06	2.0E-07	4.0E-07	1.0E-07	8.0E-07	2.0E-07
AMS-7	9/27/2007	0-5	-	5.8E-07	2.0E-06	2.0E-07	3.0E-07	8.0E-08	1.1E-06	2.0E-07
AMS-BKG	9/27/2007	0-5	-	1.9E-06	2.0E-06	2.0E-07	9.0E-07	1.0E-07	2.4E-06	4.0E-07
MPA-B01	9/25/2007	0-15	13824	-	-	-	-	-	1.4E-06	3.0E-07
MPA-B02	9/25/2007	0-15	14176	-	-	-	-	-	1.1E-06	2.0E-07
MPA-B03	9/25/2007	0-15	13006	-	-	-	-	-	1.3E-06	3.0E-07
MPA-R01	9/24/2007	0-15	13749	-	-	-	-	-	1.4E-06	2.0E-07
MPA-R02	9/24/2007	0-15	16059	-	-	-	-	-	2.6E-06	3.0E-07
MPA-R03	9/24/2007	0-15	10796	7.5E-07	7.0E-07	1.0E-07	4.0E-07	1.0E-07	1.1E-06	2.0E-07
MPA-R04	9/24/2007	0-15	10810	-	-	-	-	-	9.0E-07	2.0E-07
MPA-R04-Dup	9/24/2007	0-15	-	-	-	-	-	-	8.0E-07	2.0E-07
MPA-R05	9/24/2007	0-15	11850	-	-	-	-	-	1.2E-06	2.0E-07
NEA-R01	9/24/2007	0-15	12302	9.1E-07	7.0E-07	2.0E-07	6.0E-07	1.0E-07	1.1E-06	2.0E-07
NEA-R02	9/24/2007	0-15	13176	-	-	-	-	-	1.3E-06	2.0E-07
NEA-R03	9/24/2007	0-15	16393	-	-	-	-	-	2.2E-06	3.0E-07
NEA-R04	9/24/2007	0-15	17356	-	-	-	-	-	2.3E-06	3.0E-07
NEA-R04-Dup	9/24/2007	0-15	-	-	-	-	-	-	2.5E-06	3.0E-07
NEA-R05	9/24/2007	0-15	17269	-	-	-	-	-	2.8E-06	3.0E-07
RFA-B01A	9/26/2007	0-15	13115	8.7E-07	1.0E-06	2.0E-07	7.0E-07	1.0E-07	1.2E-06	2.0E-07
RFA-B01A-Dup	9/26/2007	0-15	-	9.0E-07	8.0E-07	1.0E-07	7.0E-07	1.0E-07	1.1E-06	2.0E-07
RFA-B02A	9/26/2007	0-15	13360	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B03	9/25/2007	0-15	14253	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B04	9/25/2007	0-15	13963	-	-	-	-	-	1.5E-06	3.0E-07
RFA-B06	9/25/2007	0-15	13819	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B07	9/25/2007	0-15	12700	-	-	-	-	-	1.7E-06	2.0E-07
RFA-B08	9/25/2007	0-15	13433	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B08-Dup	9/25/2007	0-15	13528	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B09	9/25/2007	0-15	14825	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B10	9/25/2007	0-15	13366	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B11	9/25/2007	0-15	14253	8.8E-07	1.0E-06	2.0E-07	5.0E-07	1.0E-07	1.8E-06	3.0E-07
RFA-B12	9/25/2007	0-15	13135	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B13A	9/26/2007	0-15	13987	-	-	-	-	-	1.8E-06	3.0E-07
RFA-B02A	9/26/2007	0-15	13360	-	-	-	-	-	1.6E-06	2.0E-07
RFA-B14	9/25/2007	0-15	13872	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B15A	9/26/2007	0-15	13535	-	-	-	-	-	1.4E-06	3.0E-07
RFA-B16	9/25/2007	0-15	13675	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B17A	9/26/2007	0-15	16283	-	-	-	-	-	2.0E-06	3.0E-07

Table 1.1-5: Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
RFA-B18	9/25/2007	0-15	13835	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B19	9/25/2007	0-15	13689	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B20	9/25/2007	0-15	13113	8.8E-07	1.0E-06	2.0E-07	5.0E-07	1.0E-07	1.3E-06	3.0E-07
RFA-B21A	9/26/2007	0-15	16641	-	-	-	-	-	5.6E-06	4.0E-07
RFA-B22	9/25/2007	0-15	14087	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B23	9/25/2007	0-15	19674	-	-	-	-	-	3.6E-06	4.0E-07
RFA-B24	9/25/2007	0-15	12766	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B25	9/25/2007	0-15	10300	6.7E-07	1.0E-06	2.0E-07	4.0E-07	1.0E-07	1.2E-06	2.0E-07
RFA-B26	9/25/2007	0-15	11791	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B27	9/25/2007	0-15	13794	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B28	9/25/2007	0-15	15246	-	-	-	-	-	2.4E-06	3.0E-07
RFA-B28-Dup	9/25/2007	0-15	-	-	-	-	-	-	1.8E-06	3.0E-07
RFA-B29	9/25/2007	0-15	14345	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B30A	9/26/2007	0-15	12461	-	-	-	-	-	1.8E-06	2.0E-07
RFA-B31	9/25/2007	0-15	12221	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B33	9/25/2007	0-15	13221	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B34	9/25/2007	0-15	13408	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B35	9/25/2007	0-15	12290	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B36A	9/25/2007	0-15	12465	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B37A	9/26/2007	0-15	11170	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B38	9/25/2007	0-15	11852	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B39	9/25/2007	0-15	11478	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B40	9/25/2007	0-15	12629	5.6E-07	1.0E-06	2.0E-07	3.0E-07	1.0E-07	1.1E-06	2.0E-07
RFA-B41	9/25/2007	0-15	11806	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B43	9/25/2007	0-15	13264	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B44	9/25/2007	0-15	11436	-	-	-	-	-	1.4E-06	2.0E-07
RFA-B45	9/25/2007	0-15	12242	-	-	-	-	-	1.6E-06	3.0E-07
SMA-B01	9/24/2007	0-15	10459	1.2E-06	6.0E-07	1.0E-07	5.0E-07	1.0E-07	9.0E-07	2.0E-07
SMA-B01-Dup	9/24/2007	0-15	-	1.5E-06	2.0E-06	2.0E-07	6.0E-07	1.0E-07	1.4E-06	3.0E-07
SMA-B03	9/24/2007	0-15	22410	-	-	-	-	-	1.5E-06	2.0E-07
SMA-B04	9/24/2007	0-15	15263	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B07	9/24/2007	0-15	22925	-	-	-	-	-	3.2E-06	3.0E-07

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Table 1.1-5: Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
SMA-B09	9/24/2007	0-15	12879	-	-	-	-	-	1.2E-06	2.0E-07
SMA-B09-Dup	9/24/2007	0-15	-	-	-	-	-	-	1.7E-06	2.0E-07
SMA-B10	9/25/2007	0-15	13184	-	-	-	-	-	1.4E-06	2.0E-07
SMA-B11	9/24/2007	0-15	17346	-	-	-	-	-	2.3E-06	3.0E-07
SMA-B13	9/25/2007	0-15	13252	-	-	-	-	-	1.7E-06	3.0E-07
SMA-B14	9/24/2007	0-15	14483	-	-	-	-	-	1.4E-06	3.0E-07
SMA-B14-Dup	9/24/2007	0-15	-	-	-	-	-	-	1.6E-06	2.0E-07
SMA-B15	9/24/2007	0-15	8474	-	-	-	-	-	8.0E-07	2.0E-07
SMA-B16	9/24/2007	0-15	10235	-	-	-	-	-	9.0E-07	2.0E-07
SMA-B17	9/24/2007	0-15	10139	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B18	9/25/2007	0-15	8511	-	-	-	-	-	5.0E-07	1.0E-07
SMA-B18-Dup	9/25/2007	0-15	-	-	-	-	-	-	4.0E-07	1.0E-07
SMA-B19	9/24/2007	0-15	10074	-	-	-	-	-	1.2E-06	2.0E-07
SMA-B20	9/27/2007	0-15	10897	-	-	-	-	-	9.0E-07	2.0E-07
SMA-B21	9/24/2007	0-15	16712	-	-	-	-	-	1.4E-06	2.0E-07
SMA-B22	9/24/2007	0-15	10618	-	-	-	-	-	8.0E-07	2.0E-07
SMA-B23	9/24/2007	0-15	16233	-	-	-	-	-	2.7E-06	3.0E-07
SMA-B23-Dup	9/24/2007	0-15	-	-	-	-	-	-	2.8E-06	3.0E-07
SMA-B24	9/24/2007	0-15	12662	-	-	-	-	-	1.3E-06	2.0E-07
SMA-B25	9/24/2007	0-15	9991	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B26	9/28/2007	0-15	73243	-	-	-	-	-	1.1E-05	5.0E-07
SMA-B27	9/28/2007	0-15	130293	6.7E-05	3.0E-05	8.0E-07	3.0E-05	8.0E-07	4.0E-05	1.1E-06
SMA-B28	9/29/2007	0-15	39061	-	-	-	-	-	6.4E-06	4.0E-07
SMA-B29	9/28/2007	0-15	231041	1.6E-05	2.0E-05	7.0E-07	2.0E-05	6.0E-07	2.9E-05	9.0E-07
SMA-B30	9/28/2007	0-15	89139	-	-	-	-	-	3.4E-05	9.0E-07
LAN 001A	7/18/2008	0-15	-	1.8E-06	2.4E-06	2.3E-06	1.2E-06	6.0E-07	8.0E-07	9.0E-08
LAN 002A	7/18/2008	0-15	-	8.6E-07	3.4E-06	2.3E-06	9.0E-07	5.0E-07	9.0E-07	1.0E-07
LAN 003A	7/18/2008	0-15	-	7.8E-07	8.0E-07	2.2E-06	7.0E-07	6.0E-07	1.2E-06	1.0E-07
LAN 004A	7/18/2008	0-15	-	6.9E-07	1.0E-06	1.4E-06	6.0E-07	6.0E-07	1.9E-06	2.0E-07
LAN 004A-DUP	7/18/2008	0-15	-	7.2E-07	5.0E-07	1.4E-06	4.0E-07	3.0E-07	7.0E-07	1.0E-07
LAN 005A	7/18/2008	0-15	-	8.4E-07	1.2E-06	1.4E-06	9.0E-07	5.0E-07	4.4E-06	3.0E-07
LAN 006A	7/18/2008	0-15	-	7.1E-07	-5.0E-09	1.4E-06	3.0E-07	5.0E-07	1.1E-06	1.0E-07
LAN 007A	7/18/2008	0-15	-	8.1E-07	6.0E-07	1.4E-06	3.0E-07	5.0E-07	7.0E-07	1.0E-07
LAN 008A	7/18/2008	0-15	-	2.1E-06	1.0E-06	1.4E-06	1.0E-06	7.0E-07	9.0E-07	1.0E-07
LAN 009A	7/18/2008	0-15	-	1.1E-06	-4.0E-07	1.4E-06	3.0E-07	6.0E-07	8.0E-07	1.0E-07
LAN 010A	7/18/2008	0-15	-	1.6E-06	1.8E-06	1.2E-06	1.2E-06	6.0E-07	1.2E-06	2.0E-07
LAS 001A	7/19/2008	0-15	-	1.2E-06	1.6E-06	1.2E-06	6.0E-07	5.0E-07	9.0E-07	1.0E-07
LAS 002A	7/19/2008	0-15	-	4.8E-07	1.4E-06	1.2E-06	1.0E-07	5.0E-07	7.0E-07	1.0E-07

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Table 1.1-5: Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
LAS 003A	7/19/2008	0-15	-	5.0E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 004A	7/19/2008	0-15	-	1.1E-06	1.2E-06	1.2E-06	6.0E-07	5.0E-07	8.0E-07	1.0E-07
LAS 005A	7/19/2008	0-15	-	1.2E-06	1.6E-06	1.2E-06	4.0E-07	3.0E-07	9.0E-07	1.0E-07
LAS 006A	7/19/2008	0-15	-	3.7E-07	7.0E-07	1.1E-06	6.0E-07	6.0E-07	7.0E-07	1.0E-07
LAS 007A	7/19/2008	0-15	-	4.3E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	8.0E-07	1.0E-07
RFA-B01B	9/26/2007	15-30	13115	1.1E-06	2.0E-06	2.0E-07	9.0E-01	2.0E-01	1.7E-06	2.0E-07
RFA-B01B-Dup	9/26/2007	15-30	-	9.9E-07	9.0E-07	2.0E-07	9.0E-01	2.0E-01	1.5E-06	2.0E-07
RFA-B02B	9/26/2007	15-30	-	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B13B	9/26/2007	15-30	-	-	-	-	-	-	1.8E-06	2.0E-07
RFA-B15B	9/26/2007	15-30	-	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B17B	9/26/2007	15-30	-	-	-	-	-	-	2.2E-06	3.0E-07
RFA-B21B	9/26/2007	15-30	-	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B30B	9/26/2007	15-30	-	-	-	-	-	-	2.1E-06	3.0E-07
RFA-B36B	9/26/2007	15-30	-	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B37B	9/26/2007	15-30	-	-	-	-	-	-	7.0E-07	2.0E-07
LAN 001B	7/18/2008	15-30	-	1.9E-06	4.6E-06	2.3E-06	1.4E-06	6.0E-07	8.0E-07	1.0E-07
LAN 002B	7/18/2008	15-30	-	7.5E-07	1.5E-06	2.3E-06	4.0E-07	4.0E-07	1.0E-06	1.0E-07
LAN 003B	7/18/2008	15-30	-	1.1E-06	2.4E-06	2.3E-06	8.0E-07	5.0E-07	1.2E-06	1.0E-07
LAN 004B	7/18/2008	15-30	-	7.9E-07	2.2E-06	1.4E-06	2.0E-07	5.0E-07	1.3E-06	2.0E-07
LAN 004B-DUP	7/18/2008	15-30	-	6.8E-07	-3.0E-07	1.4E-06	5.0E-07	4.0E-07	7.0E-07	1.0E-07
LAN 005B	7/18/2008	15-30	-	7.1E-07	9.0E-07	1.4E-06	6.0E-07	4.0E-07	1.6E-06	2.0E-07
LAN 006B	7/18/2008	15-30	-	7.5E-07	5.0E-07	1.4E-06	6.0E-07	4.0E-07	1.3E-06	1.0E-07
LAN 007B	7/18/2008	15-30	-	1.5E-06	6.0E-07	1.4E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAN 008B	7/18/2008	15-30	-	3.5E-06	1.0E-07	1.4E-06	9.0E-07	7.0E-07	1.0E-06	1.0E-07
LAN 009B	7/18/2008	15-30	-	1.8E-06	-3.0E-07	1.4E-06	7.0E-07	5.0E-07	4.1E-06	3.0E-07
LAN 010B	7/18/2008	15-30	-	1.5E-06	1.1E-06	1.1E-06	7.9E-06	1.2E-06	1.4E-06	2.0E-07
LAS 001B	7/19/2008	15-30	-	8.6E-07	1.1E-06	1.2E-06	4.0E-07	5.0E-07	8.0E-07	1.0E-07
LAS 002B	7/19/2008	15-30	-	7.1E-07	7.0E-07	1.2E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003B	7/19/2008	15-30	-	1.2E-06	1.1E-06	1.1E-06	5.0E-07	4.0E-07	9.0E-07	1.0E-07
LAS 004B	7/19/2008	15-30	-	9.5E-07	1.3E-06	1.2E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAS 005B	7/19/2008	15-30	-	1.6E-06	1.4E-06	1.1E-06	4.0E-07	4.0E-07	1.0E-06	2.0E-07
LAS 006B	7/19/2008	15-30	-	4.8E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 007B	7/19/2008	15-30	-	4.5E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	7.0E-07	1.0E-07
LAN 008B	7/18/2008	15-30	-	3.5E-06	1.0E-07	1.4E-06	9.0E-07	7.0E-07	1.0E-06	1.0E-07
LAN 009B	7/18/2008	15-30	-	1.8E-06	-3.0E-07	1.4E-06	7.0E-07	5.0E-07	4.1E-06	3.0E-07
LAN 010B	7/18/2008	15-30	-	1.5E-06	1.1E-06	1.1E-06	7.9E-06	1.2E-06	1.4E-06	2.0E-07
LAS 001B	7/19/2008	15-30	-	8.6E-07	1.1E-06	1.2E-06	4.0E-07	5.0E-07	8.0E-07	1.0E-07

Table 1.1-5: Radionuclide Concentrations in All Soil Samples (concluded)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
LAS 002B	7/19/2008	15-30	-	7.1E-07	7.0E-07	1.2E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003B	7/19/2008	15-30	-	1.2E-06	1.1E-06	1.1E-06	5.0E-07	4.0E-07	9.0E-07	1.0E-07
LAS 004B	7/19/2008	15-30	-	9.5E-07	1.3E-06	1.2E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAS 005B	7/19/2008	15-30	-	1.6E-06	1.4E-06	1.1E-06	4.0E-07	4.0E-07	1.0E-06	2.0E-07
LAS 006B	7/19/2008	15-30	-	4.8E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 007B	7/19/2008	15-30	-	4.5E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	7.0E-07	1.0E-07
RFA-B01C	9/26/2007	30-100	-	1.5E-06	6.0E-07	1.0E-07	8.0E-01	1.0E-01	1.2E-06	2.0E-07
RFA-B01C-Dup	9/29/2007	30-100	-	1.3E-06	1.0E-06	2.0E-07	1.0E+00	2.0E-01	1.7E-06	3.0E-07
RFA-B02C	9/26/2007	30-100	-	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B13C	9/26/2007	30-100	-	-	-	-	-	-	1.6E-06	2.0E-07
RFA-B15C	9/26/2007	30-100	-	-	-	-	-	-	1.5E-06	3.0E-07
RFA-B17C	9/26/2007	30-100	-	-	-	-	-	-	2.5E-06	3.0E-07
RFA-B21C	9/26/2007	30-100	-	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B30C	9/26/2007	30-100	-	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B36C	9/26/2007	30-100	-	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B37C	9/26/2007	30-100	-	-	-	-	-	-	1.1E-06	2.0E-07
LAN 001C	7/18/2008	30-100	-	1.9E-06	1.9E-06	2.2E-06	1.6E-06	7.0E-07	9.0E-07	1.0E-07
LAN 002C	7/18/2008	30-100	-	1.5E-06	1.1E-06	2.2E-06	3.0E-07	3.0E-07	1.2E-06	1.0E-07
LAN 003C	7/18/2008	30-100	-	2.0E-06	2.6E-06	2.3E-06	6.0E-07	3.0E-07	1.0E-06	1.0E-07
LAN 004C	7/18/2008	30-100	-	1.5E-06	8.0E-07	1.4E-06	7.0E-07	5.0E-07	1.0E-06	1.0E-07
LAN 004C-DUP	7/18/2008	30-100	-	1.3E-06	1.2E-06	1.4E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAN 005C	7/18/2008	30-100	-	7.1E-07	6.0E-07	1.4E-06	5.0E-07	4.0E-07	1.5E-06	2.0E-07
LAN 006C	7/18/2008	30-100	-	1.1E-06	7.0E-07	1.4E-06	5.0E-07	3.0E-07	1.4E-06	2.0E-07
LAN 007C	7/18/2008	30-100	-	2.5E-06	1.0E-07	1.4E-06	8.0E-07	6.0E-07	4.0E-07	1.0E-07
LAN 009C	7/18/2008	30-100	-	1.6E-06	5.0E-07	1.4E-06	1.1E-06	6.0E-07	3.9E-06	3.0E-07
LAN 010C	7/18/2008	30-100	-	2.7E-06	1.9E-06	1.2E-06	1.9E-06	8.0E-07	1.5E-06	2.0E-07
LAS 001C	7/19/2008	30-100	-	6.1E-07	9.0E-07	1.1E-06	1.0E-07	3.0E-07	8.0E-07	1.0E-07
LAS 002C	7/19/2008	30-100	-	6.3E-07	4.0E-07	1.1E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003C	7/19/2008	30-100	-	9.3E-07	7.0E-07	1.2E-06	1.0E-06	5.0E-07	8.0E-07	1.0E-07
LAS 004C	7/19/2008	30-100	-	1.3E-06	1.2E-06	1.1E-06	5.0E-07	3.0E-07	9.0E-07	1.0E-07
LAS 005C	7/19/2008	30-100	-	9.8E-07	1.2E-06	1.1E-06	7.0E-07	5.0E-07	1.1E-06	2.0E-07
LAS 006C	7/19/2008	30-100	-	6.5E-07	-3.0E-07	1.5E-06	3.0E-07	9.0E-08	6.0E-07	1.0E-07
LAS 007C	7/19/2008	30-100	-	7.2E-07	-7.0E-07	1.5E-06	5.0E-07	1.0E-07	7.0E-07	1.0E-07

Notes:
All errors reported are ± 2σ.

1.1.3.2.1 Surface Soil Sampling Results

Radium-226 Concentrations in the First Set of 80 Locations

In the set of 80 surface samples, the mean and median radium-226 concentrations are 2.9 and 1.3 pCi/g, respectively. Q1 and Q3 are 1.1 and 1.7 pCi/g, respectively. The IQR is 0.6. The mode is 1.1 pCi/g (12 observations). One result (0.45 pCi/g, Sample Location SMA-18) was a low outlier. Thirteen values exceeded 2.3 pCi/g, the cutoff for high outliers.

The soil data were fitted to normal and lognormal distributions. The p-values for both distributions are less than 0.005, indicating that at a 95 percent confidence level ($p = 0.05$), the distributions are non-normal and non-lognormal.

Considering that the data do not fit normal or lognormal distributions, and clear differences in the gamma-ray count rates obtained in the surface mine and main permit areas are indicative of differences in the levels of gamma-emitting radionuclides therein, the set of surface soil data was divided into surface mine and main permit area subsets, as discussed in the following sections.

Radium-226 Concentrations in the Surface Mine Area

Twenty-five surface soil samples were collected in the surface mine area. The data did not fit a parametric distribution. The median radium-226 concentration was 1.4 pCi/g. Five of the concentrations were outliers, exceeding a cutoff (1.5 times Q3) of 5.9 pCi/g. The outliers are the radium-226 concentrations in the five biased samples, all collected in the surface mine area.

The data set with the outliers removed fit a lognormal distribution. The central tendency and variability of a lognormal distribution are best represented by the geometric mean and geometric standard deviation, each of which is 1.3 pCi/g radium-226 in the case of the surface mine area data set. The data lie within a population range of 0.76 to 2.2 pCi/g.

Radium-226 Concentrations in the Main Permit Area

Fifty-five surface soil samples were collected in the main permit area. The data did not fit a parametric distribution. The median radium-226 concentration was 1.3 pCi/g. Three of the concentrations were outliers, exceeding a cutoff (1.5 times Q3) of 2.6 pCi/g.

The data set with the outliers removed fit a lognormal distribution. The geometric mean and geometric standard deviation of the set of main permit area radium-226 concentrations are each 1.3 pCi/g. The data lie within a population range of 0.76 to 2.2 pCi/g.

Radium-226 Concentrations in the North Section of Main Permit Area

It was stated above that elevated gamma-ray count rates were observed in an approximately 600-acre area located at the north end of the main permit area. Considering that the elevated levels are likely due to relatively higher increased levels of one or more gamma-emitting radionuclides, radium-226 concentrations in soil samples collected from this area were evaluated.

Eight surface soil samples were collected in this area (MPA-R01, NEA-R02, NEA-R03, NEA-R04, NEA-R05, RFA-03, RFA-06, and RFA-17). One of these samples was considered an outlier of the main permit area data set (NEA-R05).

There are too few soil samples collected in this area to characterize it statistically. However, the gamma-ray count rates therein differ from the main permit area, with statistical significance.

Radium-226 Concentrations in the Land Application Areas

Radium-226 concentrations in surface soils in the land application areas are summarized as follows:

- Averaged 1.1 pCi/g and ranged from 0.7 to 4.4 pCi/g in both areas
- Averaged 1.3 pCi/g in the Dewey land application area
- Averaged 0.8 pCi/g in the Burdock land application area

The concentrations of surrogate radionuclides, uranium, lead-210, and thorium-230 concentrations are consistently lower in the Burdock than in the Dewey Land Application Area, indicating that the lower radium-226 concentration is not a laboratory artifact.

Discussion of Radium-226 Concentrations

Although the distributions of the main permit and surface mine area radium-226 concentration data sets are similar, the gamma-ray count rate distributions in these two areas differ, with statistical significance. The gamma-ray count rates observed in the anomalous portion of the main permit area also differ from the main permit area.

With outliers removed, both the surface mine and main permit area radium-226 concentration data sets fit a lognormal distribution. The geometric mean and geometric standard deviation of both data sets is 1.3 pCi/g. The data lie within a population range of 0.76 to 2.2 pCi/g. The mean of 1.3 pCi/g is representative of a general background value in the majority of the project area surface soils. Exceptional areas include those in and around the artesian well discharge and open pit mines. At this time, radium-226 concentrations are not well characterized in the northern anomalous area in the main permit area and along the northwest edge of the surface mine area.

The range of radium-226 concentrations in the land application areas lies within the range of overall radium-226 concentrations, averaging 1.3 and 0.8 pCi/g in the Dewey and Burdock areas, respectively.

Other Radionuclides

Table 1.1-5 summarizes the analytical results for all samples analyzed for the extended suite of radiological parameters (all locations and depths combined). Although the sample number isn't sufficient to allow any definitive conclusions to be drawn regarding distributional characteristics or trends of non radium-226 parameters, a positive relationship between the concentrations of radium-226 and natural uranium, thorium-230, and lead-210 is apparent.

Limits of Detection

A summary of the results with respect to reporting limits and minimum detectable concentrations (MDCs) is as follows:

- The radium-226, lead-210, and thorium-230 LLDs (reported as MDCs or reporting limits) in the NEA, MPA, RFA, and SMA soil samples were all $1*10^{-7}$ µCi/g.
- The natural uranium LLDs in the NEA, MPA, RFA, and SMA samples ranged from $1.7*10^{-8}$ to $2.0*10^{-8}$ µCi/g.
- None of the results NEA, MPA, RFA, and SMA samples were below their respective LLDs.
- The lead-210 LLDs for the LAN and LAS samples ranged from $1.9*10^{-6}$ to $3.8*10^{-6}$ µCi/g. In all but one case, the lead-210 results were lower than their respective LLDs.
- The radium-226 LLDs for the LAN and LAS samples ranged from $4.0*10^{-8}$ to $1.0*10^{-7}$ µCi/g. All of the LAN and LAS results exceeded their respective LLDs.

- The thorium-230 LLD for the LAN and LAS samples was $1.0*10^{-7}$ µCi/g. Results for 17 of the 53 (surface and subsurface) samples were reported below $1.0*10^{-7}$ µCi/g.
- The natural uranium LLD for the LAN and LAS samples was $7.0*10^{-9}$ µCi/g. All of the results exceeded the LLD.

The LLD recommended in RG 4.14 for natural uranium, thorium-230, radium-226, and lead-210 in soils is $2*10^{-7}$ µCi/g. The only case for which the guidance was not followed was the LLD for lead-210 in the LAN and LAS samples.

1.1.3.2.2 Subsurface Soil Sample Results

Table 1.1-5 lists the subset of subsurface biased samples that were collected at depth in the project roll front areas: RFA-B01, RFA-B02 RFA-B13 RFA-B15, RFA-B17, RFA-B21, RFA-B30, RFA-B36, and RFA-B37. The table also lists results obtained in subsurface samples collected in the two land application areas: LAN-001 through LAN-009 and LAS-001 through LAS-007.

1.1.3.2.3 Data Uncertainty

This section briefly summarizes the results of the quality control (QC) samples collected for the baseline soil sampling program. The results of this QC effort are documented in Table 1.1-6, which lists the errors and lower limits of detection (LLDs) for each duplicate pair. Table 1.1-6 documents associated comparisons, presenting the corresponding RPD (in the case of natural uranium) and/or Replicate Error Ratio (RER) for each QC pair. The calculation of RPDs and RERs is a standard technique used to evaluate laboratory precision.

The RPD is calculated as follows:

$$RPD = \frac{|A - B|}{\frac{A + B}{2}}$$

Where A and B are the sample and duplicate results, respectively.

The RER is calculated as follows:

$$RER = \frac{|S - R|}{\sqrt{(Sx0.15)^2 + (E_s)^2} + \sqrt{(Rx0.15)^2 + (E_R)^2}}$$

Where S and are the sample and duplicate concentrations, respectively. E_S and E_R are the sample (E_S) and duplicate errors (E_R). The factor of 0.15 accounts for any inherent systematic error which cannot be quantified. The acceptance criteria are an RPD and RER of less than 40 and 1 percent for data above the minimal detectable concentration (MDC), respectively, as established in a Quality Assurance Project Plan (QAPP) (ERG 2006). This data set shows four cases where the RER for lead-210 was greater than 1 and five cases where the RPD exceeded 40. There are three cases where the RER and RPD for radium-226 are exceeded (two concurrently).

Table 1.1-6: Quality Control Analysis for Soil Samples

		Relative Percent Difference (%)				Replicate Error Ratio		
Sample ID	**Depth (cm)**	**U-nat**	**Pb-210**	**Th-230**	**Ra-226**	**Pb-210**	**Th-230**	**Ra-226**
MPA-R04+Duplicate	0-15	-	-	-	11.8	-	-	0.2
NEA-R04+Duplicate	0-15	-	-	-	8.3	-	-	0.2
RFA-B01A+Duplicate	0-15	3.4	22.2	0.0	8.7	0.0	0.0	0.2
RFA-B01B+Duplicate	15-30	10.5	**75.9**	0.0	12.5	**1.8**	0.0	0.3
RFA-B01C+Duplicate	30-100	14.3	**50.0**	22.2	34.5	**1.0**	0.5	0.8
RFA-B08+Duplicate	0-15	-	-	-	0.0	-	-	0.0
RFA-B28+Duplicate	0-15	-	-	-	28.6	-	-	0.7
SMA-B01+Duplicate	0-15	22.2	**107.7**	18.2	**43.5**	**2.8**	0.4	0.8
SMA-B09+Duplicate	0-15	-	-	-	34.5	-	-	0.8
SMA-B14+Duplicate	0-15	-	-	-	13.3	-	-	0.3
SMA-B18+Duplicate	0-15	-	-	-	22.2	-	-	0.4
SMA-B23+Duplicate	0-15	-	-	-	3.6	-	-	0.1
LAN-004A+Duplicate	0-15	-4.3	**66.7**	40.0	**92.3**	0.5	0.6	**8.5**
LAN-004B+Duplicate	15-30	15.0	**263.2**	-85.7	**60.0**	**2.5**	0.9	**4.2**
LAN-004C+Duplicate	30-100	14.3	-40.0	33.3	22.2	0.4	0.6	**1.4**

Notes:
The radium-226, lead-210, and thorium-230 LLDs were all $1*10^{-7}$ µCi/g. All results are greater than 5 times their respective MDC, with the exception of radium-226 in Sample Location SMA-B18-Dup.
The natural uranium LLDs ranged from $1.7*10^{-8}$ to $2.0*10^{-8}$ µCi/g.
None of the results were below their respective LLDs.
Bolded values are anomalous QC results.

The consequences of one radium-226 and three lead-210 results exceeding the acceptance criteria are minimal since in each case the concentrations are low. In addition, lead-210 largely has no impact when addressing the impact of the baseline radiological characteristics of the site and potential impacts from site operations.

There is close agreement for all other analytical results reported for each duplicate pair collected for all parameters. Overall, duplicate results are generally comparable for the majority of QC

samples collected. Considering the low level of radioactivity observed in most of the QC pairs, the laboratory performance on blind duplicates is satisfactory.

1.1.3.3 Conclusions

Main Project and Surface Mine Areas

Main project and surface mine area subsurface radium-226 concentrations, ranging from 0.7 to 5.6 pCi/g, are comparable to those observed in the 0 to 15 cm surface samples in the samples. There is no apparent trend with depth.

Land Application Areas

Subsurface concentrations in the land applications can be summarized as follows:

- Radium-226 concentrations range from 0.4 to 4.1 pCi/g, with a median of 0.9 pCi/g.
- Radium-226 concentrations in the project land application area have a median of 1.0 pCi/g.
- Radium-226 concentrations in the project land application area have a median of 0.8 pCi/g.

The subsurface results in both land application areas are comparable to those observed in the 0 to 15 cm surface samples in the samples. There is no apparent trend with depth.

1.1.4 Sediment Sampling

In June and August of 2008, baseline sediment sampling was conducted at the proposed project site in accordance with NRC Regulatory Guide 4.14 (NRC, 1980), which requires stream sediment samples during both seasonal runoff and low-flow conditions and one sediment sample at each impoundment to characterize radionuclide content. Stream sediment samples were collected at the same locations at which surface water quality sampling sites were located: upstream and downstream sites on Pass Creek, Beaver Creek, and the Cheyenne River, and one site on each of two ephemeral drainages located within the proposed project boundary. Impoundment sediment samples were collected in the same impoundments at which surface water chemistry was sampled. Figure 1.1-11 and Table 1.1-7 provide sediment sampling locations.

Stream sediment samples were collected upstream and downstream sites on three primary streams (Pass Creek, Beaver Creek, and the Cheyenne River) and sites on two other ephemeral drainages.

Sediment samples were collected in June 2008 from 11 surface water impoundments located in the area. Impoundments primarily consist of stockponds but also include historical open pit mines within the proposed permit boundary. At the time of sampling, the majority of subimpoundments had water present. As indicated by NRC Regulatory Guide 4.14, a one-time sampling event is sufficient to document radiological conditions of surface water impoundment sediments.

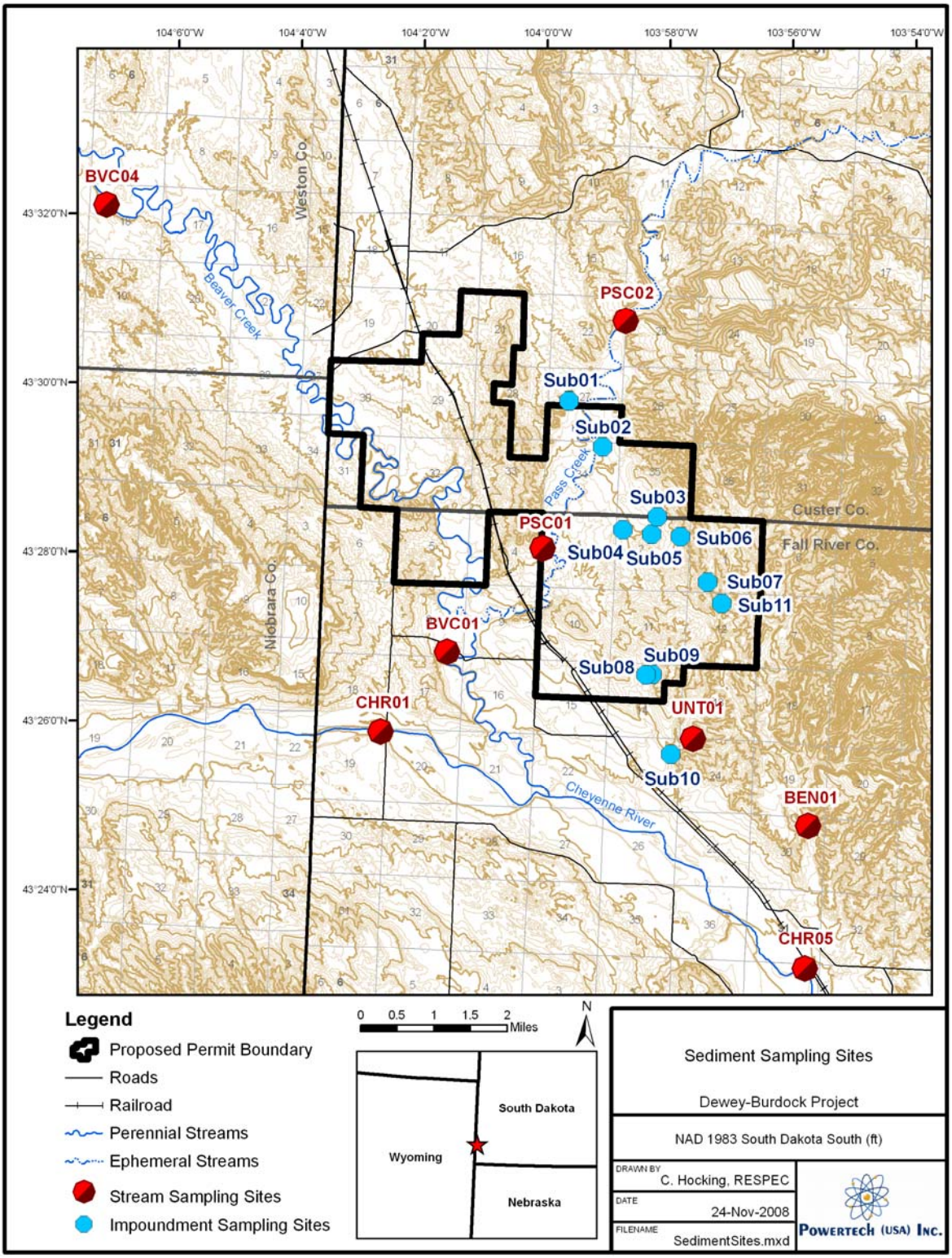

Figure 1.1-11: Sediment Sampling Sites

Table 1.1-7: Sampling Locations - Stream and Impoundment Sediment Sampling Locations

	Site ID	SD State Plane 1983		Type / Name	Groundwater Influence
		East (ft)	North (ft)		
Subimpoundments	Sub01	998654	446816	stock pond	
	Sub02	1001071	443526	Triangle Mine Pit	x
	Sub03	1005005	438448	mine dam	
	Sub04	1002542	437518	stock pond	
	Sub05	1004591	437191	mine dam	
	Sub06	1006665	437019	Darrow Mine pit - Northwest	
	Sub07	1009312	434360	stock dam	
	Sub08	1004195	427057	stock pond	x
	Sub09	1004640	427089	stock pond	
	Sub10	1005961	421367	stock pond	
	Sub11	1009659	432225	stock pond	
Streams	BVC01	989871	428716	Beaver Creek downstream	
	BVC04	965366	460922	Beaver Creek upstream	
	CHR01	985098	423010	Cheyenne River upstream	
	CHR05	1015626	405925	Cheyenne River downstream	
	PSC01	996764	436205	Pass Creek downstream	
	PSC02	1002722	452563	Pass Creek upstream	
	BEN01	1015872	416196	Bennet Canyon	
	UNT01	1007565	422482	Un-named Tributary	

1.1.4.1 Methods

1.1.4.1.1 Stream Sediment Sampling

At each location, four sediment sub-samples were collected with a plastic hand trowel to a depth of 5 cm each, along a transect spanning the width of the channel in areas where active sediment deposition was occurring. Prior to sampling at each site, the trowel was cleaned by rinsing with a liquid Alconox solution followed by a deionized water rinse. To represent the average radionuclide concentration across the channel, the four sub-samples were composited into a single sample. The composite sample was placed in a plastic zipper bag labeled with site ID, date, and time of collection, which was then placed into another plastic zipper bag and into a cooler with ice.

Samples were hand-delivered to ELI in Rapid City, SD along with the chain of custody forms. At the lab, samples were dried, crushed, ground, and thoroughly homogenized prior to analysis. All samples were analyzed for natural uranium, thorium-230, radium-226, and lead-210 by wet radiochemical methods.

1.1.4.1.2 Surface Water Impoundment Sampling

Sediment sampling locations for surface water impoundments were the same as the subset of impoundments selected for water quality analysis. Impoundments were identified on aerial photographs and topographic maps and then field verified (Figure 1.1-12). A subset of 11 of the total 48 impoundments within a 2 km radius of the proposed permit boundary were chosen based on presence of water at commencement of water-quality sampling activities and their spatial distribution. The sampled impoundments include two open pit uranium mines and nine stock dams, one of which is fed by a free-flowing artesian Sundance well.

At each of the 11 sampled impoundments, a single sample was collected with a trowel to a depth of 5 cm. Prior to sampling at each site, the trowel was cleaned by rinsing with a liquid Alconox solution followed by a deionized water rinse. Samples were collected near the waters edge in a location appearing relatively undisturbed. In dry impoundments samples were collected near the upstream side of the impoundment in an area that would be submerged if water was present. The samples were placed in a plastic zipper bag labeled with site ID, date, and time of collection, then placed into another plastic zipper bag and into a cooler with ice.

Samples were hand-delivered to ELI in Rapid City, SD along with the chain of custody forms. At the lab, samples were dried, crushed, ground, and thoroughly homogenized prior to analysis. All samples were analyzed for natural uranium, thorium-230, radium-226, and lead-210 by wet radiochemical methods.

Figure 1.1-12: Surface Water Impoundments

1.1.4.2 Sediment Sampling Results

1.1.4.2.1 Stream Sediment Sample Results

Results of the stream sediment data for each stream channel sampling location and impoundment location are provided in Table 1.1-8. Beaver Creek sediment sample results from the historical TVA survey (TVA DES, 1980) are provided in Table 1.1-9.

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Table 1.1-8: Radionuclide Concentrations in Stream Sediment Samples									
		U-nat, Total	Ra-226, Total		Pb-210, Total			Th-230, Total	
		Result	Result	Precision	Result	Precision		Result	Precision
SiteID	Date	mg/kg-dry	pCi/g-dry	+/- pCi/g-dry	pCi/g-dry	+/- pCi/g-dry	Qualifier	pCi/g-dry	+/- pCi/g-dry
BEN01	6/23/2008	1.8	0.6	0.1	2.3	2.1	U	0.6	0.2
	8/21/2008	2.4	0.6	0.1	2.0	0.7		0.5	0.02
BVC01	6/17/2008	2.0	1.3	0.2	0.5	2	U	0.8	0.2
	8/21/2008	2.0	0.6	0.1	2.6	0.7		1.2	0.03
BVC04	6/17/2008	2.0	1.5	0.2	1.9	2.1	U	0.7	0.2
	8/21/2008	2.0	1.0	0.1	1.8	0.7		1.0	0.03
CHR01	6/17/2008	1.7	1.0	0.2	0.2	2	U	0.6	0.2
	8/21/2008	2.7	0.9	0.1	1.7	0.6		1.4	0.03
CHR05	6/17/2008	6.2	2.1	0.2	1.7	2	U	1.9	0.4
	8/21/2008	1.2	0.6	0.1	1.3	0.7		0.5	0.02
PSC01	6/17/2008	3.9	2.9	0.3	4.7	2.1		2.0	0.5
	8/21/2008	6.5	1.8	0.2	4.0	0.7		4.1	0.06
PSC02	6/17/2008	1.1	0.6	0.1	1.2	2	U	0.4	0.1
	8/21/2008	1.0	0.4	0.1	0.4	0.6	U	0.4	0.02
UNT01	6/23/2008	2.0	0.8	0.1	2.2	2.1	U	0.5	0.2
	8/21/2008	2.5	0.7	0.1	1.7	0.7		1.0	0.03
Sub01	6/18/2008	2.2	1.2	0.2	0.5	2	U	0.7	0.2
	8/21/2008	3.3	1.1	0.1	1.0	0.7	U	1.0	0.03
Sub02	6/18/2008	18	3.9	0.3	2.8	2.1	U	2.9	0.7
	8/21/2008	19	1.3	0.2	3.1	0.7		6.8	0.07
Sub03	6/18/2008	7.2	4.1	0.3	3.9	2.1		2.1	0.6
	8/21/2008	4.2	1.1	0.2	3.2	0.7		1.9	0.04
Sub04	6/17/2008	6.5	2.5	0.2	1.2	2	U	0.9	0.2
	8/21/2008	5.1	0.7	0.1	2.1	0.7		1.8	0.04

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Table 1.1-8: Radionuclide Concentrations in Stream Sediment Samples (concl.)									
		U-nat, Total	Ra-226, Total		Pb-210, Total			Th-230, Total	
		Result	Result	Precision	Result	Precision		Result	Precision
SiteID	Date	mg/kg-dry	pCi/g-dry	+/- pCi/g-dry	pCi/g-dry	+/- pCi/g-dry	Qualifier	pCi/g-dry	+/- pCi/g-dry
Sub05	6/18/2008	8.5	4.2	0.3	4.2	2.1		2.4	0.5
	8/21/2008	6.0	3.0	0.2	2.8	0.7		2.3	0.04
Sub06	6/23/2008	37	8.6	0.4	9.6	2.2		7.8	1.6
	8/21/2008	32	5.2	0.3	4.0	0.7		5.9	0.07
Sub07	6/23/2008	1.7	0.7	0.1	0.6	2	U	0.5	0.2
	8/21/2008	2.2	0.4	0.1	1.9	0.7		0.9	0.03
Sub08	6/23/2008	1.2	0.6	0.1	0.6	2.1	U	0.4	0.1
	8/21/2008	1.9	0.4	0.1	1.7	0.7		0.8	0.02
Sub09	6/23/2008	2.4	1.0	0.2	1.5	2	U	0.7	0.2
	8/21/2008	2.3	0.6	0.1	1.7	0.7		0.9	0.03
Sub10	6/23/2008	1.5	0.8	0.1	1.5	2.1	U	0.7	0.3
	8/21/2008	2.1	0.6	0.1	0.9	0.7	U	0.7	0.03
Sub11	6/23/2008	2.7	0.8	0.1	2.1	2.1	U	0.5	0.2
	8/21/2008	1.8	0.6	0.1	1.5	0.7		0.8	0.03

Table 1.1-9: Historical Radionuclide Concentrations in Beaver Creek Sediment Samples

Sampling Location	Date Collected	Natural U µg/g	Ra-226 pCi/g	Pb-210 pCi/g	Th-230 pCi/g
Beaver Creek at Old Hwy 85 Bridge	7/31/1975	-	1.06 ± 0.04	-	-
	5/5/1976	2.57	1.29 ± 0.03	-	0.3 ± 0.2
	8/25/1976	1.48	1.06 ± 0.03	-	1.5 ± 0.2
	11/12/1976	1.12	0.98 ± 0.03	-	2.1 ± 0.2
	4/27/1977	1.42	1.15 ± 0.03	-	0.3 ± 0.1
	7/21/1977	3.4	0.91 ± 0.03	-	-0.05 ± 0.07
	11/15/1977	0.02	0.44 ± 0.02	3.3 ± 0.4	0.8 ± 0.2
Beaver Creek at Mouth	5/5/1976	2.65	1.25 ± 0.03	-	0.06 ± 0.2
	8/25/1976	2.23	1.71 ± 0.04	-	0.4 ± 0.1
	11/12/1976	0.86	0.84 ± 0.03	-	2.6 ± 0.3
	4/27/1977	0.87	1.31 ± 0.03	-	0.2 ± 0.1
	7/21/1977	4.1	2.45 ± 0.05	-	0.5 ± 0.2
	11/15/1977	0.72	0.83 ± 0.02	5.5 ± 0.5	0.2 ± 0.1
Beaver Creek Upstream	5/5/1976	4.37	1.03 ± 0.03	-	0.4 ± 0.3
	8/25/1976	3.01	1.23 ± 0.03	-	0.9 ± 0.2
	11/12/1976	1.5	1.01 ± 0.03	-	2.9 ± 0.3
	4/27/1977	0.89	1.34 ± 0 03	-	0.02 ± 0.07
	7/21/1977	3.7	1.41 ± 0.04	-	0.02 ± 0.08

Source: TVA DES, 1980

1.1.4.3 Conclusions

The radionuclide concentrations in sediments at the project site are generally consistent with observed US soil concentrations (Myrick 1983). Exceptions are the Darrow Mine Pit (Sub 06) and the Triangle Mine Pit (Sub 02), both of which appear to contain radionuclide concentrations in sediments considerably higher than observed in soil by (Myrick 1983). The Darrow and Triangle Mine Pits are historical open pit uranium mines and elevated radionuclide concentrations in sediments would be expected.

Radionuclide concentrations in sediment at downstream locations of Pass Creek (PSC02) and the Cheyenne River (CHR05) are elevated compared to upstream locations for the same surface water bodies indicating potential impacts from mineralized areas of the on and adjacent to the site. Radionuclide concentrations in sediment at the downstream location on Beaver Creek (BVCO1) are similar to the upstream location (BVC04).

1.1.4.4 References

Myrick T.E. et al, "*Determination of Concentrations of Selected Radionuclides in the Surface Soil in the U.S*", Health Physics Vol 45, No 3 1983

U.S. Nuclear Regulatory Commission (NRC), 1980, Regulatory Guide 4.14, "*Radiological Effluent and Environmental Monitoring at Uranium Mills, Revision 1*", Nuclear Regulatory Commission Office of Standards Development, Washington, D.C.

1.1.5 Ambient Gamma and Radon Monitoring

1.1.5.1 Methods

1.1.5.1.1 Ambient Gamma Dose Rate Monitoring

Ambient exposure rates were determined for three periods, using TLDs supplied and analyzed by Landauer, Inc. The monitoring periods were: August 18, 2007 to February 4, 2008, February 4 to May 17, 2008, and May 17 to July 17, 2008.

The TLDs were deployed at each of the eight AMS locations. Duplicates were deployed at AMS-01 and the background location (AMS-BKG).

Five of the nine TLDs deployed in the August 2007 to February 2008 period were lost, presumably by way of cattle consumption and/or disturbance.

1.1.5.1.2 Ambient Radon-222 Monitoring

Radtrak passive track etch detectors were placed at each of the eight AMS locations and an additional eight biased locations to measure radon-222 concentrations in air. For QC purposes, one duplicate detector was placed at each of two locations during each sampling event. The locations of the passive radon detectors are shown on Figure 1.1-8.

The detector measures average radon-222 concentrations in air over the measurement period. The results are reported in picocuries per liter (pCi/L).

With an overlap in time across the group of detectors, but not on an individual location basis, the four quarterly measurement periods were: August 14 to September 27, 2007; September 27, 2007 to February 1 through 12, 2008; February 1 through 12, 2008 to May 17, 2008; and May 17 to July 17, 2008.

1.1.5.2 Results

1.1.5.2.1 Ambient Gamma Dose Rate Monitoring

The ambient gamma dose rate monitoring results are listed in Table 1.1-10. The results for the TLDs reported in millirem (mrem) ambient dose equivalents are as follows:

- AMS-01: 94.9 for 303 monitored days, projected to 114 mrem/yr
- AMS-02: 54.0 for 61 monitored days, projected to 323 mrem/yr
- AMS-03: 38.6 for 103 monitored days, projected to 137 mrem/yr
- AMS-04: 152.8 for 303 monitored days, projected to 184 mrem/yr
- AMS-05: 123.7 for 303 monitored days, projected to 149 mrem/yr
- AMS-06: 88.0, for 164 monitored days projected to 196 mrem/yr
- AMS-07: 145.3 for 303 monitored days, projected to 175 mrem/yr
- AMS-BKG: 167.8 for 303 monitored days, projected to 202 mrem/yr

Excluding the result at AMS-02, the range of exposure rates, 114 to 202 mrem/yr, is similar to average worldwide exposures to natural radiation sources comprised of comic 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. The typical ranges of average worldwide exposures reported in this reference document are to 60 to160 mrem/yr.

Table 1.1-10: Ambient Gamma Dose Rates

Location	Starting Date	End Date	Dose (mrem)	Projected Doses (mrem)
AMS-01	9/18/07	2/4/08	-	114
	2/4/08	5/17/08	37.2[a]	
	5/17/08	7/17/08	57.7[a]	
AMS-02	9/18/07	2/4/08	-	323
	2/4/08	5/17/08	-	
	5/17/08	7/17/08	54.0	
AMS-03	9/18/07	2/4/08	-	137
	2/4/08	5/17/08	38.6	
	5/17/08	7/17/08		
AMS-04	9/18/07	2/4/08	62.4	184
	2/4/08	5/17/08	36.1	
	5/17/08	7/17/08	54.3	
AMS-05	9/18/07	2/4/08	50.6	149
	2/4/08	5/17/08	36.7	
	5/17/08	7/17/08	36.4	
AMS-06	9/18/07	2/4/08	-	196
	2/4/08	5/17/08	36.9	
	5/17/08	7/17/08	51.1	
AMS-07	9/18/07	2/4/08	73.7	175
	2/4/08	5/17/08	35.5	
	5/17/08	7/17/08	36.1	
AMS-BKG	9/18/07	2/4/08	68.8[a]	202
	2/4/08	5/17/08	40.5[a]	
	5/17/08	7/17/08	58.5[a]	

Notes:
a. Result is average of measurement plus duplicate.

1.1.5.2.2 Ambient Radon-222 Monitoring

The ambient radon monitoring results are listed in Table 1.1-11. Period 1 ambient radon concentrations ranged from 1.0 to 9.8, averaging 2.4 pCi/L. Period 2 concentrations ranged from 0.4 to 1.8, averaging 1.2 pCi/L. Period 3 concentrations ranged from 0.4 to 3.3, averaging 1.8 pCi/L. Period 4 concentrations ranged from 0.5 to 0.8, averaging 0.5 pCi/L.

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Table 1.1-11: Radon Concentrations in Air

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
AMS-1	8/14/07	9/27/07	1.00E-09	-	6.82E-10	7.23E-10	2.09E-10	4.92E-10	1.00E-09	1000
	9/27/07	2/1/08	7.00E-10	-	2.00E-10					700
	2/1/08	5/17/08	7.00E-10	7.1E-11	2.83E-10					700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-1[a]	8/14/07	9/27/07	1.00E-09	-	6.82E-10	5.73E-10	2.88E-10	4.00E-10	1.00E-09	1000
	9/27/07	2/1/08	4.00E-10	-	2.00E-10					400
	2/1/08	5/17/08	4.00E-10	5.2E-11	2.83E-10					400
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-2	8/15/07	9/27/07	2.20E-09	-	6.98E-10	1.70E-09	7.62E-10	4.92E-10	2.20E-09	2200
	9/27/07	2/1/08	1.20E-09	-	2.00E-10					1200
	2/1/08	5/17/08	7.00E-10	7.0E-11	2.83E-10					700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-3	8/14/07	9/27/07	1.20E-09	-	6.82E-10	1.20E-09	9.30E-10	4.92E-10	2.70E-09	1200
	9/27/07	2/4/08	1.20E-09	-	2.00E-10					1200
	2/4/08	5/17/08	2.70E-09	7.9E-11	2.91E-10					2700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-4	8/14/07	9/24/07	1.20E-09	-	7.32E-10	1.20E-09	9.98E-10	5.75E-10	2.90E-09	1200
	9/27/07	2/4/08	1.20E-09	-	2.00E-10					1200
	2/4/08	5/17/08	2.90E-09	7.8E-11	2.91E-10					2900
	5/17/08	7/17/08	5.75E-10	-	4.92E-10					575
AMS-5	8/15/07	9/27/07	2.20E-09	-	6.98E-10	1.60E-09	7.16E-10	4.92E-10	2.20E-09	2200
	9/27/07	2/1/08	1.00E-09	-	2.00E-10					1000
	2/1/08	5/17/08	1.20E-09	7.9E-11	2.83E-10					1200
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492

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Table 1.1-11: Radon Concentrations in Air (cont'd)

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
AMS-6	8/17/07	9/27/07	2.60E-09	-	7.32E-10	1.80E-09	8.40E-10	6.89E-10	2.60E-09	2600
	9/27/07	2/1/08	1.00E-09	-	2.00E-10					1000
	2/11/08	5/17/08	1.30E-09	7.6E-11	2.83E-10					1300
	5/17/08	7/17/08	6.89E-10	-	4.92E-10					689
AMS-7	8/14/07	9/27/07	1.10E-09	-	6.82E-10	1.30E-09	4.15E-10	4.92E-10	1.50E-09	1100
	9/27/07	2/1/08	1.50E-09	-	2.00E-10					1500
	2/1/08	5/17/08	1.00E-09	7.2E-11	2.83E-10					1000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-BKG	8/14/07	9/24/07	2.00E-09	-	7.32E-10	1.80E-09	6.58E-10	4.95E-10	2.00E-09	2000
	9/27/07	2/1/08	1.60E-09	-	2.00E-10					1600
	2/1/08	5/17/08	1.70E-09	8.1E-11	2.83E-10					1700
	5/17/08	7/17/08	4.95E-10	-	4.92E-10					495
AMS-BKG[a]	8/14/07	9/27/07	2.70E-09	-	6.82E-10	2.10E-09	9.03E-10	4.92E-10	2.70E-09	2700
	9/27/07	2/1/08	1.50E-09	-	2.00E-10					1500
	2/1/08	5/17/08	1.50E-09	8.1E-11	2.83E-10					1500
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 01	8/14/07	9/23/07	2.00E-09	-	7.50E-10	1.65E-09	8.35E-10	5.00E-10	2.40E-09	2000
	9/23/07	2/11/08	1.30E-09	-	2.00E-10					1300
	2/11/08	5/17/08	2.40E-09	8.5E-11	3.13E-10					2400
	5/17/08	7/17/08	5.00E-10	-	4.76E-10					500
Rn 02	8/14/07	9/23/07	9.80E-09	-	7.50E-10	3.86E-09	5.15E-09	5.75E-10	9.80E-09	9800
	9/23/07	2/11/08	1.20E-09	-	2.00E-10					1200
	no data	-	-	-	-					-
	5/17/08	7/17/08	5.75E-10	1.5E-10	4.92E-10					575

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Table 1.1-11: Radon Concentrations in Air (concl.)

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
Rn 03	8/14/07	9/23/07	1.20E-09	-	7.50E-10	1.05E-09	9.63E-10	4.92E-10	2.70E-09	1200
	9/23/07	2/11/08	9.00E-10	-	2.00E-10					900
	2/11/08	5/17/08	2.70E-09	8.6E-11	3.13E-10					2700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 04	8/14/07	9/23/07	2.00E-09	-	7.50E-10	1.70E-09	6.34E-10	5.00E-10	2.00E-09	2000
	9/23/07	2/1/08	1.40E-09	-	2.00E-10					1400
	2/11/08	5/17/08	1.00E-09	7.7E-11	2.83E-10					1000
	5/17/08	7/17/08	5.00E-10	-	4.92E-10					500
Rn 05	8/14/07	9/23/07	1.50E-09	-	7.50E-10	1.30E-09	7.82E-10	8.18E-10	2.60E-09	1500
	9/23/07	2/12/08	1.10E-09	-	2.00E-10					1100
	2/11/08	5/17/08	2.60E-09	8.6E-11	3.16E-10					2600
	5/17/08	7/17/08	8.18E-10	-	4.92E-10					818
Rn 06	8/19/07	9/23/07	3.30E-09	-	8.57E-10	2.30E-09	1.35E-09	4.92E-10	3.30E-09	3300
	9/23/07	2/11/08	1.30E-09	-	2.00E-10					1300
	2/11/08	5/17/08	3.00E-09	8.5E-11	3.13E-10					3000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 07	8/15/07	9/23/07	3.00E-09	-	7.69E-10	2.40E-09	1.18E-09	7.21E-10	3.30E-09	3000
	9/23/07	2/12/08	1.80E-09	-	2.00E-10					1800
	2/12/08	5/17/08	3.30E-09	8.3E-11	3.16E-10					3300
	5/17/08	7/17/08	7.21E-10	-	4.92E-10					721
Rn 08	8/14/07	9/23/07	1.50E-09	-	7.50E-10	1.40E-09	4.39E-10	4.92E-10	1.50E-09	1500
	9/23/07	2/1/08	1.30E-09	-	2.00E-10					1300
	9/23/07	2/1/08	1.00E-09	7.2E-11	2.83E-10					1000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492

Notes:
[a]Duplicate track etch detector
[a]Seal potentially compromised

With the exception of one location (AMS-3), Period 1 concentrations exceeded Period 2 concentrations. On average, the radon concentrations decreased by an average of 35 percent. The range in the data sets decreased from 2.1 (Period 1) to 0.3 pCi/L (Period 2), as the largest value in Period 1, 9.8 pCi/L, decreased to 1.2 pCi/L.

Figure 1.1-13 presents the ambient radon concentrations in relation to the radium-226 concentrations predicted from the gamma-ray count rate data. One expects higher radon concentrations in the mined areas. However, there is only one case where this is true: the Q1 observation at Rn-02, located adjacent to the edge of an open pit mine, is 9.8 pCi/L. There appear to be no spatial trends in the current data set, other than the levels are within the same order of magnitude across the site, i.e., all less than 10 pCi/L and averaging 2.4, 1.2, 1.8, and 0.5 pCi/L in Periods 1 through 4, respectively.

Duplicates were collected at AMS-01 and AMS-BKG in all periods. The QC summary for the radon monitoring is as follows:

- AMS-01: In Period 1, each concentration was 1.0 pCi/L and the RPD was 0. In Periods 2 and 3, the concentrations of the sample and its duplicate were 0.7 and 0.4 pCi/L. The RPD was 55.5. In Period 4, each concentration was 0.49 pCi/L and the RPD was 0.
- AMS-BKG: In Period 1, the concentrations of the sample and its duplicate were 2.0 and 2.7 pCi/L. The RPD was 29.8. In Period 2, the concentrations of the sample and its duplicate were 1.6 and 1.5 pCi/L, with an RPD of 6.5. In Period 3, the concentrations of the sample and its duplicate were 1.7 and 1.5 pCi/L, with an RPD of 12.5. In Period 4, the concentrations of the sample and its duplicate were 0.5 and 0.49 pCi/L, with an RPD of 0.7.

There are two cases where the RPDs do not meet the project acceptance criterion of 40: AMS-01 in Period 2 and 3.

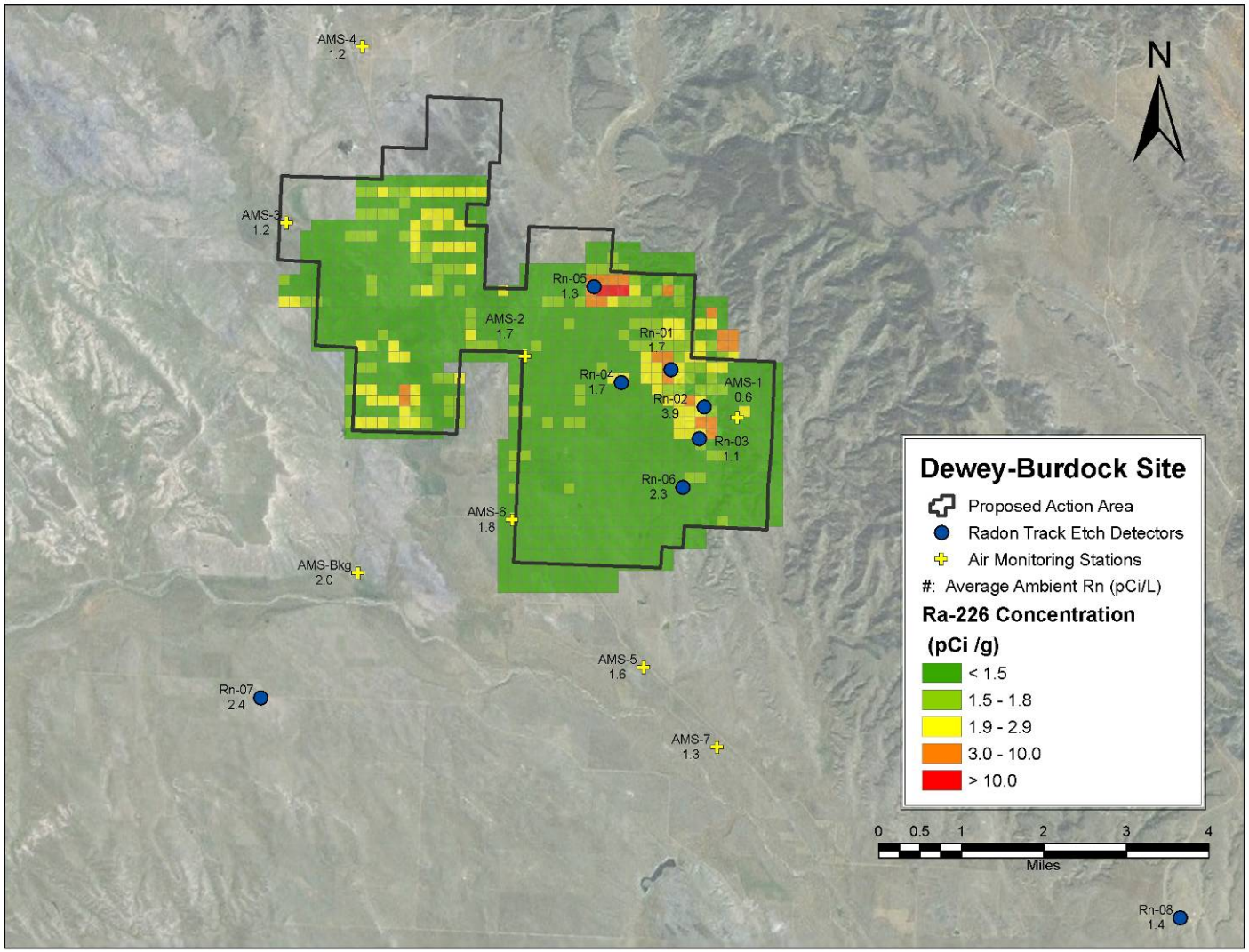

Figure 1.1-13: Radon Concentrations in Air in Relation to Predicted Radium-226 Concentrations

1.1.5.3 Conclusions

In terms of effluent limits, the measured values exceed the 10 CFR 20 limit of 0.1 pCi/L for radon-222 with daughters present. However, on average the measured values are within the range 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).

1.1.6 Air Particulate Monitoring

Air particulate monitoring was conducted at the project for one year. Particulates were collected using high volume air samplers.

1.1.6.1 Methods

Eight Hi-Q Model HVP-4200AFC high volume air samplers were established within and surrounding the proposed permit area. The samplers operated nearly continuously from August 2007 to August 2008. The locations of the air samplers are shown on Figures 1.1-8 and 1.1-13.

Each high volume air sampler was equipped with an 8-in. by 10-in. 0.8 micron glass fiber filter paper. The air filters were collected approximately bi-weekly, prior to saturation, from each of the eight air samplers. Flow rate and total flow data were recorded at the same time. The samples were collected as follows:

- Period 1: August 28 to October 2, 2007
- Period 2: October 2, 2007 to January 1, 2008
- Period 3: January 4 to April 1, 2008
- Period 4: April 1 to July 9, 2008
- Period 5: July 9 to August 13, 2008

The samples were composited and digested by the external independent analytical laboratory. The samples were analyzed for radium-226, thorium-230, natural uranium, and lead-210, using the same methods as listed for the soil samples.

The laboratory data were reported in units of picocuries per filter composite (pCi/f). The data were converted to units of micocuries per milliliter (µCi/ml), as follows:

$$Concentration, \mu Ci/ml = \frac{Filter\ Concentration}{Total\ Flow}(1*10^{-12})$$

The units of total flow and filter concentration in the equation are cubic meters and pCi/f, respectively. The resulting concentrations for each radionuclide and high volume sampler were compared to effluent concentration limits listed in Table 2 of 10 CFR 20 Appendix B and reported in Table 1.1-12 as percentages of the respective effluent limits. The most conservative effluent limits were applied to thorium-230 ($3*10^{-12}$ µCi/ml) and lead-210 ($6*10^{-13}$ µCi/ml). The Class D and W limits were applied to natural uranium ($3*10^{-12}$ µCi/ml) and radium-226 ($9*10^{-13}$ µCi/ml), respectively.

1.1.6.2 Air Particulate Sampling Results

In general and relative to one another (e.g., natural uranium to radium-226), the average concentrations of radionuclides were consistent at each location from period to period. The lowest average concentration was radium-226, followed by thorium-230, natural uranium, and lead-210. Average radium-226 concentrations were five orders of magnitude lower than lead-210 concentrations. The data are listed in Table 1.1-12 and summarized as averages and ranges in Table 1.1-13.

Site-wide, the data can be summarized as follows:

- Natural uranium concentrations ranged from $-3.0*10^{-17}$ to $9.1*10^{-15}$ µCi/ml and averaged $7.5*10^{-16}$ µCi/ml.
- Thorium-230 concentrations ranged from $-9.5*10^{-19}$ to $5.6*10^{-17}$ µCi/ml and averaged $1.2*10^{-17}$ µCi/ml.
- Radium-226 concentrations ranged from $-4.9*10^{-17}$ to $4.7*10^{-17}$ µCi/ml and averaged $8.9*10^{-19}$ µCi/ml.
- Lead-210 concentrations ranged from $-1.1*10^{-16}$ to $4.1*10^{-14}$ µCi/ml and averaged $1.4*10^{-14}$ µCi/ml.

There are no clear patterns in the data, in terms of radionuclide concentrations, when evaluating them spatially or temporally. Natural uranium concentrations at each location were on the order of 10^{-16} µCi/ml over the course of monitoring. Thorium-230 concentrations fluctuated between the orders of 10^{-17} and 10^{-18} µCi/ml. Radium-226 concentrations fluctuated between the orders of

10^{-17} and 10^{-19} µCi/ml. Finally, lead-210 concentrations at each location were all on the order of 10^{-14} µCi/ml over the course of monitoring.

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Table 1.1-12: Radionuclide Concentrations in Air

Location	Monitoring Period[a]	Concentration (µCi/ml)							% of Effluent Concentration				Lower Limit of Detection (µCi/ml)			
		U-nat	Th-230	Th-230 2σ Error	Ra-226	Ra-226 2σ Error	Pb-210	Pb-210 2σ Error	U-nat	Th-230	Ra-226	Pb-210	U-nat	Th-230	Ra-226	Pb-210
AMS-01	1	-1.3E-17	3.4E-18	1.0E-17	1.8E-17	1.7E-17	2.1E-14	2.4E-16	0.00%	0.00%	0.00%	3.54%	1.7E-18	1.7E-18	1.2E-17	2.1E-16
	2	2.4E-17	1.3E-17	9.8E-18	1.4E-17	9.7E-18	2.1E-14	4.9E-16	0.00%	0.00%	0.00%	3.51%	1.5E-18	1.5E-18	8.3E-18	4.2E-16
	3	3.7E-15	1.3E-17	4.2E-17	1.2E-17	5.7E-17	1.9E-14	9.8E-16	0.12%	0.00%	0.00%	3.13%	3.9E-15	2.3E-18	5.7E-17	3.7E-16
	4	0.0E+00	1.6E-18	1.1E-17	7.2E-18	9.1E-18	4.1E-14	6.9E-16	0.00%	0.00%	0.00%	6.78%	1.6E-16	1.6E-18	1.6E-18	7.9E-18
	5	-1.7E-17	6.5E-18	2.5E-17	-3.1E-17	2.7E-17	1.0E-14	6.5E-16	0.00%	0.00%	0.00%	1.74%	4.3E-18	4.3E-18	5.6E-17	6.7E-16
AMS-02	1	-2.0E-17	4.7E-18	1.1E-17	-8.6E-18	1.3E-17	8.9E-15	2.5E-16	0.00%	0.00%	0.00%	1.49%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	4.2E-18	0.0E+00	7.4E-18	-4.2E-18	7.4E-18	8.2E-15	4.2E-16	0.00%	0.00%	0.00%	1.37%	1.4E-18	1.4E-18	7.6E-18	3.9E-16
	3	2.9E-15	1.8E-18	2.5E-17	-2.6E-17	3.3E-17	1.2E-14	7.5E-16	0.10%	0.00%	0.00%	1.96%	3.1E-15	1.8E-18	4.1E-17	3.0E-16
	4	0.0E+00	1.6E-17	1.1E-17	-2.3E-18	7.0E-18	2.0E-14	4.7E-16	0.00%	0.00%	0.00%	3.26%	1.5E-16	1.5E-18	1.5E-18	7.6E-18
		-1.3E-17	0.0E+00	8.0E-18	-4.9E-17	2.3E-17	1.5E-14	6.5E-16	0.00%	0.00%	0.01%	2.44%	4.0E-18	4.0E-18	5.3E-17	6.2E-16
AMS-03	1	-3.0E-17	9.3E-18	1.2E-17	-1.4E-17	1.3E-17	9.2E-15	2.5E-16	0.00%	0.00%	0.00%	1.53%	1.5E-18	1.5E-18	1.2E-17	1.9E-16
	2	1.8E-17	8.9E-18	9.0E-18	9.6E-18	9.5E-18	8.0E-15	4.4E-16	0.00%	0.00%	0.00%	1.34%	1.5E-18	1.5E-18	8.9E-18	4.1E-16
	3	2.8E-15	6.9E-18	2.2E-17	-4.8E-18	3.7E-17	1.2E-14	7.5E-16	0.09%	0.00%	0.00%	1.98%	2.9E-15	1.7E-18	3.6E-17	2.8E-16
	4	0.0E+00	9.3E-18	1.0E-17	5.4E-18	8.8E-18	1.3E-14	3.9E-16	0.00%	0.00%	0.00%	2.16%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-1.6E-17	1.9E-17	9.7E-18	-3.2E-18	3.1E-17	1.2E-14	6.5E-16	0.00%	0.00%	0.00%	1.99%	4.2E-18	4.2E-18	5.0E-17	6.6E-16
AMS-04	1	-2.6E-17	2.5E-18	1.1E-17	-2.8E-17	1.2E-17	8.5E-15	2.6E-16	0.00%	0.00%	0.00%	1.42%	1.7E-18	1.7E-18	9.9E-18	2.0E-16
	2	1.9E-17	6.6E-18	9.0E-18	1.2E-17	9.5E-18	1.0E-14	4.6E-16	0.00%	0.00%	0.00%	1.74%	1.5E-18	1.5E-18	8.1E-18	4.1E-16
	3	3.0E-15	-9.5E-19	3.0E-17	2.5E-17	4.7E-17	-1.1E-16	7.0E-16	0.10%	0.00%	0.00%	0.02%	3.2E-15	1.9E-18	4.4E-17	3.1E-16
	4	0.0E+00	9.4E-18	1.1E-17	2.3E-18	8.3E-18	2.2E-14	5.1E-16	0.00%	0.00%	0.00%	3.66%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-1.0E-18	2.7E-17	9.7E-18	-5.2E-18	3.3E-17	1.3E-14	6.7E-16	0.00%	0.00%	0.00%	2.23%	4.2E-18	4.2E-18	5.5E-17	6.6E-16

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Table 1.1-12: Radionuclide Concentrations in Air (concl.)

Location	Monitoring Period	Concentration (µCi/ml)							% of Effluent Concentration				Lower Limit of Detection (µCi/ml)			
		U-nat	Th-230	Th-230 2σ Error	Ra-226	Ra-226 2σ Error	Pb-210	Pb-210 2σ Error	U-nat	Th-230	Ra-226	Pb-210	U-nat	Th-230	Ra-226	Pb-210
AMS-05	1	1.0E-18	4.7E-18	1.1E-17	1.1E-17	1.5E-17	1.0E-14	2.3E-16	0.00%	0.00%	0.00%	1.66%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	2.7E-17	1.5E-17	1.0E-17	1.5E-17	9.9E-18	1.1E-14	4.8E-16	0.00%	0.00%	0.00%	1.91%	1.5E-18	1.5E-18	8.5E-18	4.3E-16
	3	2.8E-15	3.6E-17	2.3E-17	-1.3E-17	4.0E-17	1.0E-14	7.2E-16	0.09%	0.00%	0.00%	1.68%	2.9E-15	1.7E-18	4.3E-17	2.8E-16
	4	0.0E+00	2.0E-17	1.4E-17	4.7E-17	1.3E-17	2.5E-14	5.3E-16	0.00%	0.00%	0.01%	4.09%	1.5E-16	1.5E-18	1.5E-18	7.7E-18
	5	2.4E-17	5.6E-17	9.5E-18	2.2E-17	3.4E-17	1.1E-14	6.3E-16	0.00%	0.00%	0.00%	1.85%	4.1E-18	4.1E-18	4.9E-17	6.4E-16
AMS-06	1	-1.4E-17	9.4E-18	1.2E-17	0.0E+00	1.4E-17	6.0E-15	2.2E-16	0.00%	0.00%	0.00%	1.00%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	1.7E-17	5.5E-18	1.0E-17	-5.5E-18	8.4E-18	1.1E-14	4.9E-16	0.00%	0.00%	0.00%	1.80%	1.6E-18	1.6E-18	9.5E-18	4.4E-16
	3	2.9E-15	1.0E-17	2.4E-17	-2.0E-17	3.9E-17	1.7E-14	8.2E-16	0.10%	0.00%	0.00%	2.89%	3.1E-15	1.8E-18	4.2E-17	2.9E-16
	4	0.0E+00	1.4E-17	1.2E-17	2.3E-17	1.0E-17	2.1E-14	4.8E-16	0.00%	0.00%	0.00%	3.56%	1.5E-16	1.5E-18	1.5E-18	7.3E-18
	5	-2.6E-18	2.0E-17	9.1E-18	6.9E-18	3.3E-17	1.9E-14	6.9E-16	0.00%	0.00%	0.00%	3.25%	4.0E-18	4.0E-18	4.9E-17	6.2E-16
AMS-07	1	-1.1E-17	6.4E-18	9.1E-18	-1.3E-17	1.1E-17	7.2E-15	2.2E-16	0.00%	0.00%	0.00%	1.20%	1.4E-18	1.4E-18	9.2E-18	1.7E-16
	2	2.0E-17	7.9E-18	8.1E-18	-6.6E-19	7.5E-18	1.3E-14	4.4E-16	0.00%	0.00%	0.00%	2.13%	1.3E-18	1.3E-18	7.3E-18	3.7E-16
	3	9.1E-15	2.0E-17	2.6E-17	3.9E-18	4.2E-17	1.7E-14	7.8E-16	0.30%	0.00%	0.00%	2.85%	2.9E-15	1.7E-18	4.3E-17	2.8E-16
	4	0.0E+00	1.3E-17	1.2E-17	2.9E-17	1.0E-17	2.8E-14	5.4E-16	0.00%	0.00%	0.00%	4.66%	1.4E-16	1.4E-18	1.4E-18	7.0E-18
	5	-9.2E-19	1.7E-17	8.5E-18	1.4E-17	3.0E-17	1.3E-14	5.9E-16	0.00%	0.00%	0.00%	2.10%	3.7E-18	3.7E-18	4.6E-17	5.8E-16
AMS-BKG	1	1.6E-18	2.0E-17	1.3E-17	-5.6E-18	1.4E-17	8.3E-15	2.5E-16	0.00%	0.00%	0.00%	1.38%	1.6E-18	1.6E-18	1.2E-17	2.2E-16
	2	2.1E-17	2.0E-18	1.2E-17	3.0E-18	1.1E-17	1.8E-14	6.6E-16	0.00%	0.00%	0.00%	3.05%	2.0E-18	2.0E-18	1.2E-17	5.7E-16
	3	3.0E-15	2.8E-17	2.9E-17	-5.1E-18	4.0E-17	1.3E-14	7.7E-16	0.10%	0.00%	0.00%	2.18%	3.2E-15	1.9E-18	4.1E-17	2.5E-16
	4	0.0E+00	-7.8E-19	9.4E-18	1.2E-17	9.5E-18	2.0E-14	4.8E-16	0.00%	0.00%	0.00%	3.29%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-8.1E-18	2.4E-17	9.3E-18	-1.7E-17	2.4E-17	1.2E-14	6.3E-16	0.00%	0.00%	0.00%	2.00%	4.0E-18	4.0E-18	4.0E-17	5.3E-16

Notes:

a. The laboratory reported no blank assay data for Period 5. Blank assays in the sample concentration calculation were assumed to be 50 percent of the values for blanks reported for the previous period. The assumption is based on the relative, approximate run-time of the air samplers in both periods.

NR = Not reported by the laboratory.

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Table 1.1-13: Summary of Radionuclide Concentrations in Air

Location	U-nat Concentration (µCi/ml)				Th-230 Concentration (µCi/ml)				Ra-226 Concentration (µCi/ml)				Pb-210 Concentration (µCi/ml)			
	Avg	σ	Min	Max	Avg	σ	Min	Max	Avg	σ	Min	Max	Avg	σ	Min	Max
AMS-01	7.3E-16	1.6E-15	-1.7E-17	3.7E-15	7.4E-18	5.2E-18	1.6E-18	1.3E-17	4.0E-18	2.0E-17	-3.1E-17	1.8E-17	2.2E-14	2.0E-17	9.1E-18	5.7E-17
AMS-02	5.8E-16	1.3E-15	-2.0E-17	2.9E-15	4.5E-18	6.7E-18	0.0E+00	1.6E-17	-1.8E-17	2.0E-17	-4.9E-17	-2.3E-18	1.3E-14	1.1E-17	7.0E-18	3.3E-17
AMS-03	5.5E-16	1.2E-15	-3.0E-17	2.8E-15	1.1E-17	4.7E-18	6.9E-18	1.9E-17	-1.4E-18	9.2E-18	-1.4E-17	9.6E-18	1.1E-14	1.3E-17	8.8E-18	3.7E-17
AMS-04	6.0E-16	1.3E-15	-2.6E-17	3.0E-15	9.0E-18	1.1E-17	-9.5E-19	2.7E-17	1.2E-18	2.0E-17	-2.8E-17	2.5E-17	1.1E-14	1.7E-17	8.3E-18	4.7E-17
AMS-05	5.6E-16	1.2E-15	0.0E+00	2.8E-15	2.6E-17	2.0E-17	4.7E-18	5.6E-17	1.6E-17	2.2E-17	-1.3E-17	4.7E-17	1.3E-14	1.4E-17	9.9E-18	4.0E-17
AMS-06	5.8E-16	1.3E-15	-1.4E-17	2.9E-15	1.2E-17	5.4E-18	5.5E-18	2.0E-17	8.6E-19	1.6E-17	-2.0E-17	2.3E-17	1.5E-14	1.4E-17	8.4E-18	3.9E-17
AMS-07	1.8E-15	4.1E-15	-1.1E-17	9.1E-15	1.3E-17	5.7E-18	6.4E-18	2.0E-17	6.6E-18	1.6E-17	-1.3E-17	2.9E-17	1.6E-14	1.5E-17	7.5E-18	4.2E-17
AMS-BKG	5.9E-16	1.3E-15	-8.1E-18	3.0E-15	1.5E-17	1.3E-17	-7.8E-19	2.8E-17	-2.5E-18	1.1E-17	-1.7E-17	1.2E-17	1.4E-14	1.2E-17	9.5E-18	4.0E-17

In terms of comparison to 10 CFR 20 Appendix B effluent limits, the data can be summarized as follows:

- Natural uranium concentrations were 0.0 to 0.3 percent of its effluent concentration.
- Thorium-230 concentrations were 0.0 percent of its effluent concentration.
- Radium-226 concentrations were -0.01 to 0.01 percent of its effluent concentration.
- Lead-210 concentrations were -0.02 to 6.78 percent of its effluent concentration.

The LLDs, in pCi/f, reported by the laboratory for each radionuclide were converted to µCi/ml by multiplying pCi/f by $1*10^{-12}$. In no cases were the LLDs higher that their respective 10 CFR 20 effluent concentration limits. The LLDs reported in Period 2 by the laboratory for uranium exceeded the recommendation in NRC Regulatory Guide 4.14.

The LLDs for each of the radionuclides are listed in Table 1.1-12.

1.1.6.3 Conclusions

With the exception of natural uranium, the values determined above are similar to U.S. background concentrations 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 regional concentrations reported in this reference document are: uranium-238 ($2.4*10^{-17}$ to $1.4*10^{-16}$ µCi/ml), thorium-230 ($1.6*10^{-17}$ µCi/ml), radium-226 ($1.6*10^{-17}$ µCi/ml), and lead-210 ($2.7*10^{-15}$ to $2.7*10^{-14}$ µCi/ml).

1.1.7 Radon Flux Measurements

Radon flux rates were measured at nine locations on three occasions in the Dewey and Burdock roll front areas. The locations are shown on Figure 1.1-8. The locations coincide with the nine soil samples collected from 0 to 100 cm below ground surface (not in land application areas).

The first round of flux canisters was deployed on September 26, retrieved on September 27, and analyzed on September 28, 2007. The second round of flux canisters was deployed on April 20, retrieved on April 21, and analyzed on April 22, 2008. The third round of flux canisters was deployed on July 14, retrieved on July 15, and analyzed on July 16, 2008. The canisters were analyzed using U.S. Environmental Protection Agency (EPA) Test Method 115, Monitoring for Radon-222 Emissions. Results are documented in the Table 1.1-14. Sampling for the three

periods yielded flux rates of 1.22, 0.74, and 1.5 picocuries per meter squared second (pCi/m^2-s), respectively. Flux rates ranged between 0.68 and 1.77 pCi/m^2-s in Fall 2007, 0.28 and 1.33 pCi/m^2-s in Spring 2008 and 0.48 and 2.38 pCi/m^2-s in Summer 2008.

Table 1.1-14: Baseline Radon Flux Measurements

Location	Date	Flux (pCi/m^{2}s)	Std. Dev. (pCi/m^{2}s)	LLD (pCi/m^{2}s)	Average Flux @ Location (pCi/m^{2}s)
RFA-B01	September 2007	1.68	0.06	0.18	1.57
	April 2008	0.64	0.05	0.15	
	July 2008	2.38	0.06	0.15	
RFA-B02	September 2007	0.89	0.05	0.15	0.86
	April 2008	0.76	0.05	0.16	
	July 2008	0.94	0.05	0.15	
RFA-B13	September 2007	1.77	0.06	0.17	1.53
	April 2008	0.56	0.05	0.16	
	July 2008	2.27	0.06	0.15	
RFA-B15	September 2007	1.22	0.05	0.15	1.35
	April 2008	1.12	0.06	0.16	
	July 2008	1.71	0.05	0.15	
RFA-B17	September 2007	1.25	0.06	0.16	1.05
	April 2008	0.61	0.05	0.16	
	July 2008	1.30	0.05	0.15	
RFA-B21	September 2007	0.97	0.05	0.14	0.71
	April 2008	0.28	0.05	0.16	
	July 2008	0.89	0.05	0.14	
RFA-B30	September 2007	1.73	0.06	0.17	1.49
	April 2008	0.70	0.05	0.16	
	July 2008	2.03	0.05	0.15	
RFA-B36	September 2007	0.68	0.05	0.16	0.60
	April 2008	0.64	0.05	0.16	
	July 2008	0.48	0.06	0.15	
RFA-B37	September 2007	0.80	0.05	0.14	1.13
	April 2008	1.33	0.06	0.16	
	July 2008	1.27	0.05	0.14	

1.1.7.1 Conclusions

The flux rates determined at the PAA 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 relatively low magnitude of baseline radon flux rates measured at the site.

1.1.8 Groundwater Sampling

At the project site, baseline groundwater sampling was conducted in general accordance with NRC Regulatory Guide 4.14 (NRC, 1980). Because of the significant number of groundwater wells, their geochemical similarities, and an abundance of historical water quality data, a representative subset of the wells was selected for sampling. The wells were selected based on type of use, aquifer, and location in relation to the ore bodies. For the baseline study for the NRC permit, 19 groundwater wells (14 existing and 5 newly drilled) were selected as making up a representative sampling group for the area (Figure 2.7-19 and 2.7-20, Table 2.7-27). The wells selected for sampling include eight domestic wells, six stock watering wells, with three wells being hydrologically upgradient of the proposed production areas. The subset includes wells within the Fall River Formation (4), Lakota Formation (7), Inyan Kara Group (Fall River or Lakota) (2), Sundance Formation (1), and alluvium (5). Initial baseline sampling of these wells was conducted quarterly from July 2007 through June 2008.

As required by the SD DENR (rule ARSD 74:29), an additional 12 wells were sampled monthly beginning in March 2008 and will continue to be sampled through February 2009 (Figure 2.7-20, Table 2.7-28). Of these 12 wells, six wells are in the Dewey area and six wells are near Burdock. At Dewey, there is a set of Fall River and Lakota wells sampled at three places, upgradient, within, and downgradient of proposed production activities. Near the Burdock area, the same well arrangement applies with two wells upgradient, within, and downgradient of proposed production areas. Data for radiological parameters available to date are presented in this section. As the monitoring program progresses, new data will be submitted to the NRC, DENR and EPA as they become available.

Comprehensive information on well locations and all water quality parameters is provided in sections of the project related specifically to groundwater (Section 2.7.2).

1.1.8.1 Methods

Static water levels were measured at most wells prior to sample collection with regard to a reference elevation, usually a mark on the well or on a permanent structure above or near to the well. When possible, pressure of free-flowing wells was measured with a 15 psi or 30 psi N.I.S.T. – certified pressure gauge; the well was shut in and the pressure was allowed to stabilize before a reading was recorded. Pressure values were recorded to within at least one tenth of a psi and typically to within a hundredth of a psi. Wells with subsurface water levels were measured using an electric water level tape with measurements reported to within at least one tenth of a foot and typically to within a hundredth of a foot.

Exceptions to this were domestic wells that could not be accessed at the well head or were behind a pressure tank (wells 7, 8, 13, 16, 18, 42), free-flowing wells that could not be sealed due to leaks caused by corrosion and age (wells 2, 635, 4002), free-flowing wells that could not be sealed due to poor valve fittings or cracked valves (well 696), free-flowing wells where existed the possibility of rupturing a line when pressurized due to age (well 7002), and wells that contained pumps and pump tubing making it difficult to retrieve a water level tape (well 619).

All pumped wells, with the exception of 631, had permanent pumps installed in order to obtain samples. An existing high-capacity pump in well 631, used to pump water up a hill several hundred feet to a stock tank, was not used for sampling purposes due to logistical hurdles except for the first sample collected there on September 27, 2007. For the next three samples, a small dedicated pump was used each time the well was sampled.

Continuous free-flowing wells were sampled before pressure measurements were made and were not purged before sampling. For these wells (2, 18, 42, 635, 4002, 7002), it was assumed that free-flowing well water adequately represented formation water. After collecting a sample, a spot check with a water-quality probe was made and temperature, specific conductivity, turbidity, and pH were recorded. Pressure was then measured at the wells where it was possible within limits of feasibility.

After measuring the pressure of capped free-flowing wells (where possible), the well valve was opened and the flow rate was allowed to stabilize, then flow measurements were made using a stopwatch and a marked container (usually a 5-gallon pail, but sometimes a 1-gallon container at slower-flowing wells). Casing purge time was calculated based on water column height, casing diameter, and flow rate. Three well volumes were required to have been purged before the well water was sampled. Additionally, a water-quality sonde with a flow-through cell was connected

to the well and water quality parameters were periodically recorded. If parameters had not stabilized after purging 3 volumes, wells were allowed to continue to purge until parameters had stabilized, or until the purged volume was >> 3 well volumes.

Pumped wells were purged in such a manor as to induce flow from the formation into the well so that a sample of fresh formation water was collected.

- After measuring water level (where possible), the pump was started and flow rate was measured using stopwatch and 5-gallon marked pail.
- A water-quality probe equipped with a flow-through cell was connected to outflow.
- Wells with a high enough yield were purged for a minimum of three well volumes, and also until one or more indicator parameters had stabilized. Parameters monitored for stabilization were specific conductance, temperature, and pH. Field measurements were recorded periodically during purging of 3 volumes, and at least 3 minutes apart after purging 3 volumes. Table 1.1-15 gives requirements for parameter stabilization. After 3 well volumes had been purged and parameters stabilized, a sample was collected.
- Wells that had yields too low to be continuously pumped and purged of three well volumes were pumped dry and allowed to recover. After the well had sufficiently recovered, it was pumped and sampled. Accurate records of well purging are maintained to document the number of casing volumes purged from the well before sampling, but in all cases a minimum of one casing volume was purged before sampling.
- After calculating casing volume, alluvial wells were purged of 3 well volumes into a 5-gallon marked pail using either disposable bailers or a peristaltic pump. When using bailers, water quality parameters were recorded after each well volume was purged using a water-quality probe. When using the peristaltic pump, a water-quality probe equipped with flow-through cell was connected to pump outflow and parameters were recorded periodically during the purge.

Table 1.1-15: Stability Criteria for Collecting Ground Water Samples at Pumped Wells

Field Measurement	Stability Criteria[1]
pH	+/- 0.1 standard units
Temperature	+/- 0.2 C
Specific conductivity	+/- 5% (SC <= 100 µS/cm); otherwise +/- 3%

[1]Allowable variation between 5 or more sequential field-measurement values

Additional steps taken during water quality sampling include the following:

- Sampling procedures involved labeling each sample bottle with site ID, date, and time of sampling, triple rinsing with sample water, then filling and capping.
- Radon sample bottles were filled and capped immediately and with no headspace.
- Field replicate samples, consisting of a second set of samples collected at the same time following the same protocols as the sample set, were collected periodically to determine data accuracy.
- Field blanks were collected by transporting deionized water supplied by the contract laboratory to the field during regular sampling, then transferred to collection bottles in the field in order to subject the blank water to the same transportation, handling, storage, and field conditions as regular samples.
- All samples were immediately placed in coolers on ice after collection.
- Water quality sondes used to collect field parameter measurements were calibrated periodically using N.I.S.T.-traceable standards.

A groundwater quality constituent list was developed based on NUREG-1569 groundwater parameters, NRC 4.14 parameters, and added parameters from a constituent-list review with SD DENR.

1.1.8.2 Groundwater Sampling Radiological Results

Results to date for dissolved radiological groundwater parameters are shown in Table 1.1-16 and Table 1.1-17.

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Table 1.1-16: Summary of Groundwater Radionuclide Concentrations From Quarterly Sampled Wells

Parameter	Aquifer	Alpha Particle-Dissolved				Uranium-Dissolved				Uranium-Total				Radium-226 -Dissolved				Radium-226-Total				Radon-222		
Units		pCi/L				mg/L				mg/L				pCi/L				pCi/L				pCi/L		
Sampling Quarter / Sample ID		3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008
Domestic Wells																								
2	Lakota	1.4	8.7	3.5	8.2	ND	ND	0.0004	ND	0.0004	NS	0.0004	ND	ND	1.3	1.1	2.1	2.2	NS	NS	NS	674	908	727
7	Fall River	4.4	7.2	15.5	3.3	ND	ND	ND	ND	NS	NS	ND	ND	0.6	1.1	0.7	0.9	ND	NS	NS	NS	206	242	451
8	Fall River	5	8.7	5.4	3.2	ND	0.0003	ND	ND	ND	NS	ND	ND	ND	NS	1.5	1.2	3.5	NS	NS	NS	123	329	514
13	Lakota	8.9	7.5	19.5	4.2	ND	ND	ND	ND	NS	NS	ND	ND	1.8	1.6	1.1	1.6	1.1	NS	NS	NS	305	258	412
16	Lakota	62.7	12.2	85.7	28.3	0.0021	0.0007	0.0007	<0.0003	NS	NS	0.0007	<0.0003	26.2	8.1	15.3	6.4	17.4	NS	NS	NS	1090	28200	3150
18	Fall River	15.7	18.9 (Rep 20.0)	31.7	27.5	0.0061	0.0066 (Rep 0.0065)	0.0066	0.0059	NS	NS	0.0062	0.0062	ND	3.2 (Rep 3.6)	3.2	2.6	4.0	NS	NS	NS	945 (Rep 944)	1220	1210
4002A	Other Inyan Kara	120 (Rep 141)	227	314	127	0.0026 (Rep 0.0026)	0.0026	0.0026	0.0023	NS	NS	0.0025	0.0025	63.6 (Rep 60.0)	54.2	57.0	52.3	62.7 (Rep 79.4)	NS	NS	NS	8010	9890	8780
7002	Lakota	45.6	39.8	91.4	29.5	0.0007	0.0006	0.0006	0.0005	NS	NS	0.0005	0.0006	8.5	8.1	8.8	8.0	6.3	NS	NS	NS	938	752	1270
Domestic/Stock Wells																								
42	Lakota	371	375	526	558	0.0150	0.0324	0.0194	0.0142	NS	NS	0.0198	0.0149	96.5	102	100	100	79.7	NS	NS	NS	132000	175000	219000
Stock Wells																								
619	Lakota	367	341	438	398	0.0020	0.0015	0.0015	0.0016	NS	NS	0.0018	0.0018	120	100	99.7	110	120	NS	NS	NS	2990	5580	5770
628	Other Inyan Kara	29.9	83.9	64.5	39	0.0017	0.0034	0.0030	0.0027	NS	NS	0.0031	0.0029	7.4	20.7	9.0	6.1	6.8	NS	NS	NS	2740	4360	5040
631	Fall River	51.0	46.5	162	60.7	0.0027	0.0029	0.0027	0.0026	0.003	NS	0.0026	0.0028	12.9	9.5	19.4	22.1	15.2	NS	NS	NS	4220	3920	4430
635	Sundance / Unkpapa	2.5	4.4	14.8	13.2	0.0020	0.0020	0.0021	0.0017	0.002	NS	0.0021	0.0017	1.6	0.8	1.3	NS	NS	NS	NS	NS	902	806	1070
650	Lakota	13.1	5.6	2.9	2.1	0.0019	ND	ND	ND	NS	NS	0.0004	ND	2.7	2.4	1.4	1.2	3.2	NS	NS	NS	134	202	254
Piezometer																								
675	Alluvial	18.8	18.3	29.3	55.2 (Rep 51.1)	0.0372	0.0307	0.0387	0.0493 (Rep 0.0485)	NS	NS	0.0387	0.0505 (Rep 0.0516)	ND	0.5	ND	0.7 (Rep 0.7)	2.3	NS	NS	NS	712	783	960 (Rep 960)
676	Alluvial	37.1	31.9	95.5	NS	0.0494	0.0548	0.0586	NS	NS	0	0.0687	NS	ND	ND	ND	NS	ND	NS	NS	NS	453	686	NS
677	Alluvial	41.0	38.7	129	43.1	0.0218	0.0443	0.0402	0.045	NS	0	0.0414	0.0471	0.9	ND	ND	0	ND	NS	NS	0	892	808	1250
678	Alluvial	23.2	18.9	41.4 (Rep 30.2)	54.7	0.0352	0.0349	0.0368	0.0355	NS	NS	0.0379	0.0387	ND	ND	ND (Rep ND)	NS	ND	NS	NS	NS	391	487 (Rep 418)	687
679	Alluvial	19.9	13.3	18.4	NS	0.0157	0.0144	0.0139	NS	NS	NS	0.0154	NS	ND	ND	0.9	NS	2.5	NS	NS	NS	819	2170	NS

Notes:

Yellow highlights designate concentrations over the EPA MCL

Blue highlights designate concentrations over the proposed EPA MCL for radon

ND = Not detected

NS = No sample

Rep = duplicate analysis

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Table 1.1-17: Summary of Groundwater Radionuclide Concentrations From Monthly Sampled Wells

Parameter	Aquifer	Alpha Particle-Dissolved				Uranium-Dissolved				Uranium-Total				Radium-226 -Dissolved				Radium-226-Total				Radon-222			
Units		pCi/L				mg/L				mg/L				pCi/L				pCi/L				pCi/L			
Sampling Quarter / Sample ID		Mar-08	Apr-08	May-08	Jun-08	Mar-08	Apr-08	May-08	Jun-08	Mar-08	Apr-08	May-08	Jun-08	Mar-08	Apr-08	May-08	Jun-08	Mar-08	Apr-08	May-08	Jun-08	Mar-08	Apr-08	May-08	Jun-08
615	Fall River	18	15.1	15.3	38.3	0.0026	0.0025	0.0024	0.0024	0.0026	0.0025	0.0025	0.0023	2.1	2	2	7.2	2.4	1.8	2.2	6.8	1370	1180	1070	1830
622	Fall River	15	22.6	32.6	36.4	<0.0003	0.0054	0.0056	0.0051	<0.0003	0.0065	0.0068	0.0059	2.3	2.7	3.2	4.1	3	3.6	4.2	3.9	501	1090	804	1950
680	Lakota	6440	4270	5500	4370	0.0569	0.0303	0.0343	0.0227	0.0541	0.0291	0.0256	0.0244	1150	1230	1340	1410	1152	1232	1353	1415	81000	151000	255000	91700
681	Fall River	2170	1400	1720	1390	0.0092	0.0098	0.0096	0.0097	0.0099	0.0102	0.0106	0.0102	414	377	415	434	418	377	417	435	254000	253000	462000	389000
688	Lakota	2.9	10.1	17.3	13.2	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.3	1.2	2.5	0.6	1.2	1.2	2.2	13.5	608	307	749	426
689	Fall River	64.3	25.5	34.9	36.5	0.0032	0.0037	0.0043	0.0034	0.0041	0.004	0.0117	0.006	7.9	4.2	5.7	5.5	9.9	4.2	6.2	5	1950	1540	1390	2520
694	Lakota	8.8	18.6	10.6	23.7	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	1.6	4	1.9	2.2	2.6	3.5	1.7	1.9	313	251	619	611
695	Lakota	NS	29.4	25.6	39.7	NS	0.0029	0.0029	0.0027	NS	0.0032	0.0029	0.0027	NS	5	3.7	5.2	NS	4.6	3.5	5.1	NS	1400	2090	2120
696	Lakota	3.9	5.2	14.3	23.9	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	1	0.5	1.8	3.3	1.6	0.3	1.7	2.9	190	185	497	517
697	Lakota	32.2	8.1	4.1	11.9	<0.0003	0.0030	<0.0003	<0.0003	<0.0003	0.0031	<0.0003	<0.0003	3.9	1.7	1.1	0.8	4.5	1.6	4.9	0.4	862	284	570	413
698	Fall River	1820	2110	1300	1790	0.109	0.11	0.102	0.104	0.123	0.119	0.118	0.113	393	370	413	429	408	376	427	441	30800	25800	24000	40700
3026	Lakota	47.6	43.8	92.4	116	0.0151	0.015	0.0281	0.0183	0.0097	0.0196	0.0322	0.0216	3.6	2.8	9.6	4.7	6.9	2.9	10.8	4.6	440	304	213	950

Notes:

Yellow highlights designate concentrations over the EPA MCL

Blue highlights designate concentrations over the proposed EPA MCL for radon

ND = Not detected

NS = No sample

1.1.8.3 Conclusions

The radiological baseline sampling results indicate that the groundwater contained within the ore zones of the Inyan Kara Group has concentrations of radionuclides that greatly exceed EPA MCL concentrations at levels that are not acceptable for human consumption. The aquifer does not presently, and will not in the future, serve as a source of drinking water.

1.1.9 Vegetation Sampling

Three rounds of vegetation sampling were conducted on the Dewey-Burdock Project. One vegetation sample was collected in August, 2007; and April and July, 2008 at each AMS, the locations of which are shown on Figures 1.1-8.

1.1.9.1 Methods

The samples were collected using grass clippers and placed in large plastic lawn bags, labeled appropriately, and stored in a laboratory supplied cooler until transferred to the laboratory. The analytes and corresponding analytical methods were the same as those used for soil. Polonium-210, determined using a laboratory-specific digestion and alpha spectrometry method, was added to the analytical suite (Energy Laboratories, 2008).

1.1.9.2 Vegetation Sampling Results

Table 1.1-18 presents the results of the vegetation sampling. There appear to be no temporal or spatial trends in the data. The following list is a summary of the averages for the set of samples:

- Radium-226 concentrations ranged from 0.02 to 0.09 pCi/g, averaging 0.05 pCi/g.
- Natural uranium concentrations ranged from 0.01 to 0.04 pCi/g, averaging 0.02 pCi/g.
- Thorium-230 concentrations ranged from 0.01 to 0.03 pCi/g, averaging 0.02 pCi/g.
- Lead-210 concentrations ranged from 0.6 to 1.7 pCi/g, averaging 1.2 pCi/g.
- Polonium-210 concentrations ranged from 0.08 to 0.23 pCi/g, averaging 0.15 pCi/g.

Analytical errors associated with the reported concentrations results are high, relative to the reported means.

Table 1.1-18: Baseline Radionuclide Concentrations in Vegetation

Location	Date Collected		8/14/2007	4/20/08	7/15/08	Average (µCi/kg)
AMS-01	U-nat (µCi/kg)	Concentration	1.4E-05	2.8E-02D	9.4E-06	1.4E-05
		Error ± 2σ	-	-	-	
		LLD	1.7E-06	2.4E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	5.5E-05	3.3E-05	8.1E-05	5.6E-05
		Error ± 2σ	3.2E-05	5.5E-06	1.2E-05	
		LLD	1.7E-06	3.7E-06	7.4E-06	
	Th-230 (µCi/kg)	Concentration	<1.7E-06	1.2E-05	1.2E-05	8.6E-06
		Error ± 2σ	<1.7E-06	5.2E-06	8.4E-06	
		LLD	1.7E-06	2.0E-07	8.4E-07	
	Pb-210 (µCi/kg)	Concentration	1.8E-03	2.9E-03	3.3E-04	1.7E-03
		Error ± 2σ	5.4E-04	1.1E-04	1.3E-04	
		LLD	8.6E-06	1.0E-06	2.1E-04	
	Po-210 (µCi/kg)	Concentration	1.3E-04	4.7E-04	1.7E-05	2.1E-04
		Error ± 2σ	9.8E-05	7.2E-05	1.5E-05	
		LLD	8.6E-06	1.0E-06	1.0E-06	
AMS-02	Date Collected		8/14/2007	4/20/08	7/14/08	
	U-nat (µCi/kg)	Concentration	1.0E-05	2.7E-02D	3.2E-06	6.6E-06
		Error ± 2σ	-	-	-	
		LLD	5.5E-07	2.0E-07	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	2.2E-05	3.0E-05	9.3E-06	2.0E-05
		Error ± 2σ	1.1E-05	4.5E-06	3.6E-06	
		LLD	5.5E-07	2.8E-06	4.0E-06	
	Th-230 (µCi/kg)	Concentration	4.7E-06	1.4E-05	-9.5E-07U	5.9E-06
		Error ± 2σ	6.0E-06	4.9E-06	5.0E-06	
		LLD	5.5E-07	2.0E-07	4.7E-07	
	Pb-210 (µCi/kg)	Concentration	3.3E-04	1.3E-03	1.5E-04	5.9E-04
		Error ± 2σ	1.5E-04	6.9E-05	7.3E-05	
		LLD	2.7E-06	1.0E-06	1.2E-04	

	Po-210 (µCi/kg)	Concentration	1.8E-05	2.0E-04	9.1E-06U	7.6E-05
		Error ± 2σ	2.0E-05	4.2E-05	8.5E-06	
		LLD	2.7E-06	1.0E-06	1.0E-06	

Table 1.1-18: Baseline Radionuclide Concentrations in Vegetation (cont'd)

Location	Date Collected		8/14/2007	4/20/08	7/14/08	Average (µCi/kg)
AMS-03	U-nat (µCi/kg)	Concentration	9.8E-06	1.5E-01D	7.7E-06	9.8E-06
		Error ± 2σ	-	-	-	
		LLD	6.4E-07	2.4E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	7.4E-05	1.1E-04	7.5E-06	9.2E-05
		Error ± 2σ	2.2E-05	9.7E-06	4.9E-06	
		LLD	6.4E-07	3.7E-06	6.6E-06	
	Th-230 (µCi/kg)	Concentration	2.6E-06	4.1E-05	1.0E-05	2.2E-05
		Error ± 2σ	4.4E-06	1.1E-05	6.6E-06	
		LLD	6.4E-07	2.0E-07	7.7E-07	
	Pb-210 (µCi/kg)	Concentration	9.1E-04	1.4E-03	3.3E-04	8.8E-04
		Error ± 2σ	2.2E-04	8.2E-05	1.2E-04	
		LLD	3.2E-06	1.0E-06	1.9E-04	
	Po-210 (µCi/kg)	Concentration	7.8E-05	2.3E-04	9.6E-06U	1.5E-04
		Error ± 2σ	4.4E-05	4.4E-05	1.1E-05	
		LLD	3.2E-06	1.0E-06	1.0E-06	
AMS-04	Date Collected		8/14/2007	4/20/08	7/14/08	
	U-nat (µCi/kg)	Concentration	9.3E-06	2.1E-02D	8.4E-06	9.3E-06
		Error ± 2σ	-	-	-	
		LLD	8.1E-07	1.9E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	2.3E-05	3.1E-05	9.3E-06	
		Error ± 2σ	1.4E-05	4.6E-06	5.2E-06	2.7E-05
		LLD	8.0E-07	2.8E-06	6.7E-06	
	Th-230 (µCi/kg)	Concentration	3.6E-06	8.3E-06	-2.7E-06U	6.0E-06
		Error ± 2σ	5.6E-06	4.2E-06	4.2E-06	
		LLD	8.0E-07	2.0E-07	7.7E-07	
	Pb-210 (µCi/kg)	Concentration	1.5E-03	1.2E-03	2.1E-04	1.4E-03
		Error ± 2σ	3.0E-04	6.6E-05	1.2E-04	
		LLD	4.0E-06	1.0E-06	1.9E-04	
	Po-210 (µCi/kg)	Concentration	9.8E-05	1.7E-04	9.0E-06U	
		Error ± 2σ	6.4E-05	3.9E-05	9.6E-06	1.3E-04
		LLD	4.0E-06	1.0E-06	1.0E-06	

Table 1.1-18: Baseline Radionuclide Concentrations in Vegetation (cont'd)

Location	Date Collected		8/14/2007	4/20/08	7/14/08	Average (µCi/kg)
AMS-05	U-nat (µCi/kg)	Concentration	3.7E-05	2.3E-01D	1.4E-05	3.7E-05
		Error ± 2σ	-	-		
		LLD	1.3E-06	1.3E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	2.4E-05	7.9E-05	5.9E-06U	5.2E-05
		Error ± 2σ	1.8E-05	5.7E-06	5.3E-06	
		LLD	1.3E-06	1.8E-06	7.7E-06	
	Th-230 (µCi/kg)	Concentration	1.5E-05	4.8E-05	-8.8E-07U	3.2E-05
		Error ± 2σ	1.7E-05	8.1E-06	5.7E-06	
		LLD	1.3E-06	2.0E-07	8.8E-07	
	Pb-210 (µCi/kg)	Concentration	1.7E-03	3.3E-04	3.4E-04	1.0E-03
		Error ± 2σ	4.2E-04	3.0E-05	1.4E-04	
		LLD	6.5E-06	1.0E-06	2.2E-04	
	Po-210 (µCi/kg)	Concentration	6.6E-05	1.6E-04	2.1E-05	1.1E-04
		Error ± 2σ	6.0E-05	3.1E-05	1.6E-05	
		LLD	6.5E-06	1.0E-06	1.0E-06	
AMS-06	**Date Collected**		**8/14/2007**	**4/20/08**	**7/14/08**	
	U-nat (µCi/kg)	Concentration	3.8E-05	1.3E-01D	2.2E-05	3.8E-05
		Error ± 2σ	-	-		
		LLD	8.3E-07	3.2E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	3.2E-05	9.2E-05	1.8E-05	6.2E-05
		Error ± 2σ	1.6E-05	9.9E-06	5.0E-06	
		LLD	8.2E-07	4.6E-06	5.0E-06	
	Th-230 (µCi/kg)	Concentration	1.9E-05	3.9E-05	2.1E-05	2.9E-05
		Error ± 2σ	1.3E-05	1.1E-05	7.4E-06	
		LLD	8.2E-07	2.0E-07	5.7E-07	
	Pb-210 (µCi/kg)	Concentration	1.0E-03	1.8E-03	1.4E-04U	1.4E-03
		Error ± 2σ	2.6E-04	1.1E-04	8.7E-05	
		LLD	4.1E-06	1.0E-06	1.4E-04	
	Po-210 (µCi/kg)	Concentration	6.0E-05	4.0E-04	5.7E-06U	2.3E-04
		Error ± 2σ	4.4E-05	7.7E-05	5.7E-06	
		LLD	4.1E-06	1.0E-06	1.0E-06	

Table 1.1-18: Baseline Radionuclide Concentrations in Vegetation (concl.)

Location	Date Collected		8/14/2007	4/20/08	7/14/08	Average (µCi/kg)
AMS-07	U-nat (µCi/kg)	Concentration	1.8E-05	1.4E-01 D	2.7E-05	1.8E-05
		Error ± 2σ	-	-		
		LLD	9.7E-07	21E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	2.7E-05	7.6E-05	2.4E-05	5.2E-05
		Error ± 2σ	1.6E-05	7.2E-06	7.5E-06	
		LLD	9.7E-07	3.0E-06	7.7E-06	
	Th-230 (µCi/kg)	Concentration	1.6E-05	4.0E-05	2.0E-05	2.8E-05
		Error ± 2σ	1.8E-05	1.2E-05	8.6E-06	
		LLD	9.7E-07	2.0E-07	8.6E-07	
	Pb-210 (µCi/kg)	Concentration	2.1E-03	6.2E-04	-3.2E-05U	1.4E-03
		Error ± 2σ	3.6E-04	5.3E-05	1.3E-04	
		LLD	4.8E-06	1.0E-06	2.1E-04	
	Po-210 (µCi/kg)	Concentration	1.5E-04	2.3E-04	2.0E-05	1.9E-04
		Error ± 2σ	8.2E-05	4.7E-05	1.3E-05	
		LLD	4.8E-06	1.0E-06	1.0E-06	
AMS-BKG	**Date Collected**		**8/14/2007**	**4/20/08**	**7/14/08**	
	U-nat (µCi/kg)	Concentration	4.0E-05	9.0E-02D	1.0E-05	2.5E-05
		Error ± 2σ	-	-	-	
		LLD	9.7E-07	3.8E-06	2.0E-07	
	Ra-226 (µCi/kg)	Concentration	4.1E-05	8.3E-05	1.3E-05	6.2E-05
		Error ± 2σ	2.0E-05	1.1E-05	4.6E-06	
		LLD	9.7E-07	6.4E-06	5.1E-06	
	Th-230 (µCi/kg)	Concentration	1.0E-05	3.5E-05	7.3E-06	2.3E-05
		Error ± 2σ	1.3E-05	1.2E-05	4.2E-06	
		LLD	9.7E-07	2.0E-07	5.6E-07	
	Pb-210 (µCi/kg)	Concentration	6.9E-04	1.4E-03	1.3E-04U	1.0E-03
		Error ± 2σ	2.8E-04	1.0E-04	8.6E-05	
		LLD	4.8E-06	1.0E-06		
	Po-210 (µCi/kg)	Concentration	2.5E-05	2.2E-04	9.3E-06	1.2E-04
		Error ± 2σ	3.2E-05	5.1E-05	8.8E-06	
		LLD	4.8E-06	1.0E-06	1.0E-06	

Notes:
D = Lower limit of detection increased due to sample matrix interference. Average concentrations s do not include "D"-qualified results.

1.1.9.3 Conclusions

Other than the observation that radionuclide concentrations in the vegetation samples are one to two orders of magnitude lower than those in the corresponding shallow (0 to 5 cm) soil samples, there are no apparent relationships between the media. Radium-226, natural uranium, and thorium-230 concentrations were highest in offsite soil sample AMS-BKG, located 1.9 miles west of the site near the offsite topsoil pile. Only the concentration of natural uranium was highest at this location in vegetation and soil. The concentration of radium-226 in soil at this location was in the middle of its range.

1.1.10 Food Sampling

To determine baseline radionuclide concentrations in local food, Powertech (USA) collected three tissue samples, one liver (DBAT 03) and two meat samples (DBAT 01 DBAT 02), from a locally grazing cow on June 25, 2008. The results are listed in Table 1.1-19. Errors are reported as ±2σ.

Table 1.1-19: Baseline Radionuclide Concentrations in Local Food

Sample ID	Radionuclide	Parameter	Result
DBAT-01	**U-nat (µCi/kg)**	**Concentration**	ND
		Error ± 2σ	-
		LLD	7.0E-06
	Ra-226 (µCi/kg)	Concentration	3.0E-06
		Error ± 2σ	2.0E-06
		LLD	3.0E-06
	Th-230 (µCi/kg)	Concentration	0.0
		Error ± 2σ	2.0E-05
		LLD	8.0E-06
	Pb-210 (µCi/kg)	Concentration	-7.0E-06
		Error ± 2σ	4.0E-05
		LLD	7.0E-06
	Po-210 (µCi/kg)	Concentration	8.0E-06
		Error ± 2σ	1.0E-04
		LLD	8.0E-06
DBAT-02	**U-nat (µCi/kg)**	Concentration	ND
		Error ± 2σ	-
		LLD	7.0E-06
	Ra-226 (µCi/kg)	Concentration	6.0E-05
		Error ± 2σ	3.0E-05
		LLD	4.0E-05
	Th-230 (µCi/kg)	Concentration	0.0
		Error ± 2σ	1.4E-03
		LLD	1.0E-04
	Pb-210 (µCi/kg)	Concentration	2.0E-04
		Error ± 2σ	7.0E-04
		LLD	1.2E-03
	Po-210 (µCi/kg)	Concentration	0.0
		Error ± 2σ	1.2E-03
		LLD	1.0E-04
DBAT-03	**U-nat (µCi/kg)**	Concentration	ND
		Error ± 2σ	-
		LLD	7.0E-06
	Ra-226 (µCi/kg)	Concentration	3.0E-06
		Error ± 2σ	1.0E-06
		LLD	2.0E-06
	Th-230 (µCi/kg)	Concentration	0.0
		Error ± 2σ	1.0E-04
		LLD	6.0E-06
	Pb-210 (µCi/kg)	Concentration	-7.0E-06
		Error ± 2σ	4.0E-05
		LLD	6.0E-05
	Po-210 (µCi/kg)	Concentration	2.0E-05
		Error ± 2σ	2.0E-04
		LLD	6.0E-06

There are several cases where reported concentrations are at or below LLDs that, in turn, exceed the LLDs recommended in RG 4.14. This is evident for all reported concentrations of natural uranium, radium-226 and polonium-210 in Sample DBAT-01, and lead-210 in all three samples.