Sheep Mountain Project – Mine Permit 381C

APPENDIX D-10 – RADIOLOGY
2011 ADDENDUM

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Appendix D10 - Baseline Radiological Survey Characteristics

D10.1 Introduction

This report summarizes baseline gamma levels and commensurate Radium 226 levels in soils for the Sheep Mountain Project, WDEQ/LQD Mine Permit 381C and was developed on behalf of Titan Uranium USA.

The data presented herein, is that portion of the overall radiological characterization of the site applicable to WDEQ regulatory guidance with respect to baseline gamma levels and Radium 226 soils concentrations. The data was generated and complied by Tetra Tech Inc.

The radiological surveys completed meet or exceed the criteria set forth in the WDEQ/LQD Guideline No. 3, Radiological Survey with respect to density and extent of the gamma survey. The objective of the baseline radiological survey and sampling is to:

1. Establish the nature of the pre-mining radiological environment.
2. Detect and document areas having anomalous radiation.
3. Establish pre-mining concentrations of radio nuclides in the surface materials of the lands to be affected in order to establish a goal for reclamation.

Previous gamma surveys, completed and approved for Mine Permit 381C, utilized hand-held discrete measurements on a grid basis and only addressed the proposed area of disturbance. Current surveys better define the baseline Natural Occurring Radiological Materials (NORM) and Technically Enhanced Natural Occurring Radiological Materials (TENORM)

The objective of the baseline investigation was to assess existing conditions at the site, including evaluation of the spatial distribution of baseline gamma exposure rates and soil radionuclide concentrations, prior to uranium extraction activities. Based on these findings, in concert with soils and overburden characterization and material handling procedures for the mine, specific goals with respect to post-reclamation gamma levels are proposed.

D10.2 Gamma Surveys

A field investigation was performed by Tetra Tech engineers during August 14, 2010 through August 17, 2010; additionally, a follow-up study was conducted October 19, 2010 through October 21, 2010. Activities included recording of gamma exposure rates, correlation with dose rates, and collection of soil samples to develop a correlation between radiation levels and soil radium-226 concentrations.

The gamma surveys utilized GPS-based scanning system technologies to record baseline gamma exposure rates ranging over the entire site. Unlike discrete grid-based measurements, these current-technology scanning systems efficiently develop a detailed characterization of gamma exposure rates over large areas. The system can be mounted in configurations including backpacks, off-highway vehicles (OHVs) and trucks, and has been used to characterize a larger number of former uranium mine and mill sites and

newly proposed uranium recovery sites. Both OHC's and backpack surveys were completed for the Sheep Mountain Project. The GPS-based radiation scanning data set meets or exceeds the criteria set forth in the WDEQ/LQD Guideline No. 3, Radiological Survey and the guidance outlined in USNRC Regulatory Guide 4.14.

The gamma scanning equipment employs adjustable systems with Ludlum 44-10 two-inch sodium iodide (NaI) gamma radiation detectors and paired GPS receivers mounted well away from the vehicles. The two-inch NaI detectors are coupled to Ludlum 2350-1 rate meters. The permanently paired systems are factory calibrated by Ludlum Inc., and report gamma exposure rate (μR/h) as a function of detector count rate. The detector systems are calibrated using a cesium-137 source. Simultaneous GPS and gamma radiation exposure rate data are transmitted every second for each system. Data are recorded on netbook PCs using proprietary software (ComReader©, Tetra Tech, 2007). System configuration includes 8-foot spacing between detectors, with each detector positioned roughly 3.5 feet above the ground to avoid obstructions.

Based on previous experience in the field using similar system configurations, lateral NaI detector response to significantly above-background planar (non-point) gamma sources at the ground surface is estimated to extend to roughly 3-5 feet, giving each detector an estimated "field of view" up to 10 feet in diameter. This does not imply that a detector can discriminate gamma radiation from a small point source five feet away, but does suggest that photons from larger source areas are likely to be detected at that distance. The sensitive track width for each vehicle's two-detector system is therefore estimated to be 18 feet. Vehicle scanning speeds at the Sheep Mountain Project generally ranged between 2 and 10 mph depending on the roughness of the terrain, with an average speed of approximately 5 mph.

Target coverage for the Sheep Mountain Project was 100 m spacing between the scan vehicles (10 m scan tracks). Practical considerations such as steep terrain and natural obstructions often influenced actual courses traversed by the vehicles. Due to the difficult terrain at this site, large portions were scanned using the backpack mounted systems. Where study areas were selected to develop correlations with soil samples, scan density was increased to 100% (vehicle track spacing less than 18 feet).

D10.3 Gamma/Soil Radionuclide Correlation

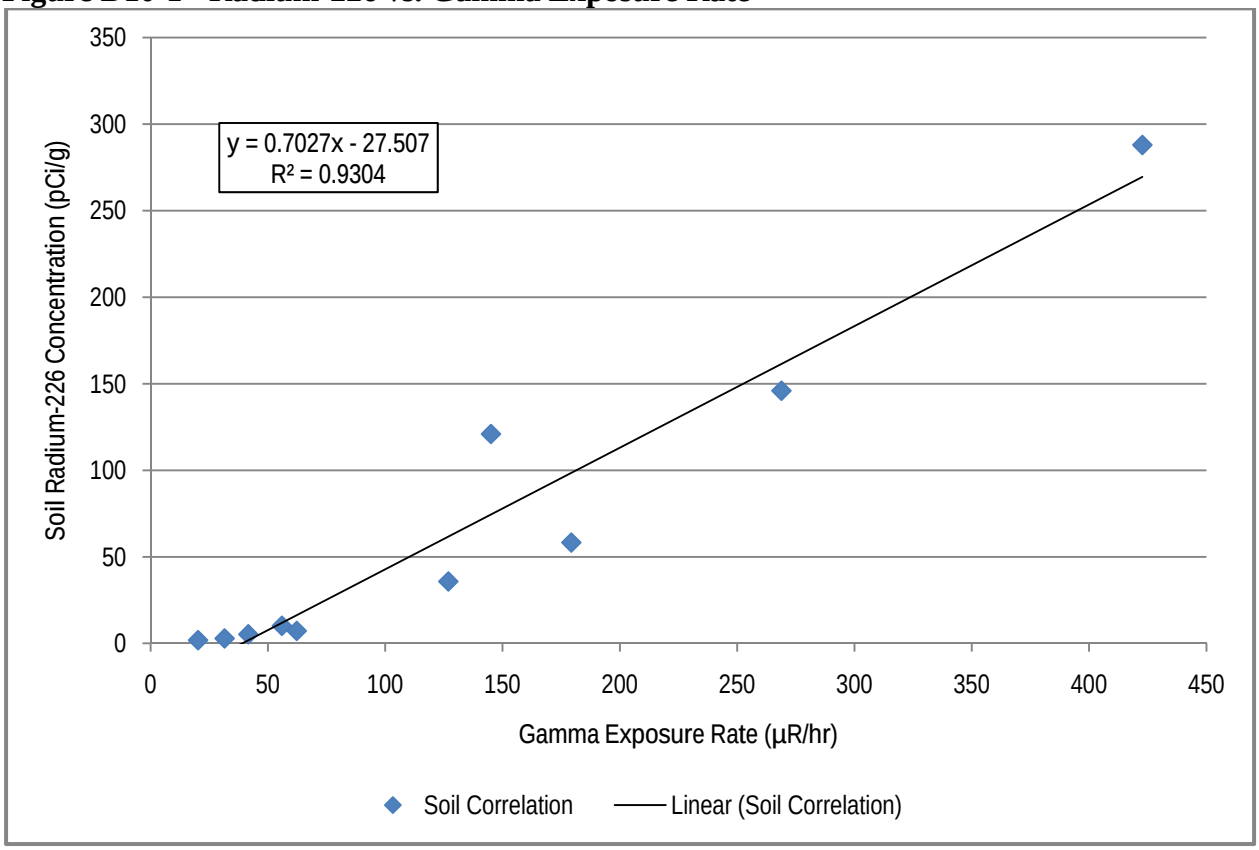
The principal radiological parameters of concern, based on potential health effects, are Radium 226 and its immediate daughter product Radon 222. Since Radon is a gas which readily disperses in an open air environment, the radiological parameter most commonly evaluated in soils and/or mine spoils is Radium 226. As radioactive materials by definition decay and emit radioactive particles and/or energy, the general levels of radioactivity can readily be measured by passive detection devices. For the evaluation of Radium 226 levels, a hand held scintillation counter is a commonly used field instrument. The field measurements can then be correlated with laboratory analyses to quantitatively estimate Radium 226 concentrations in near surface materials. Depending on the statistical strength of the relationship between gamma readings and radium-226 concentrations in surface soils, such correlations can be used to estimate near-surface soil

concentrations across the entire site, based on the gamma survey results. As subsequently discussed, the Gamma/Radium 226 correlations for the Sheep Mountain Project was strong indicating that field gamma measurements can be utilized to reasonably estimate Radium 226 concentrations in the soil.

Correlation soil sampling was conducted via composite sampling over 100 square meter plots (10 x 10 meter). Sample locations were selected by inspection of the gamma radiation survey data, covering the exposure rate range measured onsite. Within each plot, nine soil sub-samples were collected to a depth of approximately 15 cm, then composited into a single sample representative of the plot. GPS coordinates were taken at the center of each sampling plot and recorded. Samples were sent to Inter-Mountain Laboratories (IML) in Sheridan, Wyoming for analysis of radium-226 via gamma spectrometry after radon daughter equilibration. Samples were dried and homogenized prior to canning and analysis.

The gamma/radium-226 correlation analysis results shown in Figure D10-1 demonstrate a strong correlation between radium-226 soil concentration and gamma exposure rate for the soil correlation plots analyzed. Based on these correlations, approximately 70 Micro Rem per Hour (MicroR/Hr) measured in the field would equate to approximately 20 pCi/gm (pico-Curies per gram) Radium 226 at the surface.

Figure D10-1 - Radium-226 vs. Gamma Exposure Rate



Soil samples were extracted at locations selected to cover the range of common exposure rates found onsite. The Sheep Mountain Project had a wide range of exposure rates. Table D10-1 provides the summary data for the radium and gamma exposure rates for each soil correlation plot location.

Table D10-1 - Radium-226 Correlation Concentrations

Soil Correlation Plot ID	Radium-226 (pCi/g)	Exposure Rate (µR/hr)
SM SOILCORR1	5.27	42
SM SOILCORR2	58.3	179
SM SOILCORR3	7.24	62
SM SOILCORR4	121	145
SM SOILCORR5	35.8	127
SM SOILCORR6	2.91	32
SM SOILCORR7	146	269
SM SOILCORR8	288	423
SM SOILCORR9	1.86	20
SM SOILCORR10	10.2	56

D10. 4 Quality Assurance and Control Methods

Prior to the gamma radiation survey, instrument comparison QC measurements were performed at background exposure rates for all NaI detectors available to survey the Sheep Mountain project area. Instruments also meeting on-site field QC criteria are then considered qualified to replace instruments that fail in the field. Data developed using any qualified instruments are suitable for use in this report.

Field check results**:** For normally distributed data, over 99% of measurements are expected to fall within ±3 standard deviations of the mean (these are the control limits). Background, field strip and check source standard deviation values are calculated twice daily at the same locations; daily QC plots incorporate results to date. If a detector exceeds control limits on any QC check (background, field strip, or source check), it is replaced with a qualified spare system and sent back to the manufacturer for evaluation, repair and recalibration.

The daily field strip check, during which data are collected along the same 100 meter strip each morning and evening, provides an indication of total measurement uncertainty for an entire scanning system (OHV, GPS and detector systems). Note that the Ludlum 2350 data logger system employs a calibration factor to internally convert detector counts per minute to a gamma exposure rate. The calculated gamma exposure rate, directly proportional to the measured count rate, is transmitted by the data logger to the scanning system portable PC. No record of count rate is retained by the system, but count rate can

be calculated using the instrument-specific calibration factor. Factory calibration sheets for each instrument used on the Sheep Mountain Project are available upon request.

D10.5 Baseline Gamma Survey Results

A survey of baseline gamma radiation exposure rates was performed by Tetra Tech field engineers August 14, 2010 through August 17, 2010; additionally, a follow-up study was conducted October 19, 2010 through October 21, 2010. Raw data were reviewed during and following field work and faulty points removed via an automated program plus inspection. A total of 186,899 valid gamma radiation exposure data points, paired with WAAS-corrected GPS data, were collected. Summary statistics for the valid data, including a frequency histogram of the gamma exposure rates, are provided in Figure D10-2.

Exposure rates ranged from 12.9 to 1138 µR/hr, with a standard deviation of 42.3 µR/hr. Figure D10-2 shows a normal distribution of count rates, with a mean of 50.8 uR/hr. The survey data are mapped in Figure D10-3 to illustrate exposure rate variations seen over the entire site. Gamma exposure rates observed at the soil correlation plot locations ranged between 20.2 µR/hr and 423 µR/hr, with a standard deviation of 128 µR/hr.

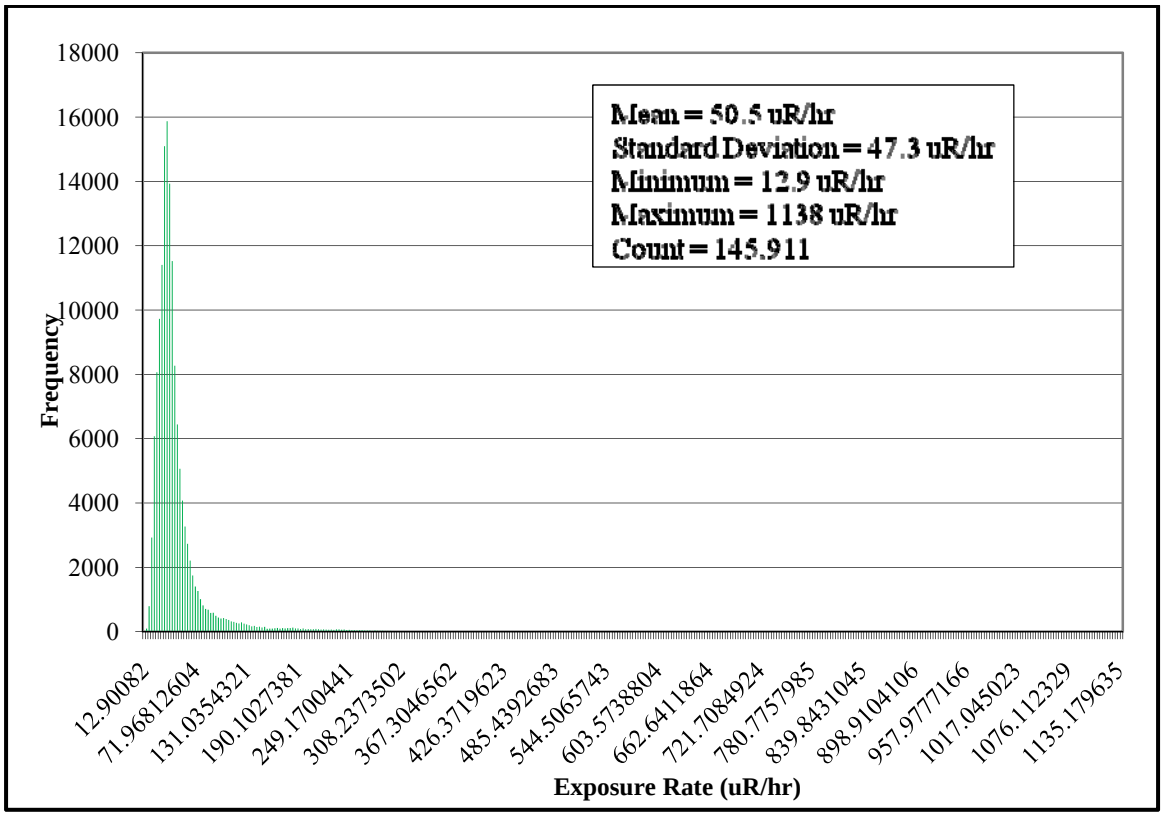
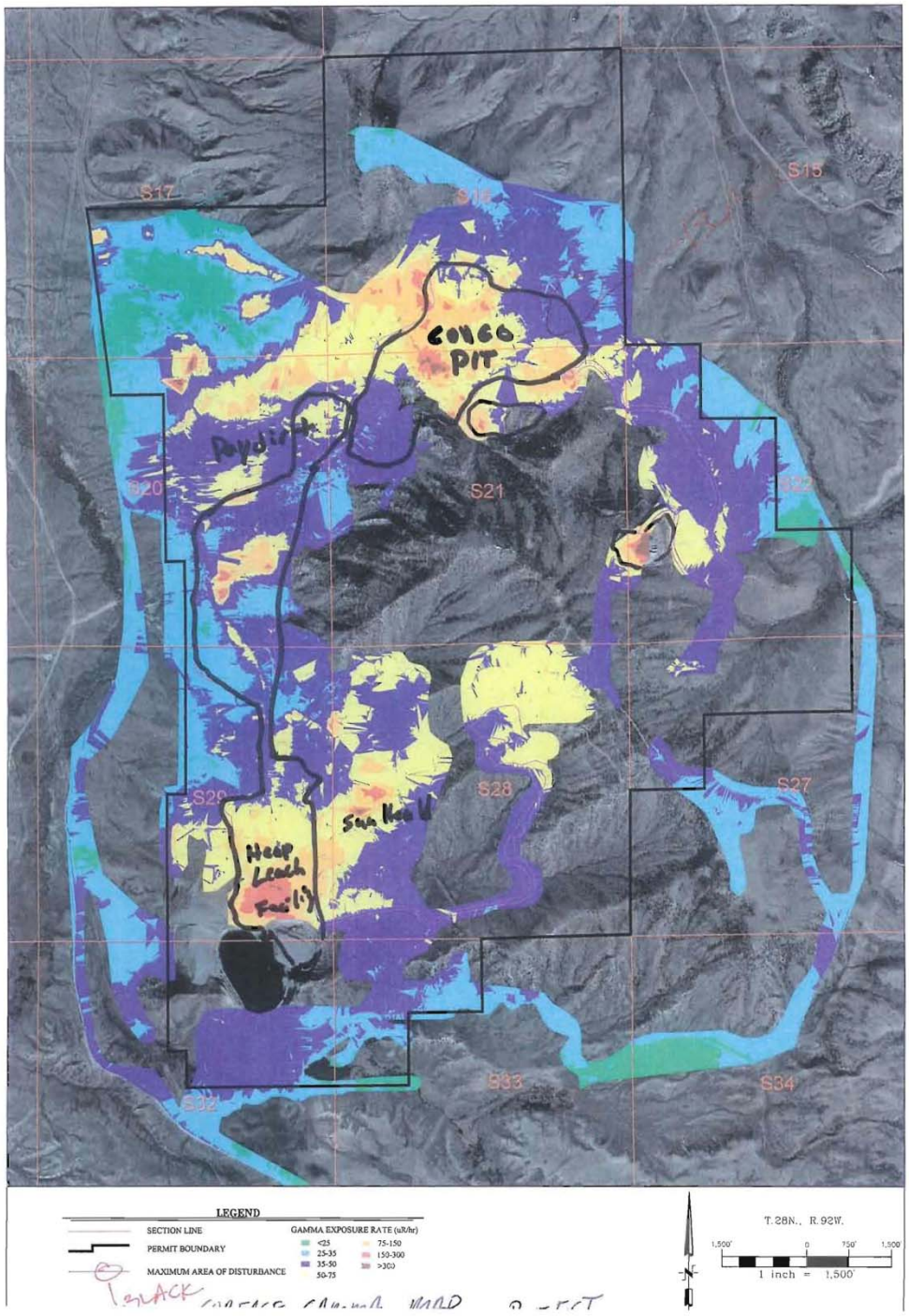


Figure D10-2 Histogram for Gamma Exposure Rates

Figure D10 – 3 – Surface Gamma Map (draft - final will be 11x17 figure)



D10.6 Gamma Survey Conclusions

The 2010 baseline gamma survey of the proposed Sheep Mountain Project provides a detailed characterization of existing gamma exposure rates, and a method to estimate dose rates over the entire permit area. In general the site shows relatively high radiological background gamma due to both NORM and TENORM concentrations of Radium 226 and other radionuclides in the near surface soils. Elevated NORM is due to outcropping of mineralization. Elevated TENORM reflects the more than 30 years of historical mining and exploration in the vicinity. The discovery of uranium mineralization at Sheep Mountain was a direct result of elevated surface gamma levels (NORM).

As discussed in Appendix D5, Geology and Overburden, the uranium mineralization within Sheep Mountain Project is hosted by the Tertiary Battle Spring Formation (Tbs) The Battle Spring Formation was deposited unconformably within a broad synclinal valley which plunges approximately 10 degrees from northwest to southeast. The Battle Spring and associated mineralization at Sheep Mountain is bounded to the east by the western flank of the Sheep Mountain Syncline and to the west by the Spring Creek Anticline. To the north the Battle Spring is exposed by erosion. To the south the Battle Spring is continues into the northern portions of the Great Divide Basin. Within the project area surficial geologic exposures include:

- Quaternary alluvial and colluvial deposits mapped as;
    - Qal - Quaternary Alluvium
    - Qf –Quaternary Floodplain
- Tertiary Battle Spring Formation (Eocene);
    - Tb Member B (Upper)
    - Tb Member A (Lower)
- Tf - Tertiary Fort Union (Paleocene)
- Kc – Cretaceous Cody Shale

The Sheep Mountain Project is bounded on three sides (north, east and west) Fort Union or Cody Shale. Both Crooks Creek to the west and Sheep Creek to the east are underlain by Cody Shale. Along the northern limit Sheep Mountain mineralized zones of the Battle Spring outcrop.

Referring to Figure D10-3, portions of Mine Permit 381C in which the surface is underlain by Cody Shale, Fort Union, and/or Quaternary alluvial and colluvial deposits derived from these formations exhibit the lowest background gamma levels and are generally less than 50 µR/hr. In contrast, areas which are underlain by Battle Spring and/or Quaternary alluvial and colluvial deposits derived from the Battle Spring exhibit background levels in excess of 50 µR/hr with natural outcrop areas, NORM, exhibiting levels in excess of 75 µR/hr. TENORM levels are related to historic mine operations and may include mine spoils, low grade ore stockpiles, and surface mines. Current existing TENORM levels exceed 150 µR/hr in most cases.

D10.7 Mine Reclamation Goals

While there are not specific numeric standards for mine reclamation with respect to surficial radiological concentrations, it is proposed that the guidance developed by the Wyoming Department of Environmental Quality, Abandoned Mine Lands Division (AML) be employed for future mining and reclamation activities at the Sheep Mountain Project under WDEQ Mine Permit 381C. Current AML practice is reclaim mine lands for unrestricted use based on an assessment of radiological health risks. Based on the findings of "Radiological Risk Assessment for Various Abandoned Mine Lands Clean-Up Criteria", Hersloff and Johnson, et al, 1988, prepared for the State of Wyoming, Abandoned Mine Lands Program, a surface clean up criteria of 20 pCi/g Radium 226 has been employed by AML. For the Sheep Mountain Project, as previously discussed, a near surface soils/overburden concentration of 20 pCi/g Radium 226 would equate to approximately 70 μR/hr. Where local conditions and such factors as availability of cover and topsoil affect the ability to meet this goal, principals of ALARA will be employed.

This approach was undertaken by AML with respect to mine reclamation projects within the project area including the Paydirt (west of the Congo Pit) and Sun Heald (east of the Heap Leach Facility) areas. The Paydirt reclamation resulted in surface gamma levels of 75 μR/hr or less. At Sun Heald the reclaimed surface exhibits higher gamma levels.

Appendix D5, Geology and Overburden, characterizes the mine spoils and overburden which will be excavated in the development of the Congo Pit and the associated selective materials handling methodology which will be employed during mining and reclamation operations in order to meet the proposed mine reclamation goal of 20 pCi/g Radium 226 equating to approximately 70 μR/hr. When implemented this procedure will reduce surface gamma levels in areas such as the Congo Pit and Heap Leach facility from level well in excess of 70 μR/hr to 70 μR/hr or less.