APPENDIX A

Gross Gamma Radiation Survey

Gross Gamma Radiation Survey of Old Church Rock Mine McKinley County, NM

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1.0 Introduction

Environmental Restoration Group, Inc. (ERG) personnel performed a radiological characterization of approximately 500 acres at the Old Church Rock Mine (OCRM) and nearby residences located in McKinley County, New Mexico, from May 18, 2009 to May 28, 2009, and July 7, 2009. The radiological characterization is in support of the overall Intera Phase 1 Site Characterization. The radiological characterization consisted of performing a GPS-based gross gamma radiation survey, making High Pressure Ionization Chamber (HPIC) dose measurements at selected locations, and collecting soil samples at selected locations. Correlations between the gross gamma count rates and the HPIC dose rate measurements, and the gross gamma count rates and Ra-226 concentrations in soil were then developed. Using the data from the correlations, figures were generated showing Site-wide dose rates and Ra-226 soil concentrations.

2.0 GPS-Based Gross Gamma Radiation Survey

GPS-based surveys were performed over approximately 500 acres of the OCRM, three surrounding residences and three NNEPA chosen background reference study areas. The surveys were performed with a detector path spacing of 25 meters or less. A higher density survey, with a detector path spacing of 10 meters or less, was used for the OCRM unnamed arroyo, drainage ditch, roads, and areas where higher survey resolution was desired. Each GPS-based radiological survey system consisted of a Ludlum Model 2221 ratemeter/scaler with a Ludlum Model 44-10, 2-inch by 2-inch sodium iodide (NaI) detector coupled to a Trimble Pro XRS mapping grade GPS survey unit. The Ludlum Model 2221 ratemeter/scalers were operated in ratemeter mode allowing for a gamma count rate (in counts per minute [cpm]) and the corresponding location coordinates to be collected at 1-second intervals. The survey systems were carried in backpacks with the detectors held approximately 0.5 meter (18 inches) above the ground surface. A survey speed of approximately 1.0 meter per second was used. At the end of each survey day, the data were downloaded onto a laptop computer and processed onsite using a combination of Trimble Pathfinder Office and ESRI ArcMap GIS computer applications.

The survey data is presented in Figure A-1, located in Appendix A.

3.0 HPIC Measurement Correlation

Fifteen on-site locations were chosen to correlate HPIC measurements to NaI detector readings. The locations were chosen based upon the NaI detector count-rate data collected during the gross gamma radiation survey. Locations spanning the total range of gross gamma count-rate values

were chosen to ensure correlation in all ranges of the survey data. Only locations that exhibited a consistent gamma count rate, approximately plus or minus 5,000 cpm in the immediate area, were chosen. HPIC correlation locations are presented in Figure A-2, located in Appendix A.

At each location a GE Energy Model RSS-133 HPIC was fixed on a tripod 1-meter above the ground surface, powered on and the dose rate readings allowed to stabilize. The dose rate readings were then logged for approximately five minutes. Also at each location a one-minute NaI detector scaler count was made and recorded with the held detector 0.5 meters (18 inches) above the ground surface. The NaI detector used in the correlation was also used in the gross gamma radiation survey. The data for each location and instrument used are shown in Table 3-1 below.

Table 3-1 - HPIC Measurement and NaI Detector Reading Correlation Data

Location	Coordinates in NAD83 New Mexico West		HPIC Measurement Average (μR/hr)	NaI Detector One-Minute Scaler Count (cpm)
	Northing (m)	Easting (m)		
1	512,557	763,873	17.1	15,754
2	513,075	764,876	24.6	40,455
3	512,741	764,827	32.1	50,361
4	512,534	764,452	38.6	58,606
5	512,705	765,122	16.2	15,488
6	512,700	764,655	20.5	25,109
7	512,643	764,849	46.2	72,243
8	512,775	764,824	49.6	88,644
9	512,050	763,949	26.7	38,263
10	512,926	764,771	284	485,066
11	512,926	764,804	53.5	99,447
12	512,894	764,950	155	260,418
13	512,856	764,876	66.3	115,879
14	512,993	765,072	38.2	58,432
15	510,498	763,172	18.5	9,965

Each average HPIC ratemeter reading was compared to its corresponding one-minute NaI detector measurement. The data obtained with the two instruments were plotted in an X-Y scatter

plot, shown below in Figure 3-1. The trend line equation obtained for the data is the correlation equation used to convert each gross gamma count rate into an exposure rate (μR/hr). This equation is: $y = 0.0006 * x + 4.5138$, where y is the calculated exposure rate (μR/hr) and x is the gross gamma count rate from the NaI detector count rate (cpm).

Figure 3-1 - HPIC Measurement and NaI Detector Reading Correlation Graph

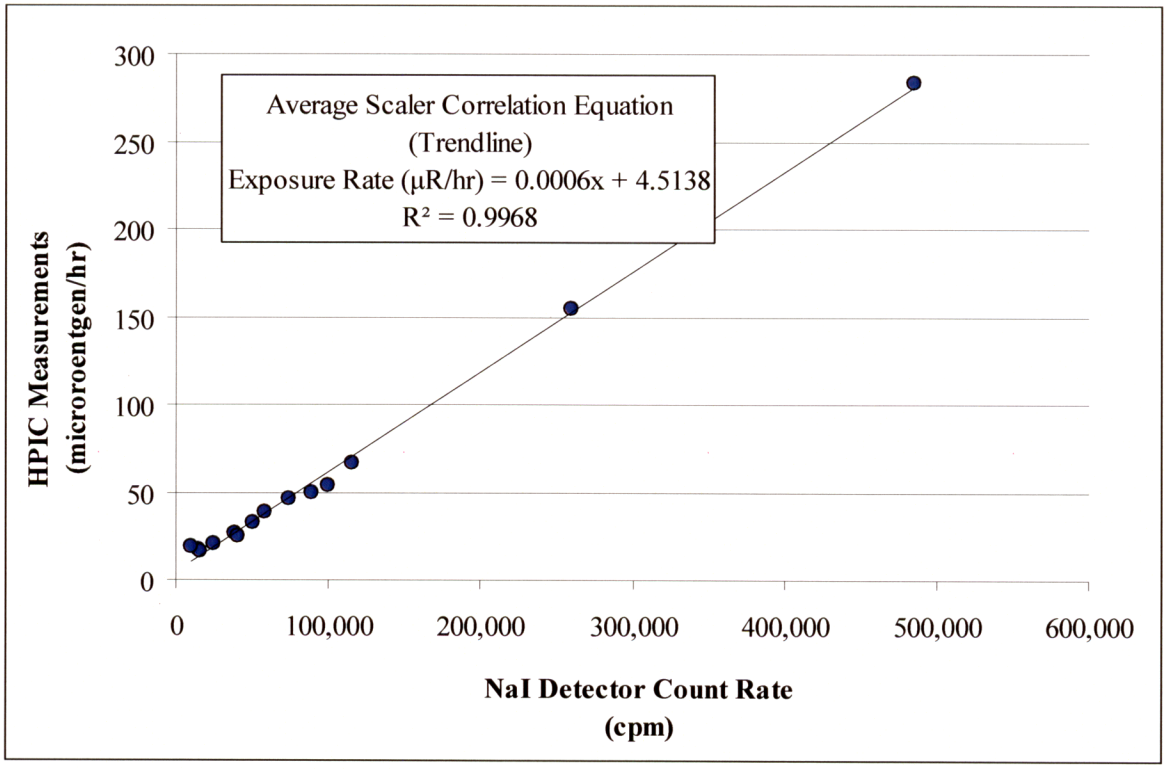


Figure A-3, located in Appendix A, shows the survey results in microroentgens per hour. The gamma count rates in cpm were converted to microroentgens per hour using the interpolated best fit line equation from the HPIC correlation.

4.0 Soil Samples

Fifteen on-site locations were chosen to correlate Ra-226 soil concentrations to NaI detector readings. The locations were chosen based upon the NaI detector count-rate data collected during the gross gamma radiation survey. To limit the selection of locations to those representative of the large majority of the site only areas exhibiting less than 110,000 cpm were chosen for sampling. Soil sample locations are presented in Figure A-4, located in Appendix A.

Prior to collecting the soil sample at each location a one-minute NaI detector scaler count was made and recorded with the detector held 0.5 meters (18 inches) above the ground surface. The NaI detector used in the correlation was also used in the gross gamma radiation survey. Samples were collected in the top 0 – 15 cm (0 – 6 inch) layer of soil using a shovel and bucket. After collection the samples were double bagged in heavy plastic bags and sent to ALS Laboratory Group, formerly Paragon Analytics, in Ft. Collins, CO for natural uranium analysis, which includes analysis for Ra-226. Soil Sample results are presented in Appendix C.

One of the 15 soil samples, SID-10, was removed from the correlation sample population due to it yielding a different uranium to radium ratio than the other 14 samples. Because of this inconsistency this sample was considered not applicable for the site-wide radium 226 correlation.

The sample concentration and gross gamma count rate for each location is shown in Table 4-1 below.

Table 4-1 - Radionuclide Concentrations in Soil Samples

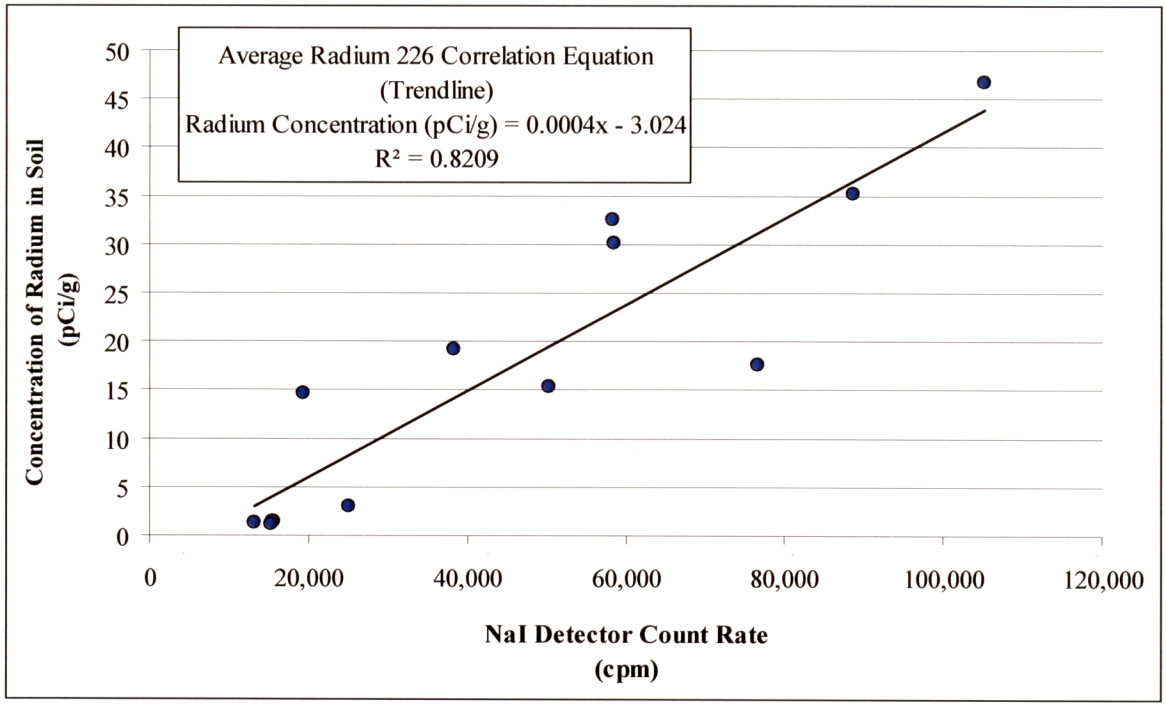
Sample ID	Coordinates in NAD83 New Mexico West		U-nat (pCi/g)	Ra-226 (pCi/g)	NaI Detector One-Minute Scaler Count (cpm)
	Northing (m)	Easting (m)			
SID-01	512,535	763,868	2.03	1.45	15,754
SID-06	512,743	764,825	9.48	15.3	50,361
SID-07	512,533	764,447	19.63	30.1	58,606
SID-08	512,701	765,117	2.64	1.36	15,488
SID-09	512,672	764,651	6.03	3.04	25,109
SID-12*	512,774	764,825	21.33	35.25	88,644
SID-14*	512,051	763,943	10.15	21.70	38,263
SID-20	512,986	765,069	23.7	32.5	58,432
SID-21	512,387	764,251	1.76	1.27	13,322
SID-23	512,767	764,394	1.49	1.14	15,249
SID-25	512,203	764,067	14.22	14.6	19,249
SID-26	512,409	764,397	37.24	46.7	105,214
SID-28	512,508	764,638	11.51	17.6	76,587

*Duplicate sample concentrations are averaged

Each Ra-226 concentration was compared to its equivalent one-minute NaI detector measurement. The corresponding data obtained were plotted in an X-Y scatter plot, shown below in Figure 4-1. The trend line equation obtained for the data is the correlation equation used to convert each gross gamma reading into Ra-226 concentration (pCi/g). This equation is:

$y=0.0004*x-3.024$, where y is the calculated Ra-226 concentration (pCi/g) and x is the gross gamma reading from the NaI detector count rate (cpm).

Figure 4-1 – Radium Concentration and NaI Detector Reading Correlation Graph



The gross gamma survey data converted into Ra-226 concentration in soil is displayed in Figure A-4.

5.0 Background Study

At the request of the NNEPA three background reference areas were chosen for additional survey. The survey data was collected to obtain background level gross gamma data for comparison. The background reference areas are located north west of the study area boundary and were surveyed using the same methods and equipment as used in the overall GPS-based gross gamma survey. A detector path spacing of approximately 10 meters and a survey speed of 1.0 meter per second was used for the areas. Figure A-5 shows the background reference areas survey data and the areas locations in relation to the OCRM survey area boundary.

6.0 Survey Results

Statistics on the OCRM gross gamma survey data collected are shown below in Table 6-1.

Table 6-1 - Gross Gamma Radiation Survey Data Statistics

Survey	Number of Records	Average	Standard Deviation	Maximum Reading	Minimum Reading
Gross Gamma Radiation (cpm)	100,269	21,729	27,843	522,983	8,106
External Exposure Rate (μR/hr)	100,269	17.55	16.71	318.30	9.38
Ra-226 Concentration (pCi/g)	100,269	7.19	13.92	257.82	0.38

The highest readings were observed primarily in mine facility area with additional elevated readings observed in isolated areas as seen in survey figures. The surveys performed surrounding two residences west of the OCRM survey area show no elevated readings present. The residence located to the east of the former mine area showed elevated readings as indicated on the survey

Statistics on the gross gamma surveys performed on the NNEPA selected background reference areas are shown in Table 6.2. The readings are consistent with readings observed in the majority of the site.

Table 6-2 –Background Area Gross Gamma Radiation Survey Data Statistics

Survey	Number of Records	Average Reading	Standard Deviation	Maximum Reading	Minimum Reading
Gross Gamma Radiation (cpm)	6,483	15,535	1,130	20,191	11,644
External Exposure Rate (μR/hr)	6,483	13.83	0.68	16.63	11.5
Ra-226 Concentration (pCi/g)	6,483	4.09	0.57	6.42	2.15

7.0 Data Quality Control

All radiological instrumentation was calibrated within a six-month period prior to use, using National Institute of Standards and Technology (NIST)-traceable sources and a reference pulse-rate generator. At the beginning of the project a location of with a background count rate of approximately 10,000 cpm was chosen for daily function checks. The site is located off highway 566 approximately 1.5 kilometers southwest of the site. Throughout the project each radiation survey instrument was function checked at this location before and after use each day. The net count rate was calculated and verified to be within 5% of the mean net count rate for that

particular instrument. The HPIC was also function checked at this location prior to use. Function check forms and calibration sheets are attached in Appendix A.

Duplicate soil samples were collected at soil sample locations 12 and 14. The error of the duplicate samples for radium was calculated using the replicate error ratio.

The RER is determined as follows:

$$RER = \frac{|S - R|}{\sqrt{(S \times 0.15)^2 + (E_S)^2} + \sqrt{(R \times 0.15)^2 + (E_R)^2}}$$

where:

RER = replicate error ratio,

S = sample value,

E_S = sample counting error (at 2 standard deviations),

R = replicate value, and

E_R = replicate counting error (at 2 standard deviations).

Results for the two duplicate samples show they are within 1.95% percent difference for Ra-226 analysis. Results show a 14% relative percent difference for U-nat. These values are acceptable.

Appendix A

Figures

Figure A-1 – GPS-Based Gross Gamma Survey

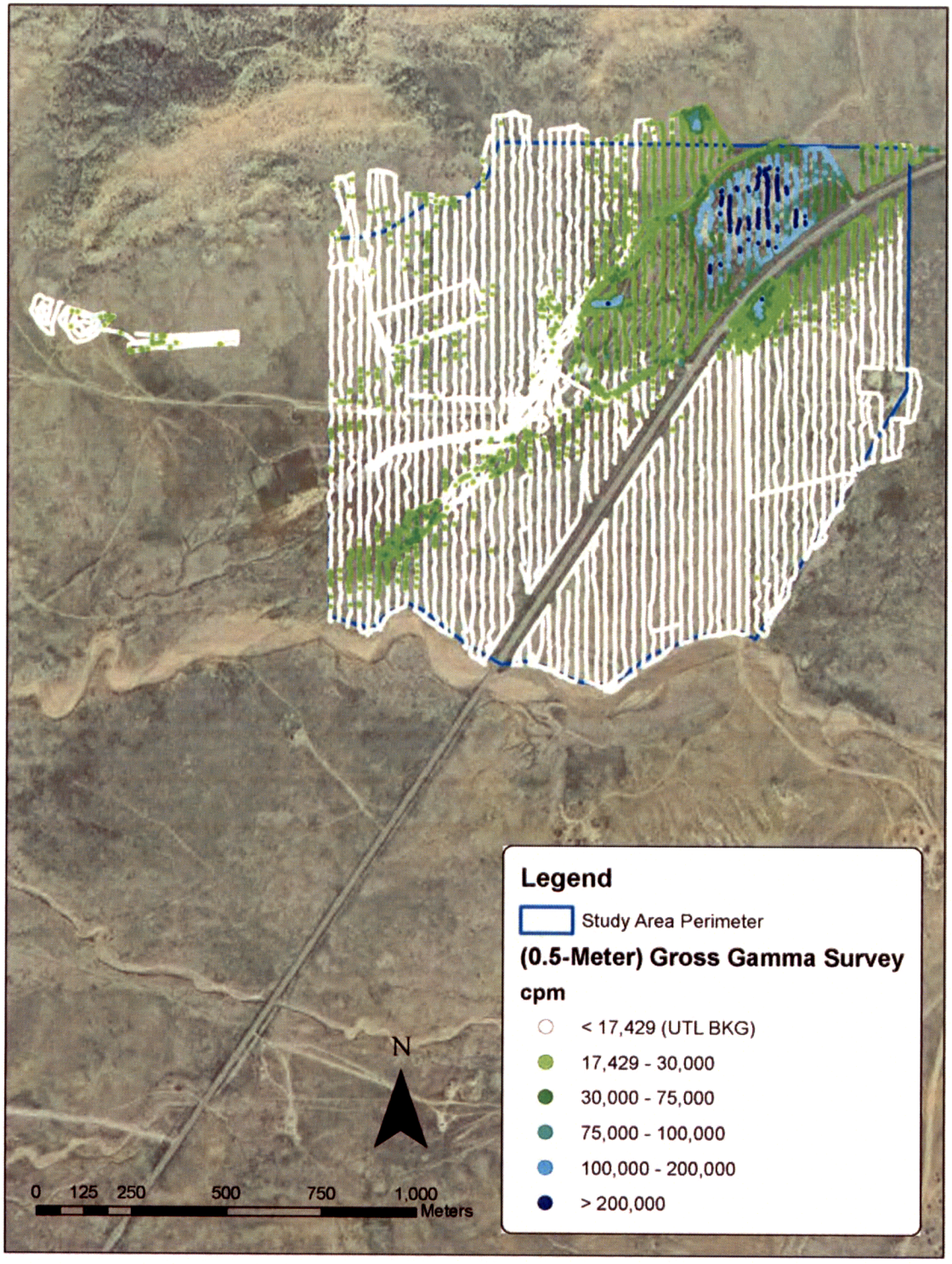


Figure A-2 – HPIC Correlation Measurement Locations

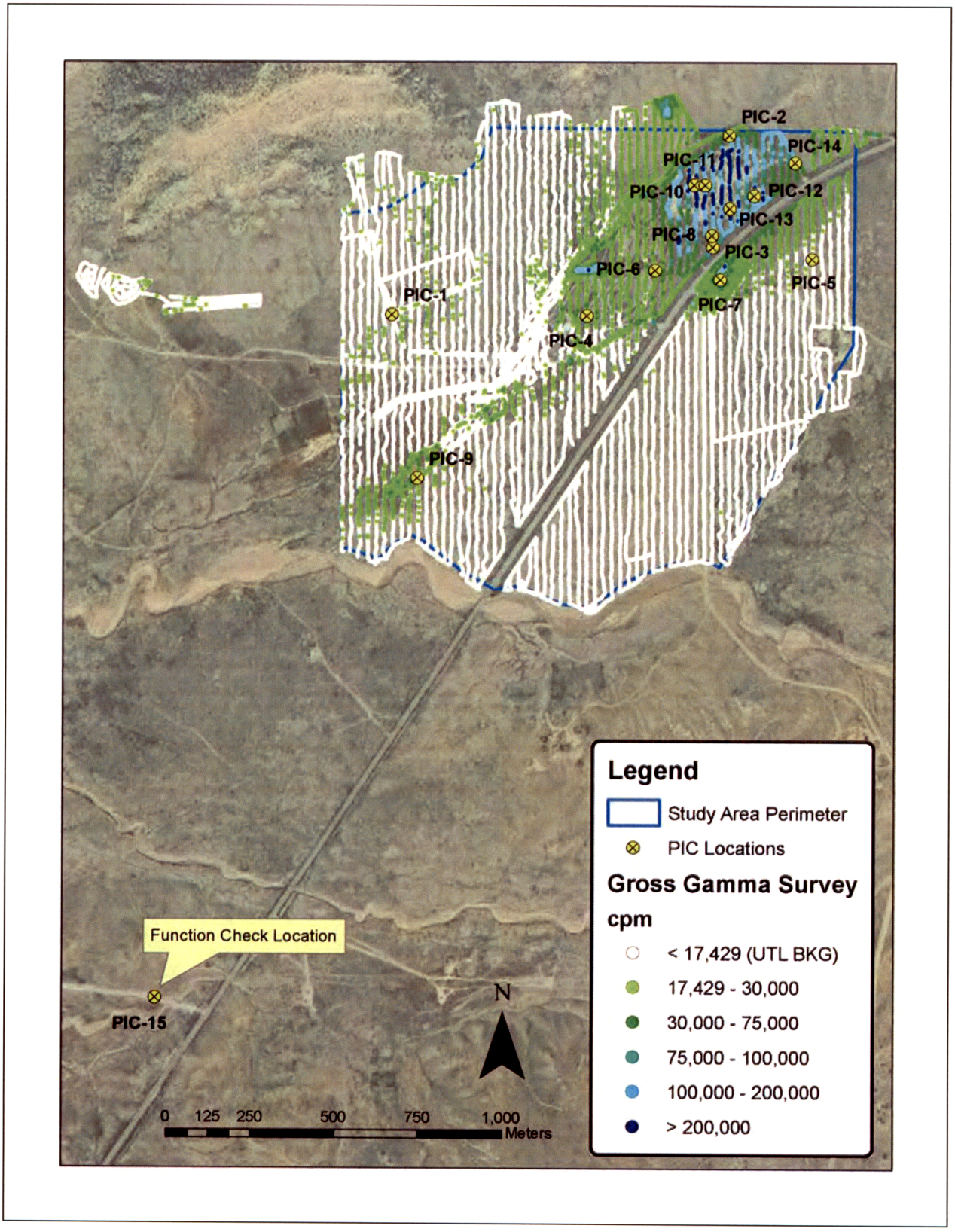


Figure A-3 – Exposure Rates for Site