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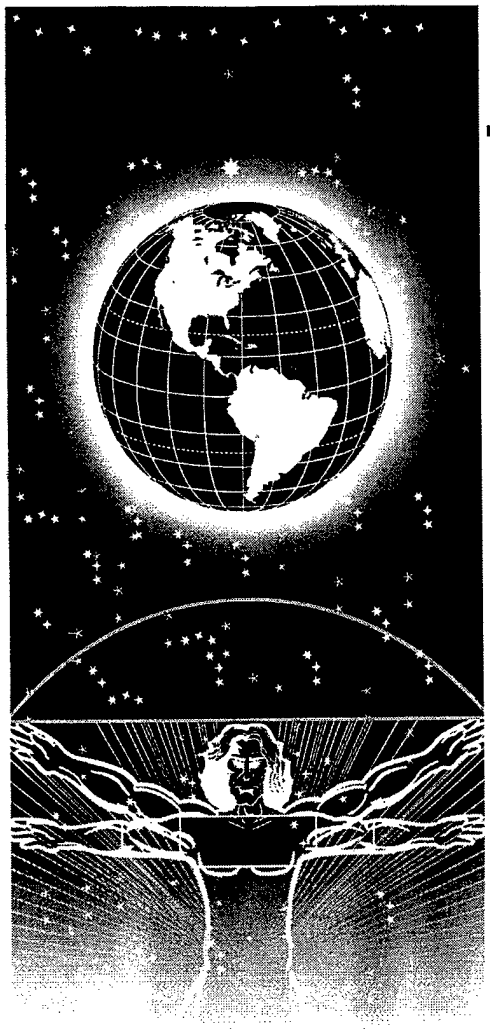

UNITED STATES AIR FORCE
IERA

Radiological Characterization Survey Report, 1964 B-58 Accident Site, Grissom Air Reserve Base, Bunker Hill, Indiana

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May 2000

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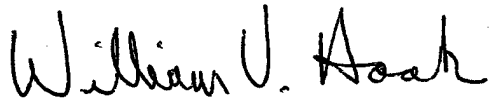

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13. ABSTRACT *(Maximum 200 words)*

On December 8, 1964, during a routine Operational Readiness Inspection, a B-58 strategic bomber skidded off the runway at Bunker Hill AFB, IN (later named Grissom Air Force Base). The consequence of the accident was a fire and destruction of five nuclear weapons on the aircraft. The high explosives in the weapons did not detonate, but melted and burned, leaving some residual radioactive contamination in soils adjacent to the runway. The contaminated area was excavated and buried along with the aircraft wreckage at a different location on base. In June 1996, the Air Force Safety Center conducted a review of both classified and unclassified documents in its possession and concluded that sufficient data did not exist to support closure of the site. Since that time, the State of Indiana and this organization performed small-scale scoping surveys that identified a small area with elevated gamma radiation exposure levels. Soil samples collected from the area indicated the presence of depleted uranium. This report details the historical site assessment, the results of the scoping surveys, and details of the comprehensive characterization survey that was accomplished in October 1999. The results of the survey confirm that a small area of the site investigated contains depleted uranium contamination. The investigation area was about 8,800 square meters and had an estimated excess surface activity concentration of 1 pCi/g averaged over the entire area. Within this area, the contamination zone is limited to an area of 1000 square meters, with a mean excess uranium activity concentration of 7 pCi/g.

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1. Introduction

a. Purpose. The purpose of this characterization survey was to collect adequate data to determine the magnitude and extent of previously reported radiological contamination on the B-58 accident site at Grissom Air Reserve Base (ARB). The field investigation occurred 25 – 27 Oct 99.

b. Site Description. The site is located in a grassy area alongside NE-SW Runway 23 (Figures 1 and 2). The area is bounded on four sides by concrete runway or taxiways and contains aircraft navigational aids and a windsock in its center. The vegetation consists of native grasses that are mowed on a regular basis to a height of less then 15 centimeters. The terrain is relatively flat but is marked by irregularly spaced depressions less then 30 centimeters deep. Approximately 50 meters southwest from the windsock a drainage ditch is terminated in a culvert.

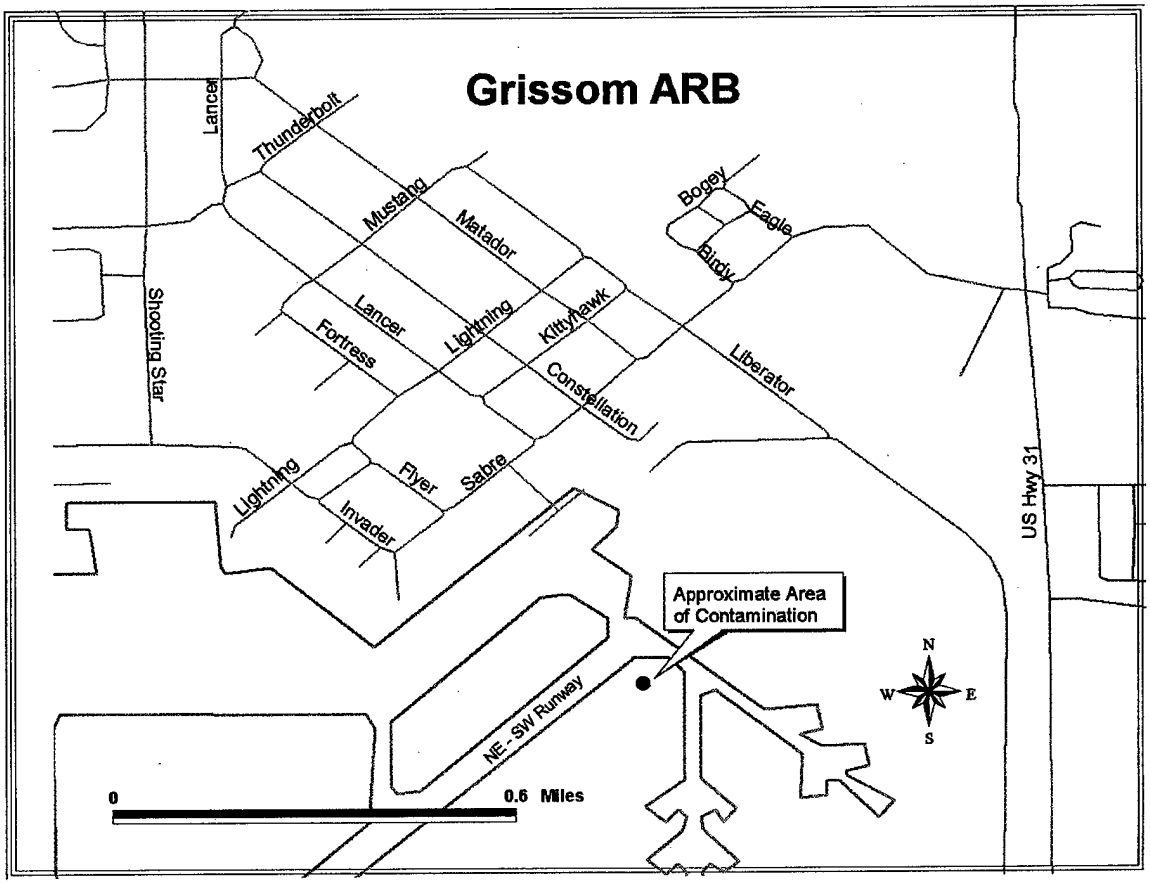


Figure 1: Site Location and Surrounding Area

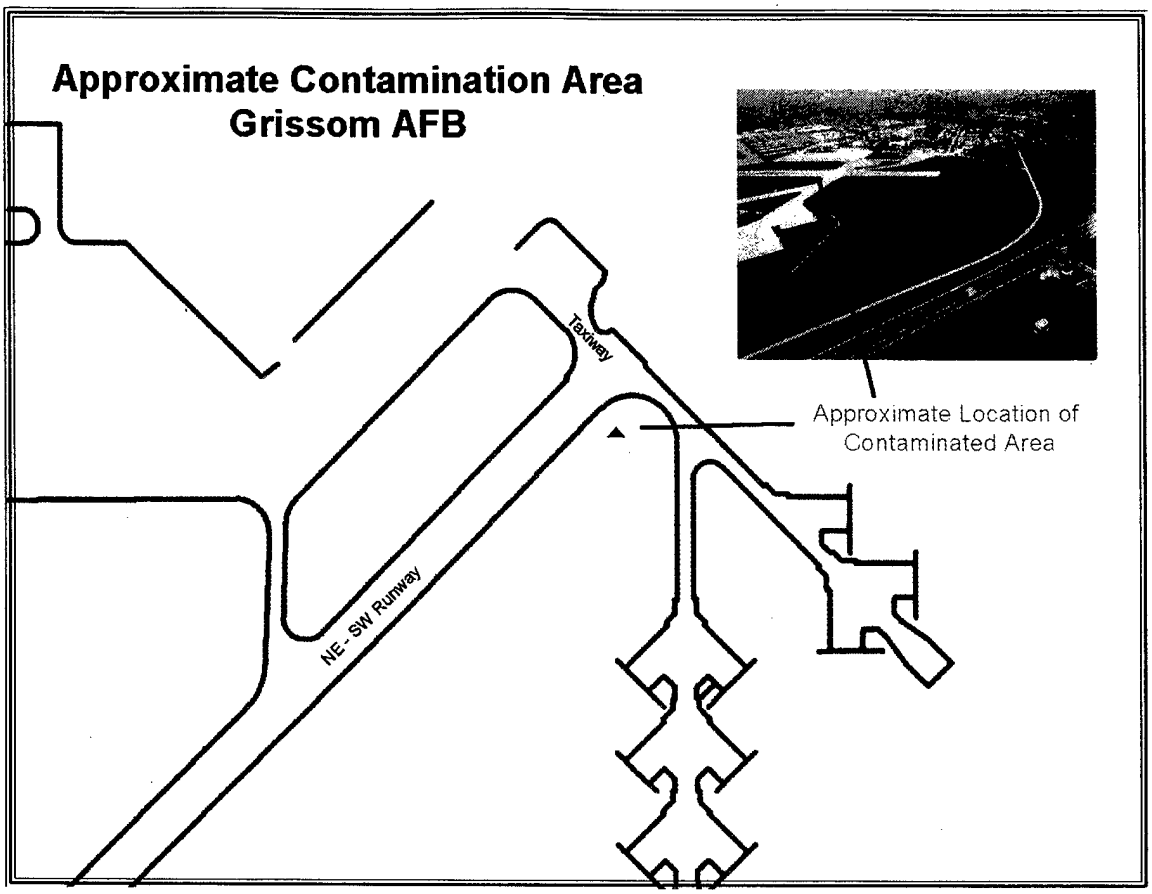


Figure 2: Site Location

Due to its close proximity to active flight operations, access to the site is tightly controlled. Grissom Air Force Base was realigned under the Base Realignment and Closure Commission and was renamed Grissom Air Reserve Base (ARB); however, it still maintains an active flying mission, with the Air Force Reserve's 434th Air Refueling Wing (ARW). The 434th ARW is equipped with 22 KC-135 Aircraft and 1300 personnel. There are currently no plans to relinquish Air Force control of the area investigated.

c. Summary Findings. The results of this survey confirm that a small region of the site investigated contains depleted uranium contamination, a contaminant identified in previous scoping survey sample analyses. Other contaminants of concern identified in the historical site assessment were not detected in samples analyzed in this effort. The results of this survey are adequate to complete a risk assessment, evaluate remediation options, and costs, if remediation is the course of action selected. The characterization determined that the site does not present immediate health hazard concerns to the public or Grissom Air Reserve Personnel working at the site.

2. Historical Site Assessment

a. Historical Record of Accident

On December 8, 1964, during a routine Operational Readiness Inspection, a B-58 strategic bomber skidded off the runway at Bunker Hill AFB, IN (later renamed Grissom Air Force Base). The landing gear subsequently collapsed, rupturing a fuel tank. The ensuing fire burnt portions of the five nuclear weapons on board the aircraft. The high explosives in the weapons did not detonate, although some portions melted and burned (Sandia 97). One weapon that caught fire was removed from the accident area, and extinguished by placing it in a shallow trench and covering it with sand. The trench was located approximately 150 ft from the aircraft wreckage in the grassy area between the runway and alert area taxiway based on written and photographic records. The precise location of the trench in investigation area is unknown. The historical record indicates radioactive contamination was confined to a 2 m x 6 m x 10 cm volume (HQ Air Force Safety Center 96). The contaminated area was excavated and buried along with the aircraft wreckage at a different location on the base (this location was not investigated during this survey). Extensive sampling of the accident area soon after the accident was said to have demonstrated that the area was free of contamination. Written documentation of the post accident sampling has not been located. Additionally, the instrumentation available at the time of the accident (primarily alpha scintillation and Geiger-Mueller detectors) coupled with the wet conditions at the time of accident was problematic.

The recovered weapons and weapon debris were sent to Atomic Energy Commission facilities in Clarksville, TN; Medina Base, TX; Rocky Flats, CO; Miamisburg, OH; and Oakridge, TN. (Sandia 97). Subsequent analysis of the damaged weapons and debris indicated that plutonium was not released to the environment because all of the plutonium bearing components were intact (Rademacher 99).

In June of 1996, the Air Force Safety Center, at the request of Grissom ARB, conducted a review of both the classified and unclassified documents in its possession and concluded that sufficient data did not exist to support unrestricted release of the site (Headquarters Air Force Safety Center 96). Subsequently, the State of Indiana Department of Health (IDH) performed gamma exposure rate measurements and collected soil samples from the accident site. The IDH identified a small area with γ-radiation exposure rates eight to ten times background rates. Soil samples collected from this

area contained concentrations that were several hundred times background for ^{238}U. ^{235}U and ^{234}U concentrations were also elevated in proportion to that of depleted uranium. Plutonium concentrations were consistent with levels typical of background (EPA 96).

During a February 1999 meeting of representatives from Grissom ARB, the Air Force Safety Center, IDH, and the US Environmental Protection Agency it was agreed that further steps were warranted to characterize the crash site. Grissom ARB requested the assistance of and provided funding for the Air Force Institute for Environment, Occupational Safety, and Health Risk Assessment (IERA), Brooks AFB, TX, to perform a radiological characterization and risk assessment of the crash site.

b. Contaminants of Concern

Based on the nature of nuclear weapon involved in the accident and the results of measurements conducted by both IDH and IERA, both weapons grade (natural uranium enriched in the ^{235}U and ^{234}U isotopes) and depleted uranium (natural uranium depleted in ^{235}U and ^{234}U isotopes) are the contaminants of concern. Based on the results of preliminary soil samples and historical records review, plutonium and beryllium are not likely contaminants. Ten percent of the soil samples collected were analyzed for beryllium to further ensure they are not present at the site. All γ-spectroscopy analyses have shown no activity concentration of ^{241}Am above minimum detectable concentrations. Presence of significant concentrations of ^{241}Am would be indicative of potential weapons grade plutonium contamination.

Uranium, a naturally occurring radioactive element, is silver-white in its pure form. It is a heavy metal nearly twice as dense as lead (19 g cm^{-3}). Uranium occurs in nature in a wide variety of solid, liquid, and gaseous compounds. It readily combines with other elements to form uranium oxides, silicates, carbonates and hydroxides. These compounds range from being highly mobile (soluble) to being relatively immobile (insoluble) in the environment.

Uranium metal alloys are readily machinable and have metallurgical properties similar to those of high-strength steels. Finely divided uranium metal is pyrophoric (i.e., burns spontaneously in air). A comparison between naturally occurring uranium and depleted uranium is shown in Table 1. Table 2 provides a partial list of nuclides and their emissions from the ^{238}U decay series. The ^{235}U decay series is shown in Table 3.

Table 1: Characteristics of Natural and Depleted Uranium.

Material	Component by Weight Percentage				Specific Activity ($\mu Ci\ g^{-1}$)
	^{234}U	^{235}U	^{236}U	^{238}U	
Natural U	0.0057%	0.72%	0%	99.28%	0.7
Depleted Uranium	0.0001%	0.20%	0.0003%	99.8%	0.4

Table 2: U-238 Decay Series.

Isotope	Half-life	Radiation	Energy (MeV)	Percent Yield
^{238}U	4.5×10^9 y	α	4.2	75
			4.15	23
		γ	0.0496	0.07
^{234}Th	24 d	β	0.192	65
			0.100	35
		γ	0.092	4
^{234m}Pa	1.2 min	β	2.29	98
			1.53	<1
			1.25	<1
		γ	0.39	0.13
			0.817	4
^{234}U	2.5×10^5 y	α	4.77	72
			4.72	28
		γ	0.093	5

Table 3: U-235 Decay Series.

Isotope	Half-life	Radiation	Energy (MeV)	Percent Yield
^{235}U	7.1×10^8 y	α	4.32	3
			4.21	5.7
			4.58	8
			4.5	1.2
			4.4	57
			4.37	18
		γ	0.110	2.5
			0.143	11
			0.163	5
			0.185	54
			0.205	5
^{231}Th	25.64 h	β	0.302	52
			0.218	20
			0.138	22
		γ	0.026	2
			0.085	10

c. May 1999 Scoping Survey.

On 27 May 99, IERA along with representatives from the EPA, IDH, and Grissom ARB visited the accident site to collect soil samples and perform external gamma radiation measurements. Seven soil samples were collected by IERA, including two from a background reference area located on the other side of the flight line, approximately 400 meters away. The EPA surveyed the area using a 3 x 3 NaI detector (3 inch by 3 inch) coupled with a portable multi-channel analyzer. While areas of

elevated activity were found, the precise area where IDH had identified significantly elevated exposure rates and collected soil samples in 1996 could not be confirmed.

The results of α-spectroscopy analyses of the soils collected by IERA are shown in Table 4. The approximate collection location is shown in Figure 3. The radioactivity concentration levels from sample locations 1 and 2 are consistent with those of the background area. The activity concentration of soil from locations 3, 4, and 5 are significantly higher than background. The mass ratio of ^{235}U to ^{238}U in naturally occurring uranium is generally reported to have a value of 0.71%. The ^{235}U to ^{238}U mass ratio for samples 3, 4, and 5 is significantly less. This result is consistent with the soil analyzed by the Environmental Protection Agency for the IDH. The wide variation in the ^{235}U to ^{238}U ratio values in the background samples is most likely due to the high uncertainties from counting low activity samples. All seven samples were submitted to IERA's Analytical Chemistry Division for beryllium analysis. None had beryllium concentrations above the detection limit of 0.50 $\mu g\ g^{-1}$.

Table 4: Scoping Survey Soil Sample α-Spectroscopy Analysis Results.

Sample Number	Location	Activity Concentration ($pCi\ g^{-1}$)			Mass Percent ^{235}U
		^{234}U	^{235}U	^{238}U	
1	Surface Soil sample	0.59	0.06	0.7	1.3 %
2	Surface Soil sample	0.4	0.04	0.66	0.95 %
3	Surface Soil sample	9.2	1.2	41	0.45 %
4	Surface Soil sample	12	1.6	66	0.39 %
5	Soil at 4 inches below ground surface	14	1.7	79	0.34 %
6	Background	0.52	0.04	0.77	0.81 %
7	Background	0.49	0.06	0.54	1.7 %

Figure 4 contains a plot of the ^{238}U to ^{234}U activity ratio with respect to total uranium ($^{234}U + ^{235}U + ^{238}U$) for the soil samples collected in May 1999 and 1996. The plot contains theoretical ratios for natural, depleted, and enriched uranium contamination in the presence of 1.1 $pCi\ g^{-1}$ of natural

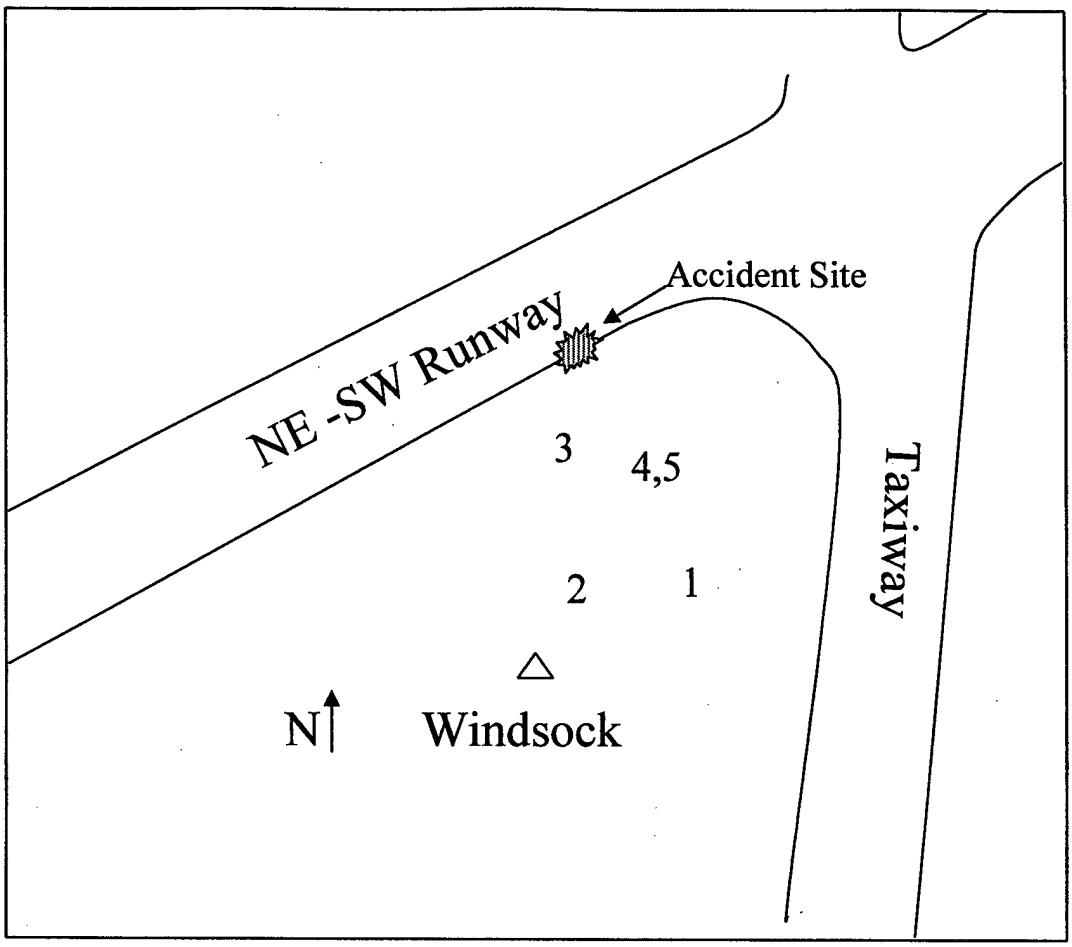


Figure 3: Approximate Scoping Survey Sample Locations

background uranium. Because the precise isotopic concentration of weapons grade uranium is classified, the example for enriched uranium in the plot is based on generic numbers only. From examination of the data in the plot, there is a good agreement between the May 1999 data and the characteristics of depleted uranium.

d. Extent of Contamination

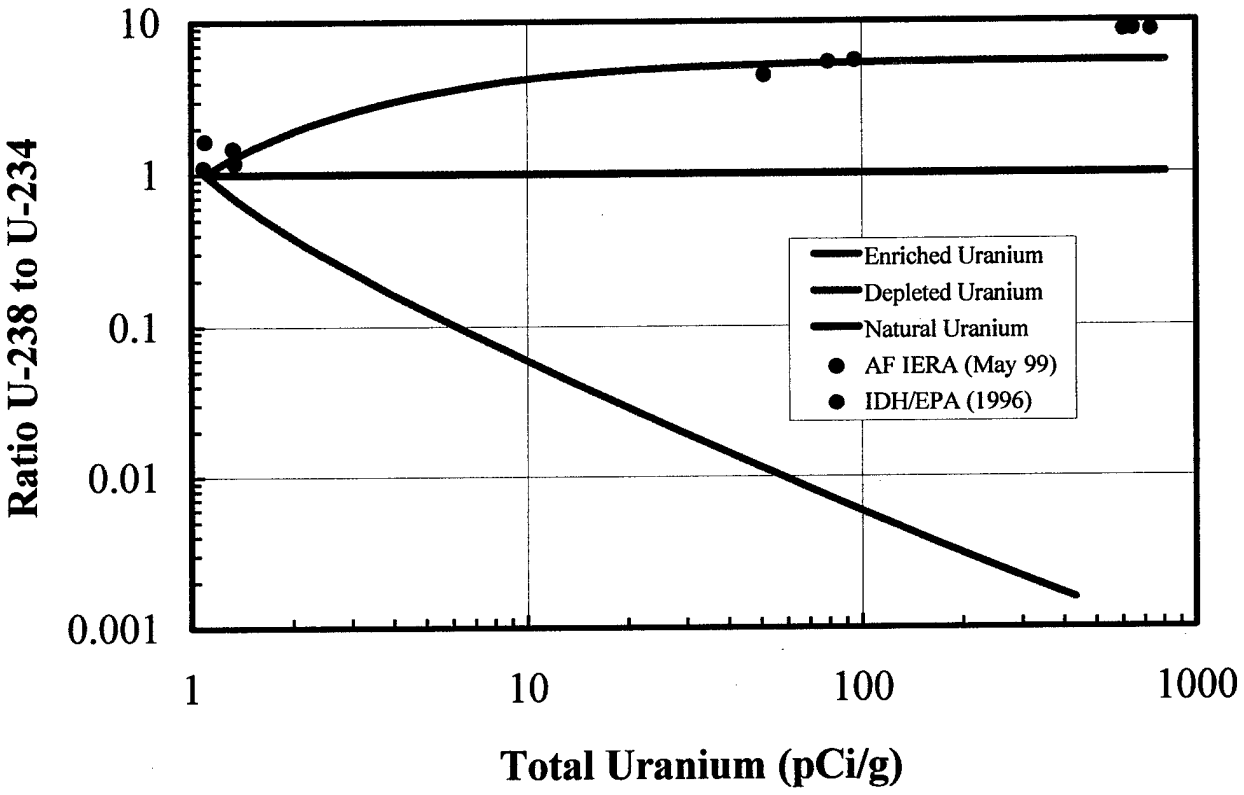
The historical record, conditions present at the time of the accident, and survey results to date all indicate that the contamination is contained within the upper left quadrant of the investigation area shown in Figure 1. The two events that are likely to be responsible for release of radioactive material to the environment are:

- the accident and ensuing fire along the edge of the runway and
- the effort to extinguish the burning weapon by placing it in the trench.

Both events occurred in the investigation area. The burning weapon and associated smoke plume had the potential to cause contamination outside of the immediate area; however, the weather

conditions and fire fighting activities likely minimized the magnitude of the plume height and transport. The U.S. Public Health Service conducted air sampling and snow sampling at a distance of 500 to 650 m from the accident and detected no activity above minimum detection limits (0.04 pCi m^{-3} (air) and 5 pCi L^{-1} (water)) (U. S. Public Health Service 64). After the fire was extinguished the weapons were moved to the weapons storage area for inspection and packaging for shipment to AEC facilities. The weapons storage area was surveyed in 1992. One small area was found to have elevated uranium (0.5 – 1.0 pCi g^{-1} ^{235}U, 0.6 pCi g^{-1} ^{238}U). This area was remediated and the facility released for unrestricted use as part of a routine decommissioning effort (Armstrong Laboratory 92).

Figure 4. U-238 to U-234 Ratios for Depleted, Enriched, and Natural Uranium in Soils with a Natural Background of 1.1 pCi/g Total Uranium (1996 and May 1999 Scoping Data Included).



3. Methodology

a. Survey Team Personnel. Table 5 lists the survey team personnel.

Table 5: Survey Team Personnel

Name	Position	Organization
Major William Hoak, CHP	IERA Leader/Survey Chief	IERA/SDRH, Brooks AFB TX
Major Steven Rademacher, PhD, CHP	AF Regulatory Oversight	Air Force Safety Center, Kirtland AFB NM
2nd Lt Jessica Joyner	Chemist/Sample Control	IERA/SDRR, Brooks AFB TX
TSgt David Martin	Health Physics Technician	IERA/SDRH, Brooks AFB TX
SSgt Alvaro Magana	Health Physics Technician	IERA/SDRH, Brooks AFB TX
SSgt Jeffery Compton	Health Physics Technician	IERA/SDRH, Brooks AFB TX

b. Data Collection

The data collection was accomplished using many of the techniques and methods recommended in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NUREG 1575). While the purpose of MARSSIM is to provide guidance for final status surveys (i.e. after remediation) much of its guidance is applicable to characterization surveys. The objectives of the characterization survey include:

- Determine the nature and extent of the contamination
- Evaluate remedial alternatives and technologies
- Evaluate whether survey plan can be optimized for use in the final status survey
- Provide input to the final status survey design

c. Instrumentation and Analytical Methods

General. Table 6 lists the measurements that were accomplished in the background and accident regions; and analyses performed on soil samples collected from these regions. EPA (EPA 99) proposed a preliminary remediation goal (PRG) of 10 pCi g^{-1} total uranium above background for an industrial scenario and 3 pCi g^{-1} for a residential scenario. Direct measurements (fixed in-situ) used to define the average radiological conditions of a site should be capable of measuring levels 10-50% below the desired concentration guidelines (MARSSIM 97). Detection of uranium contamination at these levels in the environment by in-situ methods presents many challenges if the contaminant is natural or depleted. Direct measurements using scanning techniques are performed to locate potential anomalies, indicative of small areas of high residual gross activity

that may require further investigation (i.e collection of discrete soil samples and fixed in-situ measurements). Soil sampling and subsequent analysis provides greater precision and specificity of radionuclides contained in the sample.

Depleted Uranium. The analysis for depleted uranium exploits the more easily detected gamma radiation from its decay daughters. Shortly after ^{238}U is separated from the other materials, there is in-growth of decay daughters. Within a few months, secular equilibrium is established between ^{238}U and the daughters down to ^{234}Pa ($^{238}U \rightarrow {}^{234}Th \rightarrow {}^{234m}Th \rightarrow {}^{234}Pa$). Activity concentration levels of the daughter radionuclides, as determined by γ-spectroscopy analysis, directly express to the ^{238}U activity concentration.

Scanning Measurements. Scans of the investigation area were accomplished using a 3 x 3 NaI (Tl) detector coupled with a ratemeter/scaler. Since the contaminants of concern emitted γ-radiations across a broad range of energies, the detector was operated in gross counts mode. Background count rates were established in the background area. The entire accident investigation area was scanned in an "S" pattern with the width of each pass being approximately 3 m. The detector was held at approximately 10 cm from the ground surface and moved over the surface at approximately 0.5 m s^{-1}. Any ratemeter measurement (updated every two seconds) that exceeded the 99.9 % confidence interval of background was flagged for an additional fixed measurement and soil sample.

Instrument Calibrations. All portable Air Force field instrumentation was calibrated at the IERA Radiation Instrumentation Calibration Facility. The portable gamma radiation exposure meter used by the IDH was calibrated by the manufacturer, 16 Feb 99.

Surface Soils. Surface soils were collected from each grid location. Each sample was a composite of four sub-samples collected from random locations within the grid block. Nominal sample size was about two kilograms. The samples were collected using a small shovel. The shovel was decontaminated using distilled water between samples. Samples were containerized in one gallon screw top HPDE soil jars (NSN 8125-01-227-6038). The sample containers were wiped with a damp cloth prior to packaging to remove exterior contamination. The container lids were sealed with tape and packaged in partitioned cardboard boxes. Chain of custody was documented on a chain of custody form with specific sample data recorded on an AF Form 2753,

Radiological Sampling Data. To maintain chain of custody, all samples were under constant observation, or secured. All sample labels were completed using waterproof ink.

Table 6: Instrumentation and Analytical Methods

Measurement Type	Location	Instrumentation	Estimated Minimum Detectable Concentration
In-situ gamma (scanning)	Entire accident region – 4" above surface	3 x 3 NaI (Tl) detector (Bicron) w/ Ludlum 2221 Ratemeter/Scaler	25 pCi g^{-1} (DU)*
Surface soil samples	Surface samples from top 3" of soil – composite within grids Core samples – surface to clayey layer	Laboratory gamma spectroscopy – U-238 U-235 Ra-226 Am-241 Laboratory radon emanation (Ra-226) Laboratory alpha spectroscopy – U-234, U-235, U-238, Pu-239/240	 1.0 pCi g^{-1} 0.1 pCi g^{-1} 1.0 pCi g^{-1} 0.5 pCi g^{-1} 0.1 pCi g^{-1} 0.1 pCi g^{-1}
In-situ gamma (Fixed)	Selected locations in accident & back-ground regions – 10 cm above surface	3 x 3 inch NaI (Tl) detector (Bicron) w/ Ludlum 2221 Ratemeter/Scaler	10 pCi g^{-1} (U)**
Gamma Exposure	Selected locations in accident region	Explorium Model GR-130 S/N 9894	5 μR h^{-1}
Beryllium	Selected samples from accident region - highest total U activity concentrations	EPA Method SW 3050/6010B	50 μg g^{-1}

* See Appendix 1 ** Based on Site Measurements Compared to Soil Sampling Results

Core Soil Samples. Core samples were collected at select locations with the objective of determining the depth distribution of the contaminant, depth distribution of natural background radionuclides, and contaminant concentrations at discrete locations. Sample depth was limited due to difficulties in penetrating the clayey layer. The samples were collected with a manual split spoon sampler. The samples were containerized in one gallon screw top HPDE soil jars (NSN 8125-01-

227-6038). Chain of custody and processing procedures were identical to surface soils. The split spoon sampler was decontaminated using distilled water and chem wipes between samples.

Reference Coordinate System. The accident investigation region was sectioned off into 10 m x 10 m grids. The general layout is shown in Figure 5. The grid lines will run North-South and East-West. The grid was constructed using a compass, a GPS receiver, 100 m tape, and flags to mark the corner of each grid block. The windsock present at the site serves as the reference point for the coordinate system. Note that the windsock was moved after the scoping survey approximately 20 m to the SE from its original location. The reference coordinate system delineated in the workplan differs from the coordinate system in this report for this reason.

d. Quality Assurance/Quality Control

General. Quality assurance (QA) refers to the planning, implementation, and oversight conducted to ensure the data produced can be used as intended for interpretation and decision making. QA measures that were implemented included chain of custody controls and documentation, review of data collection procedures and documentation, and review of laboratory results. Quality Control (QC) is the system or series of activities conducted to control and measure the validity and completeness of the data produced. QC measures that were implemented include function and radiation response checks at the beginning and end of each workday for radiation detection instrumentation and use redundant radiation detector systems (duplicate measurements). QC measures for collection of soils included collection of one set of QC samples for every ten samples of a given type (soil surface, subsurface) collected. The set of QC samples consists of the following:

- **Collocated Samples**: Collocated samples are samples collected adjacent to the routine field sample to determine local variability of the radionuclide concentration. Typically, collocated samples are collected about one-quarter to one meter away from the selected sample location. Analytical results from collocated samples can be used to assess site variation, but only in the immediate sampling area.
- **Field Replicates**: Field replicates are those obtained from one location, homogenized, divided into separate containers, and treated as separate samples throughout the remaining sample handling and analytical processes. These samples are used to assess error associated with sample heterogeneity, sample methodology and analytical procedures.

- **Background Sample**: Background sample are those collected in an area where there is little or no chance of migration of the contaminants of concern. Background samples are collected from the background reference area and are considered "clean" samples. They provide a basis for comparison of contaminant concentration levels with samples collected from the site of suspected contamination.

Additionally, Indiana State Department of Health collected a number of samples for comparison to IERA analyses results.

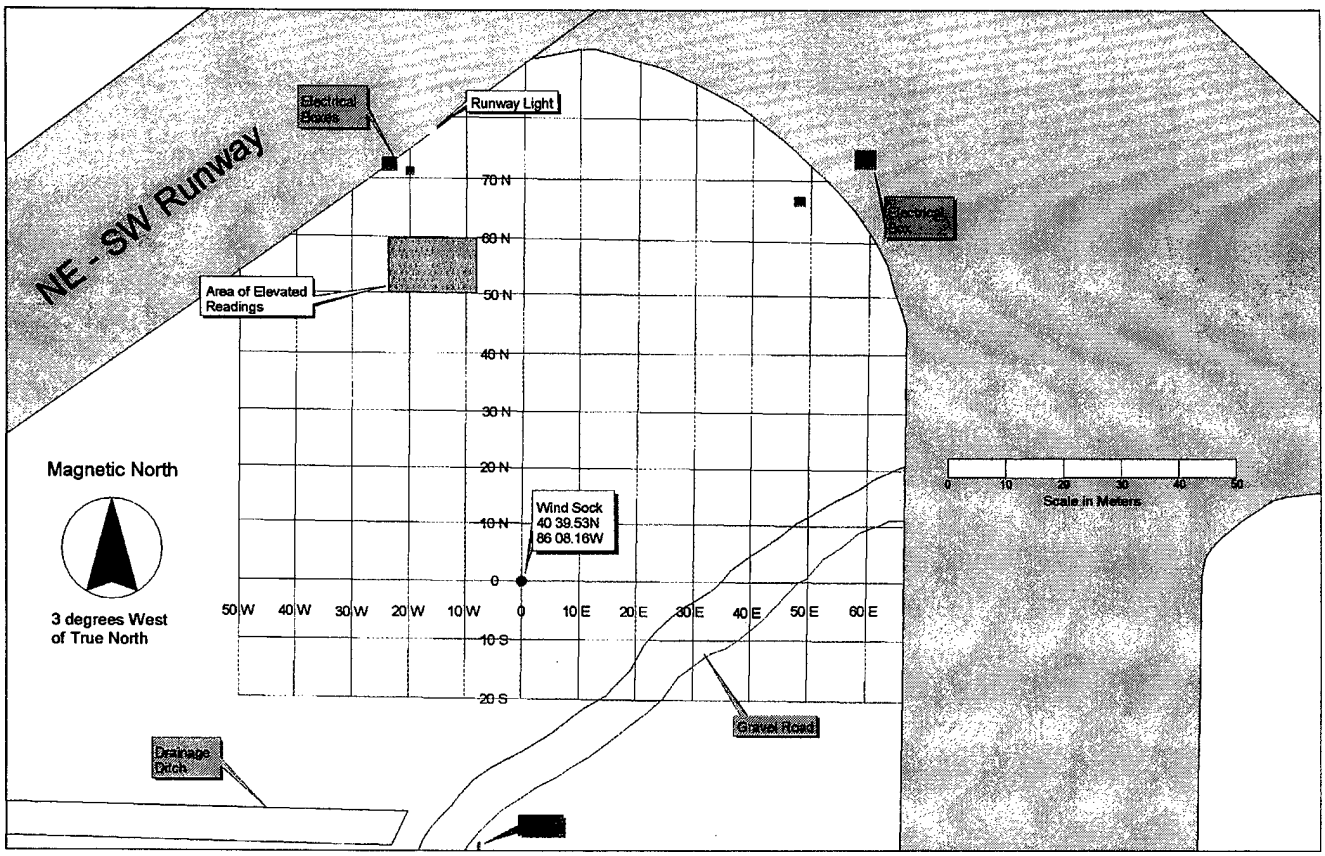


Figure 5: Reference Coordinate System

4. Characterization Results

a. Background Region In-Situ Gamma Measurements and Soil Sampling Results

γ-Spectroscopy and Gross Alpha Analysis. Table 7 contains the γ-spectroscopy and gross alpha analysis results for the background sampling region. The γ-spectroscopy results are listed for ^{234}Th and ^{235}U; complete analyses are listed in Appendix 2 according to Base Sample

Number. Because ^{234}Th is in equilibrium with ^{238}U, the reported ^{234}Th activity concentrations are equivalent to that of ^{238}U. Of the 28 sample results reported, half are below the MDC. MDC values ranged from 0.5 to 1.1 pCi g^{-1}. The mean ^{234}Th activity concentration is 0.87 pCi g^{-1} (maximum = 1.2 pCi g^{-1}), with a standard deviation of 0.2 pCi g^{-1}, using the MDC in place of the activity concentration for samples with an unreported concentration. This type of estimator is inherently high biased. As well, because results reported as being below the MDC are assumed to have a concentration equal to the MDC, variability in the data set is underestimated. Only four samples had a reported ^{235}U, with the highest being 0.18 $\pm$ 0.05 pCi g^{-1}. Due to the high fraction of samples with reported ^{235}U concentrations below the MDC, estimation of the background ^{235}U cannot be made. The mean gross alpha concentration is 2.0 pCi g^{-1}, with a standard deviation of 0.3 pCi g^{-1}, and range of 1.6 to 3.0 pCi g^{-1}. All of the ^{241}Am analyses were below the MDC. For the analyses, the MDC varied between 0.03 and 0.1 pCi g^{-1}, with a minimum of 0.06 pCi g^{-1}.

In-Situ Gamma Measurements. Table 8 contains the fixed in-situ gamma measurements from the background region. Two-minute count times were used. The mean (μ) count rate is 22,676 counts per minute (cpm), with a standard deviation (σ) of 631 cpm, and a percent coefficient of variation (100 * σ/μ) of 2.8 %. There are many sources of variability in the observed count rate of this instrumentation and include variability in background radiation, random counting statistics, and electrical variations in the measurement system. For two minute counting periods, random counting statistics represents a very small contribution (~ 3 %) to total variability.

b. Scanning Threshold for In-Situ Measurements of the Accident Region

The Ludlum Model 2221 Ratemeter/Scaler can be operated in either rate or scaler mode. For scanning measurements, the instrument was operated in the rate mode, with count rate updates every two seconds. Based on the data of Table 8, the probability of a count rate update in excess of 26,000 cpm is less than 0.07 %. For instrument updates every two seconds, the false positive rate (e.g. reporting excess radiation in a condition of background) is about 1.3/hour. A threshold of 26,000 cpm was chosen to insure that scanning primarily identified regions of contamination rather than variations in background and/or random counting statistics.

Table 7: Gamma Spectroscopy and Gross Alpha
Results For Background Sampling Region

Sampling Location		Base Sample Number	Activity Concentration pCi/g		
			^{234}Th	^{235}U	Gross Alpha
Bkgd-1	Surface	GS9900277	< 1.1	< 0.1	1.8 ± 0.7
Bkgd-2	Surface	GS9900278	< 1.1	< 0.1	2.0 ± 0.6
Bkgd-3	Surface	GS9900279	< 1.0	< 0.1	1.9 ± 0.6
Bkgd-4	Surface	GS9900280	< 1.1	< 0.12	1.7 ± 0.6
Bkgd-5	Surface	GS9900281	< 1.1	< 0.1	1.9 ± 0.6
Bkgd-6	Surface	GS9900282	< 0.74	< 0.1	2.4 ± 0.6
Bkgd-7	Surface	GS9900283	< 1.1	< 0.1	2.0 ± 0.6
Bkgd-8	Surface	GS9900284	< 1.1	0.09 ± 0.07	1.8 ± 0.6
Bkgd-9	Surface	GS9900285	0.9 ± 0.3	< 0.03	1.7 ± 0.9
Bkgd-10	Surface	GS9900286	0.8 ± 0.5	< 0.06	2.2 ± 0.6
Bkgd-11	Surface	GS9900287	1.0 ± 0.6	< 0.06	1.6 ± 0.6
Bkgd-12	Surface	GS9900288	0.7 ± 0.3	< 0.03	2.1 ± 0.7
Bkgd-13	Surface	GS9900289	1.0 ± 0.3	< 0.02	2.3 ± 0.6
Bkgd-14	Surface	GS9900290	1.1 ± 0.3	< 0.02	1.9 ± 0.7
Bkgd-15	Surface	GS9900291	0.8 ± 0.3	< 0.03	2.1 ± 0.7
Bkgd-16	Surface	GS9900292	0.7 ± 0.3	< 0.02	2.2 ± 0.6
Bkgd-17	Surface	GS9900293	0.9 ± 0.3	< 0.02	1.9 ± 0.6
Bkgd-18	Surface	GS9900294	0.9 ± 0.3	< 0.03	2.1 ± 0.7
Bkgd-19	Surface	GS9900295	1.0 ± 0.3	< 0.02	2.0 ± 0.6
Bkgd-20	Surface	GS9900296	< 0.5	< 0.06	2.6 ± 0.7
Bkgd-core-1	0 – 1 ft	GS9900297	0.7 ± 0.6	< 0.06	1.9 ± 0.7
Bkgd-core-1	1 – 2 ft	GS9900298	0.6 ± 0.5	< 0.06	1.8 ± 0.6
Bkgd-core-2	0 – 1 ft	GS9900299	< 0.7	< 0.07	1.8 ± 0.6
Bkgd-core-2	1 – 2 ft	GS9900300	< 0.6	0.12 ± 0.05	2.0 ± 0.7
Bkgd-core-3	0 – 1 ft	GS9900301	1.2 ± 0.6	< 0.06	2.1 ± 0.7
Bkgd-core-3	1 – 2 ft	GS9900302	< 0.7	< 0.07	2.2 ± 0.6
Bkgd-core-4	0 – 1 ft	GS9900303	< 0.5	0.11 ± 0.05	3.0 ± 0.7
Bkgd-core-4	1 – 2 ft	GS9900304	< 0.7	0.18 ± 0.5	2.2 ± 0.7

Uncertainty Values at the 95 % Confidence Level

c. In-Situ Gamma Measurement and Soil Sample Results for Accident Region

General-Grids. Table 9 contains the γ-spectroscopy and gross alpha analysis results for the accident region. The γ-spectroscopy results are listed for ^{234}Th and ^{235}U; complete analyses results are listed in Appendix 2 according to Base Sample Number. ^{234}Th analyses results between 2 and 4 pCi g^{-1} are displayed in blue, while those > 4 pCi g^{-1} are in red.

Table 8. Fixed In-Situ Gamma Measurements of Background Region with 3 x 3 NaI(Tl) at 10 cm from Surface

Location Number	Counts (2-minutes)	Standard Error (counts)
1	46087	215
2	46629	216
3	46494	216
4	45702	214
5	44902	212
6	45273	213
7	44688	211
8	44834	212
9	42766	207
10	44229	210
11	46411	215
12	46924	217
13	45742	214
14	47607	218
15	44933	212
16	43172	208
17	43934	210
18	44778	212
19	45282	213
20	46647	216

^{235}U in Grids. For ^{235}U, a vast majority of the sample activity concentrations were below the MDC, similar to that reported for the background region, with 0.40 ± 0.08 pCi g^{-1} being the highest reported activity concentration. This sample had a corresponding ^{234}Th activity concentration of 18 ± 2 pCi g^{-1}, to provide a ^{238}U to ^{235}U ratio of 45 ± 10 (2σ), characteristic of depleted uranium. For the other grids, the ^{235}U activity concentrations are similar to those of the background region.

^{238}U in Grids. For ^{234}Th analyses, seven of the grids had a mean surface activity concentration greater than 4 pCi g^{-1}. Three of the grids had a mean surface activity concentration between 2 and 4 pCi g^{-1}, while the remainder (78) were less than 2 pCi g^{-1}.

Gross Alpha in Grids. The mean gross alpha concentration is 2.2 pCi g^{-1}, with a standard deviation of 0.4 pCi g^{-1}, and range of 1.5 to 4.4. The mean for the accident region is about 10 % greater than the background region.

Table 9. Gamma Spectroscopy and Gross Alpha Results
for Accident Region – Grid Sampling - Composites

Sampling Location		Base Sample Number	Activity Concentration pCi/g		
			^{234}Th	^{235}U	Gross Alpha
0N – 50E	Surface	GS9900362	1.5 ± 1.4	< 0.1	1.7 ± 0.5
10N – 50E	Surface	GS9900366	0.7 ± 0.5	< 0.07	2.3 ± 0.6
20N – 50E	Surface	GS9900359	0.7 ± 0.5	< 0.07	1.7 ± 0.5
30N – 50E	Surface	GS9900363	1.2 ± 0.5	< 0.03	2.0 ± 0.6
40N – 50E	Surface	GS9900364	< 0.7	< 0.08	2.4 ± 0.6
50N – 50E	Surface	GS9900365	0.9 ± 0.5	< 0.03	2.3 ± 0.6
60N – 50E	Surface	GS9900367	1.0 ± 0.5	< 0.03	1.9 ± 0.6
70N – 50E	Surface	GS9900356	1.6 ± 0.5	< 0.04	1.6 ± 0.5
0N – 40E	Surface	GS9900353	0.8 ± 0.3	< 0.03	1.2 ± 0.5
10N – 40E	Surface	GS9900355	0.7 ± 0.3	< 0.03	2.5 ± 0.7
20N – 40E	Surface	GS9900354	< 1.0	< 0.01	2.6 ± 0.7
30N – 40E	Surface	GS9900351	1.1 ± 1.0	< 0.01	2.4 ± 0.7
40N – 40E	Surface	GS9900350	0.8 ± 0.3	< 0.03	2.1 ± 0.6
50N – 40E	Surface	GS9900352	0.7 ± 0.3	< 0.03	2.5 ± 0.7
60N – 40E	Surface	GS9900348	1.8 ± 0.7	< 0.06	2.5 ± 0.7
70N – 40E	Surface	GS9900349	< 1.1	< 0.01	2.3 ± 0.6
80N – 40E	Surface	GS9900347	< 0.5	< 0.06	2.7 ± 0.7
0N – 30E	Surface	GS9900337	< 1.6	< 0.02	2.1 ± 0.6
10N – 30E	Surface	GS9900333	< 1.9	< 0.02	2.5 ± 0.7
20N – 30E	Surface	GS9900332	< 1.7	< 0.01	1.8 ± 0.6
30N – 30E	Surface	GS9900342	0.9 ± 0.4	< 0.03	2.1 ± 0.6
40N – 30E	Surface	GS9900340	1.2 ± 0.4	< 0.03	2.1 ± 0.7
50N – 30E	Surface	GS9900331	0.5 ± 0.3	< 0.04	2.0 ± 0.6
60N – 30E	Surface	GS9900338	< 1.6	< 0.02	2.4 ± 0.7
70N – 30E	Surface	GS9900343	< 0.7	0.08 ± 0.05	2.3 ± 0.6
80N – 30E	Surface	GS9900341	0.7 + 0.6	< 0.07	2.3 ± 0.6
0N – 20E	Surface	GS9900325	1.2 ± 0.6	< 0.06	1.7 ± 0.6
10N – 20E	Surface	GS9900326	< 1.1	0.11 + 0.07	1.7 ± 0.6
20N – 20E	Surface	GS9900327	1.1 + 0.4	< 0.04	2.1 ± 0.6
30N – 20E	Surface	GS9900328	< 1.0	0.20 + 0.08	2.4 ± 0.7
40N – 20E	Surface	GS9900329	< 1.6	< 0.02	2.4 ± 0.6
50N – 20E	Surface	GS9900330	0.7 ± 0.4	< 0.04	1.5 ± 0.5
60N – 20E	Surface	GS9900335	< 1.6	< 0.02	2.1 ± 0.6
70N – 20E	Surface	GS9900336	< 1.6	< 0.01	1.9 ± 0.6
80N – 20E	Surface	GS9900334	< 1.7	< 0.02	2.4 ± 0.6
90N – 20E	Surface	GS9900339	< 0.7	< 0.07	2.6 ± 0.7

Uncertainty Values at the 95 % Confidence Level

Table 9 (continued). Gamma Spectroscopy and Gross Alpha Results for Accident Region – Grid Sampling - Composites

Sampling Location		Base Sample Number	Activity Concentration pCi/g		
			^{234}Th	^{235}U	Gross Alpha
0N – 10E	Surface	GS9900306	< 0.7	< 0.08	2.1 ± 0.6
10N – 10E	Surface	GS9900305	< 0.6	< 0.06	1.6 ± 0.6
20N – 10E	Surface	GS9900311	< 1.6	< 0.16	1.5 ± 0.6
30N – 10E	Surface	GS9900308	0.6 ± 0.6	< 0.08	2.3 ± 0.7
40N – 10E	Surface	GS9900307	1.0 ± 0.7	< 0.08	1.5 ± 0.5
50N – 10E	Surface	GS9900312	< 1.7	0.18 ± 0.14	1.9 ± 0.6
60N – 10E	Surface	GS9900310	1.0 ± 0.7	< 0.08	1.8 ± 0.6
70N – 10E	Surface	GS9900309	1.1 ± 0.6	0.15 ± 0.07	1.9 ± 0.6
80N – 10E	Surface	GS9900323	< 0.5	< 0.06	2.2 ± 0.6
90N – 10E	Surface	GS9900324	< 0.5	< 0.06	2.6 ± 0.7
0N – 0E	Surface	GS9900315	< 1.6	< 0.02	2.3 ± 0.7
10N – 0E	Surface	GS9900314	< 1.2	< 0.02	2.0 ± 0.6
20N – 0E	Surface	GS9900313	< 1.8	< 0.02	1.9 ± 0.6
30N – 0E	Surface	GS9900318	1.3 ± 0.9	< 0.01	2.4 ± 0.7
40N – 0E	Surface	GS9900317	< 1.1	< 0.01	2.3 ± 0.7
50N – 0E	Surface	GS9900316	1.1 ± 0.9	< 0.01	1.9 ± 0.6
60N – 0E	Surface	GS9900321	0.9 ± 0.5	< 0.06	2.7 ± 0.7
70N – 0E	Surface	GS9900320	< 0.9	< 0.01	2.3 ± 0.7
0N – 10W	Surface	GS9900360	1.2 ± 0.5	< 0.03	2.1 ± 0.6
10N – 10W	Surface	GS9900361	1.2 ± 0.5	< 0.03	2.0 ± 0.6
20N – 10W	Surface	GS9900357	1.4 ± 0.4	< 0.03	2.4 ± 0.6
30N – 10W	Surface	GS9900358	1.3 ± 0.4	< 0.03	2.5 ± 0.7
40N – 10W	Surface	GS9900378	2.7 ± 0.5	< 0.03	1.8 ± 0.7
50N – 10W	Surface	GS9900377	8.3 ± 1.0	< 0.03	2.6 ± 0.7
60N – 10W	Surface	GS9900374	11.0 ± 1.2	< 0.03	2.8 ± 0.7
70N – 10W	Surface	GS9900376	0.8 ± 0.3	0.14 ± 0.03	2.5 ± 0.7
80N – 10W	Surface	GS9900375	0.9 ± 0.3	< 0.03	2.6 ± 0.7
0N – 20W	Surface	GS9900398	< 0.8	< 0.08	2.1 ± 0.6
10N – 20W	Surface	GS9900368	1.3 ± 0.8	< 0.08	2.3 ± 0.7
20N – 20W	Surface	GS9900369	0.6 ± 0.5	< 0.06	2.5 ± 0.6
30N – 20W	Surface	GS9900370	1.4 ± 0.4	< 0.03	1.7 ± 0.5
40N – 20W	Surface	GS9900372	4.1 ± 0.5	< 0.03	2.2 ± 0.6
50N – 20W	Surface	GS9900373	18 ± 2	0.40 ± 0.08	4.4 ± 0.8
60N – 20W	Surface	GS9900371	4.9 ± 0.6	< 0.03	2.9 ± 0.7
70N – 20W	Surface	GS9900381	0.9 ± 0.4	< 0.04	2.8 ± 0.7
80N – 20W	Surface	GS9900379	< 1.8	< 0.02	2.6 ± 0.7

Uncertainty Values at the 95 % Confidence Level

Table 9 (continued). Gamma Spectroscopy and Gross Alpha Results for Accident Region – Grid Sampling - Composites

Sampling Location		Base Sample Number	Activity Concentration pCi/g		
			^{234}Th	^{235}U	Gross Alpha
0N – 30W	Surface	GS9900388	1.2 ± 0.4	< 0.04	1.9 ± 0.6
10N – 30W	Surface	GS9900387	< 1.1	< 0.01	2.5 ± 0.7
20N – 30W	Surface	GS9900382	< 1.7	< 0.16	1.8 ± 0.6
30N – 30W	Surface	GS9900383	0.7 ± 0.4	< 0.04	1.8 ± 0.6
40N – 30W	Surface	GS9900399	6.6 ± 0.9	< 0.04	2.5 ± 0.7
50N – 30W	Surface	GS9900389	0.7 ± 0.4	< 0.06	2.2 ± 0.6
60N – 30W	Surface	GS9900392	0.6 ± 0.5	< 0.06	2.4 ± 0.6
70N – 30W	Surface	GS9900384	0.5 ± 0.3	< 0.03	2.0 ± 0.6
20N – 40W	Surface	GS9900390	0.8 ± 0.4	< 0.03	2.2 ± 0.6
30N – 40W	Surface	GS9900386	1.8 ± 0.5	0.16 + 0.04	2.6 ± 0.7
40N – 40W	Surface	GS9900385	2.3 ± 0.5	0.16 + 0.03	2.3 ± 0.6
50N – 40W	Surface	GS9900393	1.3 ± 0.3	< 0.03	2.7 ± 0.7
20N – 50W	Surface	GS9900397	1.8 + 0.5	< 0.03	2.0 ± 0.6
30N – 50W	Surface	GS9900391	4.4 ± 0.6	< 0.03	3.3 ± 0.7
40N – 50W	Surface	GS9900380	1.2 + 0.4	< 0.04	2.1 ± 0.6
50N – 50W	Surface	GS9900396	2.4 ± 0.7	< 0.03	2.4 ± 0.7

Uncertainty Values at the 95 % Confidence Level

^{241}Am in Grids and Discrete Locations. All of the ^{241}Am analyses results were below the MDC. For the analyses, the MDC varied between 0.03 and 0.21 pCi g^{-1}, with an arithmetic mean of 0.07 pCi g^{-1}. Overall, the ^{241}Am results from the accident region had slightly higher MDCs over the background region. This is due to elevations in the Compton continuum of the spectra of the samples containing DU. Because ^{241}Am exists in weapons grade plutonium (WGP), it is reasonable to conclude that WGP is not present in significant concentrations to warrant further consideration. Based on other WGP contaminated sites from the time period of this accident, the $^{239/240}$Pu to ^{241}Am ratio is about 5.4 (Rademacher 99b), making the highest sample $^{239/240}$Pu MDC about 1.1 pCi g^{-1}.

Discrete Sampling Locations.

Table 10 contains the γ-spectroscopy and gross alpha analysis results for discrete sampling locations in the accident region. The γ-spectroscopy results are listed for ^{234}Th and ^{235}U; complete analyses are listed in Appendix 2 according to Base Sample Number. ^{234}Th analysis results between 2 and 4 pCi g^{-1} are displayed in blue, while those > 4 pCi g^{-1} are in red. The highest ^{234}Th activity concentration among the samples was 35 pCi g^{-1} (54N – 16W) and had a ^{238}U to ^{235}U ratio of 50 ± 9

(2σ). This sample was collected in an area that was sampled by IERA in 1999 and IDH in 1996. The sample activity concentration was about half that reported by IERA and a tenth of that by IDH. Ten sampling locations had samples collected at multiple depths. At five of these locations, the surface soil sample had a ^{234}Th activity concentration greater than 2 pCi g^{-1}. Corresponding samples at depth had progressively lower activity concentration. For some, the deepest sample had an activity concentration indicative of background, while one location had an activity concentration of 3.2 pCi g^{-1} at the 18 – 24 inch depth. Another had a surface sample with ^{234}Th activity concentration < 1.1 pCi g^{-1} and the 6 – 12 inch depth sample at 2.1 ± 1.3 pCi g^{-1}. The high variability in the latter result doesn't allow a conclusion to be formed on the depth distribution at this sampling location.

Table 11 contains fixed in-situ gamma measurement results for the accident region. The measurements range from 22,465 to 153,678 counts (1-minute), with the highest integrated count at 54.25N – 17W. For a location 100 cm away from this spot, a measurement of 33,932 counts was recorded - 4.5 fold lower. Figure 6 provides a plot of the integrated counts with respect to E-W location with N-S location fixed at 54N. One measurement location on the plot (16W) had a surface soil sample ^{234}Th activity concentration of 35 pCi g^{-1}, for a correlation coefficient of roughly 250 cpm pCi^{-1}. A correlation between the fixed in-situ gamma measurement and soil sampling results was not performed in this report. This parameter may be useful for remediation activities. Due to the drastic changes in activity concentration in the contamination zone, collimated probes may be advantageous - reducing the influence of adjacent contamination on instrument response.

Figure 6. Plot of In-Situ Gamma Measurements vs. E-W Location (54N).

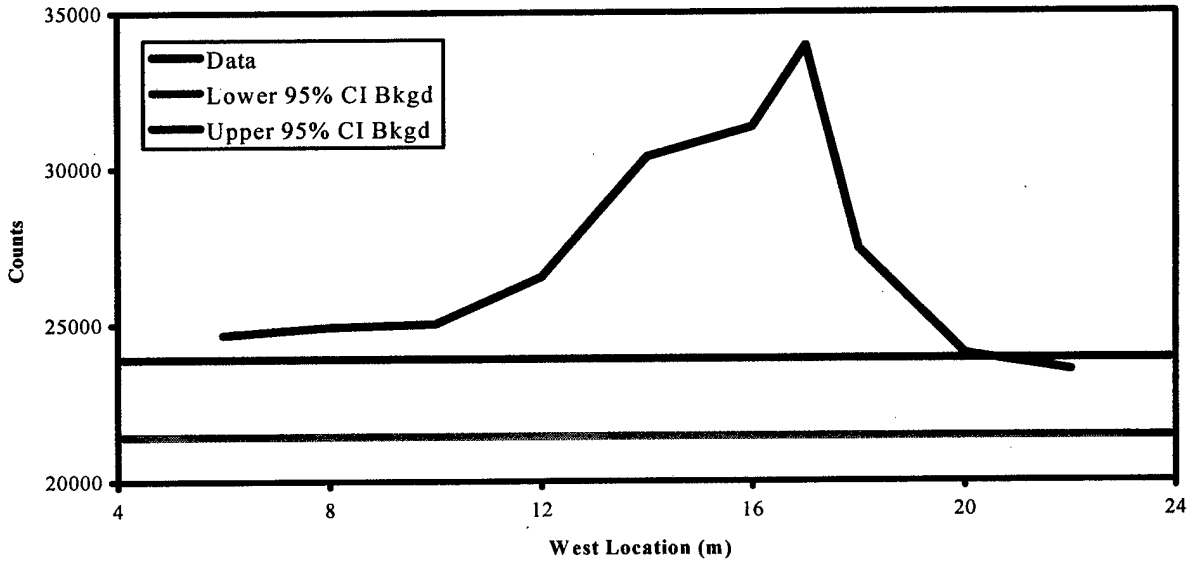


Table 10. Gamma Spectroscopy and Gross Alpha
Results for Accident Region – Discrete Sampling Locations

Sampling Location		Base Sample Number	Activity Concentration pCi/g – dried		
			^{234}Th	^{235}U	Gross Alpha
0N – 20W	Top 15 cm	GS9900421	0.8 ± 0.6	< 0.09	2.5 ± 0.7
0N – 20W	15 – 30 cm	GS9900422	1.3 ± 0.5	< 0.03	2.6 ± 0.7
56N – 22W	Top 15 cm	GS9900420	< 0.9	< 0.01	2.6 ± 0.5
56N – 22W	15 – 25 cm	GS9900418	1.3 ± 0.9	0.13 + 0.08	3.1 ± 0.8
56N – 22W	30 cm	GS9900419	1.0 ± 0.9	< 0.09	2.8 ± 0.7
55N – 17W	Top 10 cm	GS9900400	15 ± 2	< 0.01	3.6 ± 0.8
55N – 17W	10 – 20 cm	GS9900401	8.2 ± 1.2	< 0.03	3.3 ± 0.8
55N – 17W	20 – 30 cm	GS9900402	7.8 ± 1.2	< 0.08	3.4 ± 0.8
55N – 17W	30 – 45 cm	GS9900408	4.5 ± 0.9	0.20 ± 0.06	4.0 ± 0.9
56N – 20W	Top 15 cm	GS9900417	1.5 ± 1.0	< 0.01	2.7 ± 0.7
56N – 20W	15 – 30 cm	GS9900416	< 1.3	< 0.01	1.5 ± 0.6
54N – 16W	Top 15 cm	GS9900409	35 ± 4	0.70 ± 0.09	7.1 ± 1.1
54N – 16W	15 – 30 cm	GS9900410	18 ± 2	0.51 ± 0.08	5.3 ± 1.0
56N – 17W	Top 15 cm	GS9900406	11.0 ± 1.4	0.28 ± 0.07	3.9 ± 0.9
56N – 17W	45 – 60 cm	GS9900405	3.2 ± 0.7	0.17 ± 0.06	2.7 ± 0.7
60N – 40E	Top 15 cm	GS9900423	< 0.8	< 0.08	2.0 ± 0.6
60N – 40E	15 – 30 cm	GS9900424	0.8 ± 0.5	< 0.09	2.8 ± 0.7
56N – 16W	Top 15 cm	GS9900404	11.0 ± 1.2	0.28 + 0.03	3.6 ± 0.8
56N – 16W	15 – 30 cm	GS9900407	4.2 ± 0.8	< 0.08	3.0 ± 0.7
56N – 16W	15 – 20 cm	GS9900411	2.3 ± 1.1	< 0.12	3.2 ± 0.8
56N – 18W	Top 15 cm	GS9900412	2.5 ± 1.1	< 0.11	2.0 ± 0.6
56N – 18W	15 – 30 cm	GS9900413	1.6 ± 1.0	0.31 ± 0.10	3.4 ± 0.8
58N – 18W	Top 15 cm	GS9900415	< 1.1	< 0.1	2.4 ± 0.7
58N – 18W	15 – 30 cm	GS9900414	2.1 ± 1.3	< 0.11	3.0 ± 0.8
72N – 0W	Surface	GS9900322	0.8 ± 0.6	< 0.06	3.2 ± 0.7
71N – 0W	Surface	GS9900319	< 1.1	< 0.1	2.3 ± 0.6
55N – 17W	Surface	GS9900403	6.5 ± 1.0	0.21 ± 0.06	3.7 ± 0.8
Ditch #1	Surface	GS9900344	0.4 ± 0.4	0.05 ± 0.03	2.0 ± 0.5
Ditch #2	Surface	GS9900345	0.4 ± 0.4	< 0.04	2.0 ± 0.5
Ditch #3	Surface	GS9900346	0.6 ± 0.5	< 0.06	2.1 ± 0.6

Uncertainty Values at the 95 % Confidence Level

Table 11. Fixed In-Situ Gamma Measurements of Investigation Region with 3 x 3 NaI(Tl) at 10 cm from Surface

Grid Location (meters)		Counts	Standard Error
N-S	E-W	(1-minute)	(counts)
40 N	10 W	24,218	156
40 N	20 W	23,781	154
40 N	30 W	24,170	155
46 N	20 W	24,827	158
46 N	22 W	24,960	158
48 N	18 W	24,523	157
48 N	20 W	24,567	157
48 N	22 W	25,687	160
48 N	24 W	24,627	157
50 N	0 W	24,509	157
50 N	10 W	24,394	156
50 N	14 W	24,760	157
50 N	16 W	24,573	157
50 N	18 W	24,408	156
50 N	20 W	24,687	157
50 N	22 W	24,509	157
50 N	24 W	26,440	163
50 N	26 W	23,771	154
50 N	30 W	22,789	151
51 N	21 W	37,339	193
51 N	22 W	27,607	166
51 N	23 W	24,113	155
52 N	10 W	24,173	155
52 N	12 W	24,577	157
52 N	14 W	26,413	163
52 N	15 W	26,446	163
52 N	16 W	26,453	163
52 N	18 W	26,638	163
52 N	19 W	26,123	162
52 N	20 W	27,000	164
52 N	21 W	25,911	161
52 N	22 W	25,241	159
52 N	24 W	23,973	155
53 N	15 W	28,906	170
53 N	19 W	27,910	167
54 N	6 W	24,682	157
54 N	8 W	24,937	158
54 N	10 W	25,033	158
54 N	12 W	26,520	163
54 N	14 W	30,374	174

Table 11 (continued). Fixed In-Situ Gamma Measurements of Investigation Region with 3 x 3 NaI(Tl) at 10 cm from Surface

Grid Location (meters)		Counts	Standard Error
N-S	E-W	(1-minute)	(counts)
54 N	16 W	31,324	177
54 N	17 W	33,932	184
54 N	18 W	27,429	166
54 N	20 W	24,058	155
54 N	22 W	23,532	153
54.25 N	17 W	153,678	392
55 N	16 W	34,337	185
55 N	17 W	48,252	220
55 N	18 W	27,860	167
56 N	6 W	24,937	158
56 N	8 W	25,230	159
56 N	10 W	27,328	165
56 N	12 W	29,985	173
56 N	14 W	31,507	178
56 N	16 W	28,158	168
56 N	17 W	25,827	161
56 N	18 W	24,442	156
56 N	20 W	23,203	152
56 N	22 W	22,857	151
57 N	13 W	33,567	183
57 N	14 W	32,448	180
57 N	15 W	27,758	167
58 N	6 W	25,029	158
58 N	8 W	25,868	161
58 N	10 W	31,481	177
58 N	12 W	27,990	167
58 N	14 W	25,735	160
58 N	16 W	23,770	154
58 N	18 W	22,861	151
58 N	20 W	22,696	151
59 N	9 W	28,814	170
59 N	10 W	30,894	176
59 N	11 W	26,912	164
60 N	0 W	23,915	155
60 N	6 W	24,927	158
60 N	8 W	26,412	163
60 N	9 W	26,067	161
60 N	10 W	26,239	162
60 N	11 W	25,155	159

Table 11 (continued). Fixed In-Situ Gamma Measurements of Investigation Region with 3 x 3 NaI(Tl) at 10 cm from Surface

Grid Location (meters)		Counts	Standard Error
N-S	E-W	(1-minute)	(counts)
60 N	12 W	25,041	158
60 N	14 W	23,596	154
60 N	16 W	23,203	152
60 N	20 W	22,714	151
70 N	0 W	22,465	150
70 N	10 W	21,536	147

d. Alpha Spectroscopy Analyses Results.

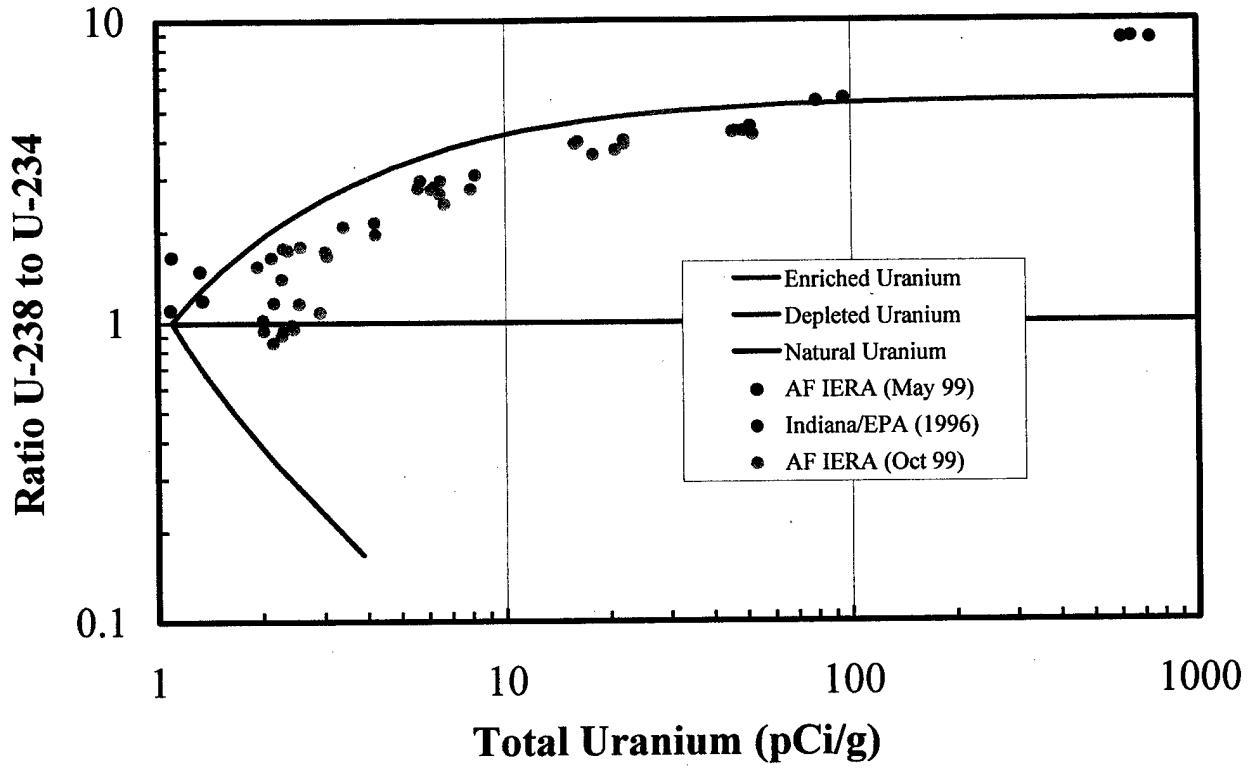
General. Alpha spectroscopy analysis was included for many reasons. First, the analysis is effective in evaluating the isotopic composition of the uranium in the sample, providing more conclusive evidence on the nature of the contaminant. Second, many soil samples had multiple aliquots analyzed, fulfilling the Work Plan requirement for replicate sample analysis. Third, multiple aliquot analysis allows investigation of potential heterogeneity effects that may be responsible for unusually high total uranium activity concentration reported by IDH from their 1996 sampling effort.

Results. The alpha spectroscopy results are contained in Table 12. Figure 7 contains a plot of the ^{238}U to ^{234}U ratio for the samples versus the total uranium concentration, under the assumption of a natural uranium background concentration of 1.1 pCi g^{-1}. From the plot, the most recent data (represented by the light-blue circles) shows good agreement to the previous IERA data represented by the maroon circles and expectations for a depleted uranium contaminant. For samples with low total uranium concentration, there is a greater degree of variability and deviation from the depleted uranium theoretical ratio as compared to samples with higher concentrations. The high variability is due to the greater degree of uncertainty associated with analysis of low activity samples. As well, at low activity concentrations, agreement with a theoretical ratio is highly dependent on the natural background uranium in the soil. The 1.1 pCi g^{-1} assumption made for derivation of the theoretical ratio in the figure was based on information from the EPA (EPA 1999) for the region. On an individual sample basis, however, background can be highly variable. For the analyses completed in this study, it is especially true since sample size was only about 0.5 g. For some, the analytical results indicate that natural background uranium could be twice the average.

Table 12. Alpha Spectroscopy Results for Selected Soil Samples

Sampling Location	Base Sample Number	Activity Concentration (pCi g^{-1})					
		Gamma	Alpha Spectroscopy Results				Ratio:
		^{234}Th	^{234}U	^{235}U	^{238}U	Total	^{238}U to ^{234}U
Background Core-1 0 – 30 cm	GS9900297	0.7 ± 0.6	1.23 ± 0.19	0.06 ± 0.04	1.17 ± 0.19	2.46	1.0 ± 0.2
			1.16 ± 0.18	0.07 ± 0.04	1.05 ± 0.17	2.28	0.9 ± 0.2
			1.14 ± 0.18	0.09 ± 0.05	1.08 ± 0.18	2.31	1.0 ± 0.2
Background Core-1 30 – 60 cm	GS9900298	0.6 ± 0.5	1.00 ± 0.17	0.08 ± 0.04	0.94 ± 0.16	2.02	0.9 ± 0.2
			1.11 ± 0.16	0.09 ± 0.04	0.95 ± 0.15	2.15	0.9 ± 0.2
			1.17 ± 0.19	0.11 ± 0.05	1.15 ± 0.18	2.43	1.0 ± 0.2
60N – 40E	GS9900423	< 0.08	1.34 ± 0.20	0.14 ± 0.06	1.45 ± 0.21	2.93	1.1 ± 0.2
50N – 30W	GS9900389	0.7 ± 0.4	0.93 ± 0.16	0.05 ± 0.03	1.30 ± 0.21	2.28	1.4 ± 0.3
			0.97 ± 0.15	0.06 ± 0.04	1.13 ± 0.17	2.16	1.2 ± 0.3
			0.74 ± 0.13	0.06 ± 0.03	1.14 ± 0.18	1.94	1.5 ± 0.4
40N – 40W	GS9900385	2.3 ± 0.5	1.08 ± 0.17	0.09 ± 0.04	1.86 ± 0.25	3.03	1.7 ± 0.4
			0.81 ± 0.14	0.06 ± 0.03	1.43 ± 0.21	2.30	1.8 ± 0.4
			0.79 ± 0.15	0.04 ± 0.03	1.30 ± 0.21	2.13	1.6 ± 0.4
40N – 10W	GS9900378	2.7 ± 0.5	0.84 ± 0.14	0.07 ± 0.04	1.46 ± 0.20	2.37	1.7 ± 0.4
			1.13 ± 0.18	0.06 ± 0.03	1.88 ± 0.26	3.07	1.7 ± 0.4
			0.90 ± 0.14	0.07 ± 0.04	1.61 ± 0.21	2.58	1.8 ± 0.4
30N – 50W	GS9900391	4.4 ± 0.6	1.38 ± 0.22	0.14 ± 0.06	2.71 ± 0.37	4.23	2.0 ± 0.4
			1.30 ± 0.19	0.12 ± 0.05	2.79 ± 0.34	4.21	2.1 ± 0.4
			1.08 ± 0.18	0.09 ± 0.05	2.25 ± 0.31	3.42	2.1 ± 0.5
40N – 30W	GS9900399	6.6 ± 0.9	1.74 ± 0.26	0.1 ± 0.05	4.66 ± 0.58	6.40	2.7 ± 0.5
			1.88 ± 0.25	0.16 ± 0.06	4.65 ± 0.53	6.69	2.5 ± 0.4
			1.61 ± 0.21	0.16 ± 0.06	4.75 ± 0.50	6.52	3.0 ± 0.5
			1.40 ± 0.20	0.18 ± 0.06	4.14 ± 0.47	5.72	3.0 ± 0.5
			1.84 ± 0.24	0.15 ± 0.06	4.63 ± 0.51	6.62	2.5 ± 0.4
55N – 17W	GS9900401	8.2 ± 1.2	3.81 ± 0.46	0.48 ± 0.12	13.7 ± 1.4	18.0	3.6 ± 0.6
			3.17 ± 0.41	0.38 ± 0.10	12.4 ± 1.4	16.0	3.9 ± 0.7
			4.31 ± 0.49	0.51 ± 0.12	17.3 ± 1.7	22.1	4.0 ± 0.6
60N – 10W	GS9900374	11.0 ± 1.2	1.61 ± 0.23	0.14 ± 0.05	4.55 ± 0.54	6.30	2.8 ± 0.5
			2.08 ± 0.26	0.15 ± 0.06	5.76 ± 0.62	7.99	2.8 ± 0.5
			1.97 ± 0.28	0.17 ± 0.06	6.08 ± 0.72	8.22	3.1 ± 0.6
			1.60 ± 0.22	0.12 ± 0.05	4.43 ± 0.50	6.15	2.8 ± 0.5
			1.45 ± 0.22	0.13 ± 0.05	4.05 ± 0.49	5.63	2.8 ± 0.5
50N – 20W	GS9900373	18 ± 2	4.29 ± 0.54	0.63 ± 0.14	16.0 ± 1.8	20.9	3.7 ± 0.6
			4.43 ± 0.58	0.41 ± 0.11	17.3 ± 2.0	22.1	3.9 ± 0.7
			3.22 ± 0.41	0.26 ± 0.08	12.8 ± 1.4	16.3	4.0 ± 0.7
54N – 16W	GS9900409	35 ± 4	9.16 ± 1.23	1.04 ± 0.23	39.5 ± 4.9	49.7	4.3 ± 0.8
			8.61 ± 0.95	0.86 ± 0.18	37.0 ± 3.7	46.5	4.3 ± 0.6
			9.03 ± 1.15	0.85 ± 0.19	38.8 ± 4.6	48.7	4.3 ± 0.7
			8.46 ± 0.98	0.98 ± 0.20	36.1 ± 3.8	45.5	4.3 ± 0.7
			9.9 ± 1.3	1.06 ± 0.23	41.3 ± 5.0	52.3	4.2 ± 0.7
Bkgd-8	GS9900284	< 1.1	0.98 ± 0.15	0.03 ± 0.02	1.00 ± 0.16	2.01	1.0 ± 0.2
			1.15 ± 0.19	0.07 ± 0.04	1.33 ± 0.21	2.55	1.2 ± 0.3
			1.14 ± 0.17	0.10 ± 0.05	1.08 ± 0.16	2.32	1.0 ± 0.2

Figure 7. U-238 to U-234 Activity Concentration Ratios vs. Total Uranium Activity Concentrations in Presence of 1.1 pC g^{-1} Natural Uranium Background



e. Beryllium Sampling Results. Table 13 contains the beryllium analysis results for samples selected for analysis. Samples were chosen from areas suspect for high contaminant concentrations as well as those believed to be in uncontaminated areas. ^{234}Th γ-spectroscopy results are listed as a basis for comparison. Half of the samples analyzed had beryllium concentrations below the limit of detection for the measurement system. The highest measured concentration was 0.61 μg g^{-1} (54N – 16W) and had a corresponding ^{234}Th activity concentration of 18 ± 2 pCi g^{-1}. Another sample (55N – 17W) had a ^{234}Th activity concentration of 15 ± 2 pCi g^{-1}, but had undetectable levels of beryllium. If the accident created both beryllium and DU contamination, it is a logical assumption that there would be some correlation in the concentrations of these contaminants. Overall, however, for the 10 samples analyzed for beryllium, there did not appear to be a correlation between DU and beryllium concentrations, providing evidence that beryllium was not released to the site from the accident. Nevertheless, all of the samples with measured beryllium concentrations are well below the lowest preliminary remediation goal (PRG) concentration of 156 mg/kg (μg g^{-1}).

Table 13. Beryllium Sampling Results.

Base Sample Number	Location	^{234}Th pCi g^{-1}	Beryllium $\mu g\ g^{-1}$
GM000267	0N – 30E	< 1.6	0.52
GM000268	40N – 40W	2.3 ± 0.5	< 0.50
GM000269	Bkgd-Core-1 (Top 30 cm)	0.7 ± 0.6	0.54
GM000270	56N – 18W (Top 15 cm)	2.5 ± 1.1	< 0.50
GM000271	80N – 20E	< 1.7	< 0.50
GM000272	55N – 17W (45 – 60 cm)	4.5 ± 0.9	0.51
GM000273	55N – 17W (10 cm)	15 ± 2	< 0.50
GM000274	56N – 20W (15 – 30 cm)	< 1.3	< 0.50
GM000275	54N – 16W (15 – 30 cm)	18 ± 2	0.61
GM000276	0N – 20W	0.8 ± 0.6	0.57

f. Gamma Exposure Rates. Table 14 lists exposure rates for selected locations in the accident region. The exposure rate at the location with the highest 3 x 3 NaI(Tl) measurement was 54 $\mu R\ h^{-1}$ at the ground surface. At a height of 1 meter, however, the exposure rate was only about 50 % higher than that of background (20N – 10W). The exposure rate at the hot spot is highly localized – a surface measurement 30 cm away provided an exposure rate measurement one-half as high. For the exposure measured at a height of one meter at the hot spot, the rate was 2.5 $\mu R\ h^{-1}$ higher than background. This excess exposure rate is very low, providing an insignificant increase in exposure to personnel working in the region.

Table 14. In-Situ Gamma Exposure Measurements @ Selected Locations and Multiple Heights (In-Situ Gamma Measurements Included)

Grid Location (meters)		Height	Exposure Rate	3 x 3 NaI(Tl)
N-S	E-W	(cm)	$\mu R\ h^{-1}$	(1-minute)
55 N	17 W	Surface	25	48,252
		30	12	
		100	7	
55.25 N	17 W	Surface	54	153,678
		30	13	
		100	7.5	
56 N	14 W	Surface	8.5	31,507
		30	6.5	
		100	6.0	
20 N	10 W	Surface	5.2	Not Performed
		30	5.5	
		100	5.0	

g. Extent of the Contamination Zone.

Figure 8 contains a plot of the contaminated area of the investigation region. The plot contains notation of the mean surface soils sampling results for (^{234}Th) each grid and fixed in-situ gamma measurements. The pink rectangular box roughly represents the contamination zone and has an area of 300 m^2. The mean surface excess total uranium concentration is estimated to be about 15 to 20 pCi g^{-1} in this area, using the conversion line of the plot in Figure 9 and conservative assumptions regarding activity concentration of grids partially included in the zone. For the 10 grids (1,000 m^2) with mean surface ^{234}Th activity concentrations greater than 2 pCi g^{-1}, the mean excess uranium activity concentration is about 7 pCi g^{-1}, with a standard deviation of 6 pCi g^{-1}. Averaged over the investigation region (8,800 m^2), the mean excess uranium activity concentration in surface soils is estimated at 1 pCi g^{-1}. Complete maps of the investigation region and analytical results are provided in Appendix 3.

IDH in their 1996 scoping survey of the site had a soil sample with total uranium in excess of 700 pCi g^{-1}. The maximum activity concentration from this survey was 50 pCi g^{-1}. It is possible that the sample collected by the IDH was a localized "hot spot" and the sampling effort removed the most highly contaminated part of the zone. The α-spectroscopy analysis results indicated that heterogeneity is not the likely cause of the discrepancy.

h. Quality Assurance/Quality Control Measures. The quality assurance/quality control measures accomplished for this study demonstrated satisfactory laboratory and field data results. The following summary is provided in support of this conclusion.

Replicate Sample Analysis Results. Thirteen samples that had γ-spectroscopy analysis were selected for α-spectroscopy analysis. Nine of the samples had three aliquots analyzed, two had five aliquots, while one had a single aliquot. The sample analysis results are presented in Table 12. Table 15 provides a summary of the variability among aliquot total uranium activity concentration and the ratio of ^{238}U to ^{234}U. Variability is listed in terms of percent coefficient of variation (100 * σ/μ) (% CV). For the ratio summary, variability among aliquots is very low, with the highest % CV being 13.4 % and most being in single digits. For the total uranium activity concentration, variability was higher, but less than 20 % for all samples. For evaluation of the effects of heterogeneity, this index is important. Because the variability is small among aliquots, heterogeneity within samples is not an important factor for this study.

Figure 8. Fixed In-Situ Gamma Measurement Results for Hot-Spot Area and Accompanying Mean Grid Surface Soil Sampling Results for ^{234}Th (pCi/g) – Grid in Meters.

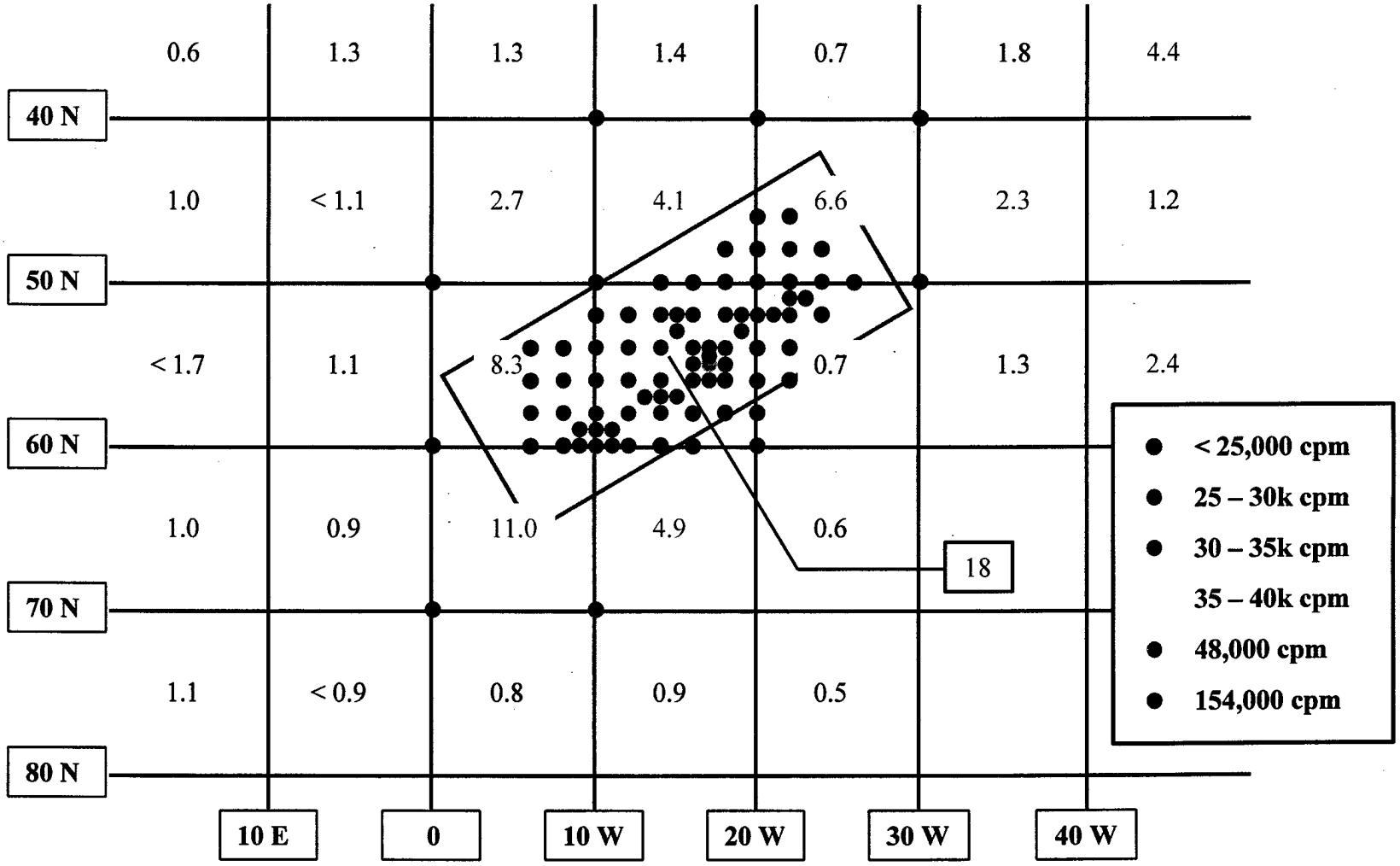


Figure 9. Excess Activity Concentration of Total Uranium vs. Measured U-238 for Background Total Uranium = 1.1 pCi g^{-1}.

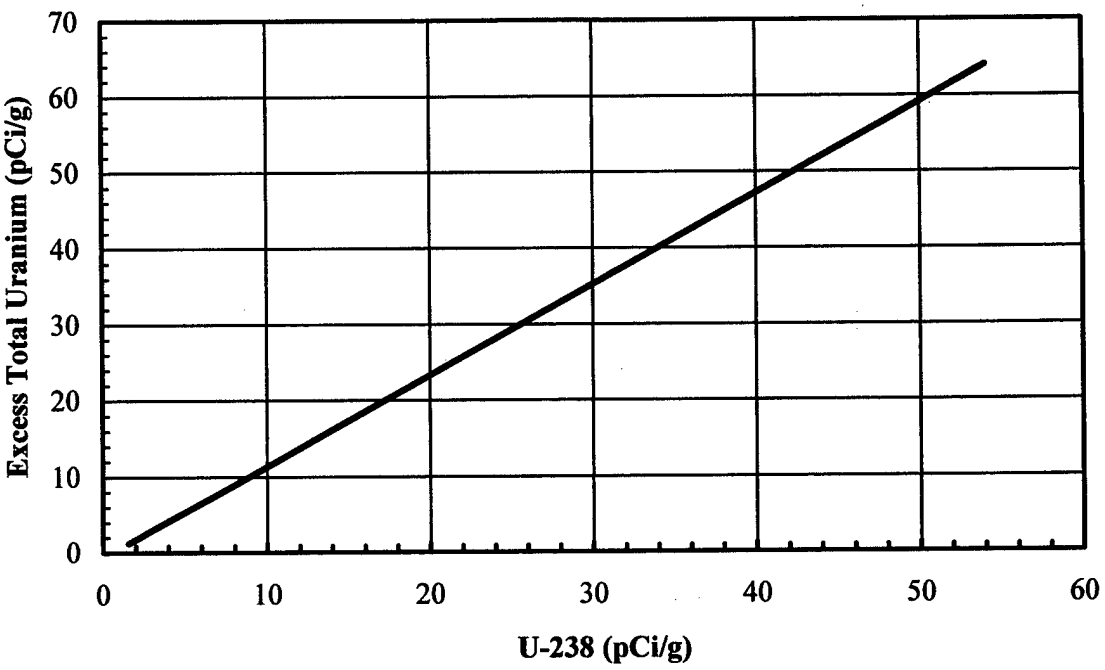


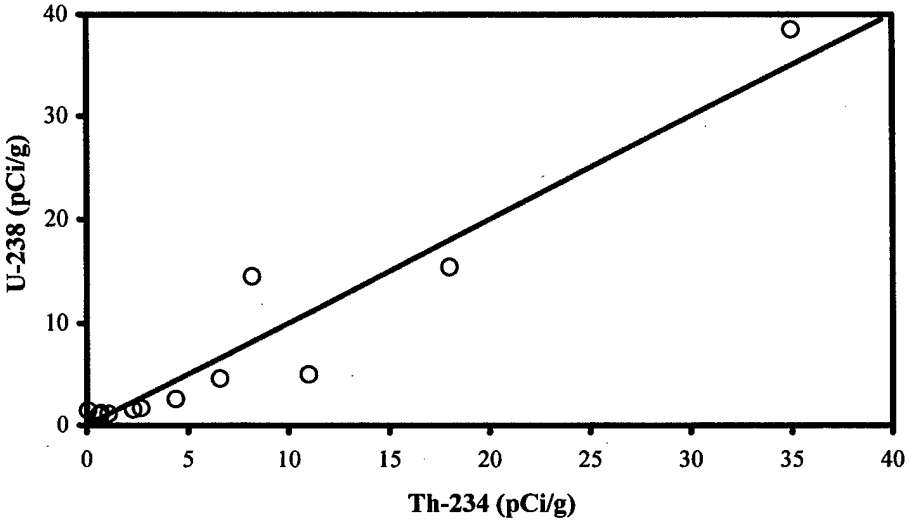
Table 15. Quality Assurance Indices for Multiple Aliquot Analysis of Data from Table 12.

Base Sample Number	Variability in Ratio Of ^{238}U to ^{234}U		Variability in Total Uranium Activity Concentration	
	Mean Ratio	Percent CV (σ/μ)	Mean pCi g^{-1}	Percent CV (σ/μ)
GS9900389	1.37	11.2	2.13	8.1
GS9900298	0.933	6.2	2.2	9.5
GS9900284	1.07	10.7	2.29	11.8
GS9900297	0.967	6.0	2.35	4.1
GS9900385	1.7	5.9	2.49	19.2
GS9900378	2.67	13.4	2.67	13.4
GS9900391	2.07	2.8	3.95	11.7
GS9900374	2.86	4.7	4.97	17.9
GS9900399	2.74	9.2	6.39	6.1
GS9900401	3.83	5.4	18.7	16.6
GS9900373	3.87	4.0	19.8	15.5
GS9900409	4.28	1.0	48.5	5.6

Comparison of ^{238}U α-Spectroscopy to ^{234}Th γ-Spectroscopy Analysis. For the 13 samples that had α-spectroscopy analysis, a comparison between the ^{238}U and ^{234}Th activity concentrations are made in Figure 10. In the Figure, the data is represented by the red circles, while

the green line represents a one-to-one correlation between the parameters. A regression analysis of the data provided a slope value of 1.02 with a squared correlation coefficient of 0.92. The data set does not have any gross outliers; however, conclusions regarding bias should not be inferred because of the smallness of the data set.

Figure 10. Activity Concentration: U-238 α-Spectroscopy vs. Th-234 γ-Spectroscopy.



Sample Results for Closely –Spaced Samples in Contamination Zone. Analysis of closely-spaced samples provides a measure of the spatial heterogeneity of the contaminant. Some selected sampling results from Table 10 are graphically presented in Figure 11. From the plot, apparent are the abrupt changes in activity concentration of the contaminant within distances of only a few meters.

5. Risk Assessment.

a. EPA Draft Preliminary Remediation Goals. In 1999, the Environmental Protection Agency (EPA) calculated preliminary remediation goals for the contaminants of concern. The EPA provided calculations for uranium, beryllium, and lithium; and included evaluation of cancer, non-cancer risks, and chemical toxicity risks for uranium. The chemical and radiological PRGs are summarized in Table 16. For the cancer risks from the uranium, both the RAGS-HHEM (EPA) and RESRAD (DOE) modeling codes. The two codes provided similar results for cancer risk for the isotopes of ^{234}U and ^{238}U. For ^{235}U, however, the risks are almost three-fold different.

Figure 11. Surface Soil Sample Results for Select Samples in the Contamination Zone (Grid in Meters – Sample Results in pCi g^{-1} Th-234)

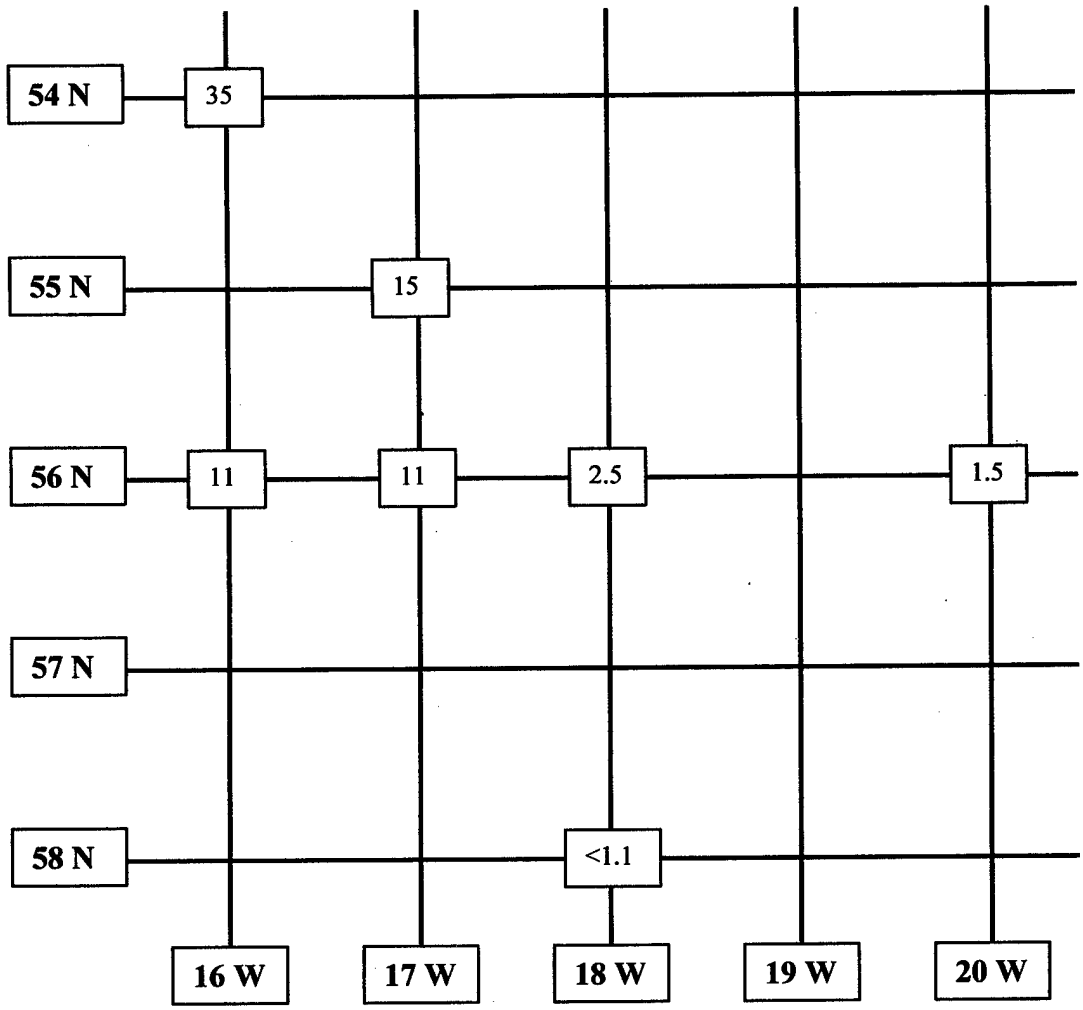


Table 16. Chemical and Radiological PRGs for Residential (EPA 1999).

Metal	Cancer (1×10^{-4} y^{-1}) (RAGS-HHEM/RESRAD)	Non-Cancer* (child/adult)
U-234	10.3/9.7 pCi g^{-1}	$1.5/2.9 \times 10^{6}$ pCi g^{-1}
U-235	7.8/2.8 pCi g^{-1}	502/1004 pCi g^{-1}
U-238	7.1/10.3 pCi g^{-1}	79/158 pCi g^{-1}
Beryllium	1,040*	156/313 μg g^{-1}
Lithium	NA	7,800/15,600 μg g^{-1}

* Risk Assessment Guidance for Superfund Sites

b. IERA Generated RESRAD Dose Estimates. Dose estimates with RESRAD version 5.82 were performed by IERA using most of the parameters and assumptions used by the EPA in their evaluation (EPA 99). Table 17 contains a summary of the dose calculations. With a listing of parameters that varied from the EPA assumptions.

Table 17. RESRAD Dose Estimates with Various Parameters and Assumptions

Area (m^2)	Contamination Zone Thickness (m)	Length of Contamination Zone (m)	DU Activity Concentration (pCi g^{-1})	Years Post Deposition Dose (max)	Dose Equivalent (mrem y^{-1})
10,000	2	100	1	815	1.0
1,000	0.5	50	20	745	5.2
1,000	0.5	50	7	745	1.8
300	0.5	25	23.3	457	5.4

*Dose summaries from the code calculations are included in Appendix 3.

Case 1. The first case listed in the table is very similar in assumptions to that of the EPA's RESRAD calculation, except that the radionuclide distribution among the uranium isotopes resembles that of DU. This case approximates the condition where the contaminant is uniformly distributed on the accident region. Note that the investigation region has an area of 8,800 m^2. This case is the least restrictive of the four considered, but has the least resemblance to actual site conditions.

Case 2 and 3. The second and third cases more closely resemble the actual site conditions in the areal extent and thickness of the contamination zone. Case two assumes that the mean contaminant concentration is uniform, but at an excess activity concentration equivalent to the maximum of any one survey grid sampling result. Contrary, for case 2, the mean contaminant concentration is assumed to be equivalent to that among all survey grids.

Case 4. The fourth case listed in the table represents the extreme in that all of the contaminant is assumed to be present in an area of 300 m^2. The resulting maximum dose equivalent is 5.4 mrem y^{-1}.

c. RESRAD vs. RAGS/HHEM. The EPA provided the following comparison of the two codes (EPA 1999).

"The modified RAGS/HHEM is the simplest and more conservative. It does not include corrections for radioactive decay or progeny ingrowth, nor does it provide for depletion of

radionuclides in the contaminated soil by leaching or erosion. Ingrowth of progeny are included at the outset. Accordingly, the contaminated zone is assumed to be a non depleting source of radioactivity for the calculations. This assumption provided the upper bound estimate of exposure to radionuclides in soil."

The RESRAD code is more flexible allowing better representations of the contamination zone and potential absorbed doses.

6. Conclusions. This characterization study determined that contaminants in the soil in the investigation region resemble DU and are residual contamination from the nuclear weapons accident that occurred in 1964 at the site. The contaminated region encompasses an area about 1000 m^2 with thickness of about 0.5 m. The most highly contaminated area encompasses about 300 m^2, where the excess total uranium activity concentration in surface soils is about 15 to 20 pCi g^{-1}. Because of the limited extent of contamination, the site does not present any health hazards to base personnel working in the region. Other contaminants of concern were not identified by the sampling effort.

7. References.

Armstrong Laboratory, Consultative Letter, AL-CL-11992-0186, Radiological Decommissioning Survey of Selected Weapons Storage Facilities at Grissom AFB, Nov 1992.

Headquarters Air Force Safety Center, Letter from Col Burl E. Hickman to Valerie Stacy Grissom ARB, Review of Documents Regarding 1964 Bunker Hill AFB Broken Arrow, 1996.

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Rademacher, S.E., Review of the Pu-239/240 to Am-241 Activity Ratio Analysis for Work Related to Remediation of the BOMARC Missile Accident Site, Technical Report AFSC-TR-1999-0002, Air Force Safety Center, Kirtland Air Force Base, New Mexico, November 1999.

Sandia National Laboratories, *United States Nuclear Weapons Accidents*, February 1997.

United States Environmental Protection Agency, Radiation Sciences Analysis Program, Letter to Jane Smith, Indiana Department of Health, October 1996.

United States Environmental Protection Agency, Emergency Response Branch, *Draft Risk-Based Preliminary Remediation Goals for Soil Contamination at the B-58 Hustler Crash/Burial Site at Grissom Air Reserve Base, Bunker Hill, Indiana*, 1999.

United States Public Health Service – Bureau of State Services, Washington DC, Letter from D.J. Nelson Jr., to Program Director, Radiological Health, Region V, et al, Preliminary and Final Reports – DPH Broken Arrow Team, December 15, 1964.

Appendix 1

Minimum Detectable Concentration for a Small Area of Elevated Radionuclide Concentration for 3 inch by 3 inch NaI Detector

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References: 1. NUREG-1507 - Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions

2. Ludlum Instruments Inc. 1998 Product Catalog

The goal of this analysis is to relate a Minimum Detectable Count Rate (MDCR) to radionuclide concentration in soil (pCi/g). Determination of the MDCR depends on several factors:

- Extent of the hot spot
- Depth of the hot spot
- Radionuclide of interest (energy and yield of gamma emissions)

Obviously, it is not possible to precisely know these parameters before the investigation begins so assumptions must be made. If the assumptions prove to be incorrect then the MDC must be recomputed after empirical characterization data is available.

The computation details for a 2 inch by 2 inch (2 x 2) NaI detector are provided in NUREG-1507 and are not repeated here except for the factors that vary between the 2x2 detector and the 3x3 detector . Assumptions used in NUREG-1507:

- Cylindrical hot spot of 28 cm radius
- Depth of hot spot 15 cm
- Dose point 10 cm above ground surface
- Soil Density of 1.6 g/cm^3

For a 2 x 2 detector, Table 6.4 of NUREG-1507 provides a Scan MDC for of 6.4 pCi/g for Cs-137 and 56 pCi/g for Depleted Uranium (DU). The detector has a count rate to exposure rate of 900 cpm/μR/hr (Cs-137) and a background count rate of 10,000 cpm.

The Model 44-20 3 x 3 inch NaI detector sensitivity is 2700 cpm/μR/hr (Cs-137) (from the Ludlum Instruments catalog). The measured background count rate at Brooks AFB, TX for this detector is approximately 17,700 cpm. Using this data and the computational procedure outlined in NUREG-

1507 results in a calculated Scan MDC of 2.85 pCi/g for Cs-137. Using a simple ratio comparison with the 2 x 2 detector:

$$\frac{(6.4\ \text{pCi/g})\ \{2\text{x}2, \text{Cs-}137\}}{(2.9\ \text{pCi/g})\ \{3\text{x}3, \text{Cs-}137\}} = \frac{(56\ \text{pCi/g})\ \{2\text{x}2, \text{DU}\}}{(\text{X pCi/g})\ \{3\text{x}3. \text{DU}\}}$$

X = 25.4 pCi/g {3 x 3, DU)

This simple ratio method does not consider energy response differences between the two detectors. Intuitively, the differences in efficiencies at lower energies than Cs-137 would be smaller, although not significantly so. Additionally, the evaluation only considers primary photon energies when calculating the contribution from scattered photons, the field response of the detector will be greater since the detector is more efficient at detecting the lower energy scattered photons.

Appendix 2

Laboratory Radioanalytical Results

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IERA/SDR	Base	Gamma Spectroscopy Analysis (pCi/g - Wet)													Gross Alpha		Gross Beta	
Sample	Sample	Am-241	Bi-214		Pb-214		Th-232		Th-234		U-235		Cs-137		pCi/g - Wet		pCi/g - Wet	
Number	Number	MDC*	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error
19900979	GS9900277	0.09	0.54	0.14	0.6	0.16	0.5	0.23	< 1.07		< 0.1		0.14	0.08	1.8	0.7	15.5	0.8
19900980	GS9900278	0.09	0.48	0.15	0.5	0.14	0.55	0.24	< 1.05		< 0.1		0.24	0.08	2	0.6	17.4	0.9
19900981	GS9900279	0.09	0.39	0.13	0.4	0.13	0.41	0.22	< 1.01		< 0.1		0.25	0.08	1.9	0.6	17.2	0.9
19900982	GS9900280	0.09	0.54	0.16	0.48	0.16	0.49	0.23	< 1.05		0.12	0.08	0.31	0.09	1.7	0.6	15.6	0.8
19900983	GS9900281	0.09	0.45	0.13	0.59	0.16	0.61	0.23	< 1.08		< 0.1				1.9	0.6	16.8	0.9
19900984	GS9900282	0.03	0.53	0.07	0.55	0.06	0.69	0.1	0.74	0.31	0.11	0.03	0.04	0.02	2.4	0.6	18.4	1
19900985	GS9900283	0.1	0.55	0.16	0.55	0.13	0.69	0.25	< 1.06		< 0.1		0.47	0.09	2	0.6	17.1	0.9
19900986	GS9900284	0.1	0.85	0.18	0.93	0.19	0.57	0.23	< 1.08		0.09	0.07	0.37	0.08	1.8	0.6	14.4	0.8
19900987	GS9900285	0.04	0.57	0.08	0.61	0.08	0.62	0.1	0.85	0.33	< 0.03		0.54	0.07	1.7	0.6	16.9	0.9
19900988	GS9900286	0.05	0.49	0.12	0.56	0.1	0.61	0.23	0.75	0.52	< 0.06		0.38	0.06	2.2	0.6	18.3	1
19900989	GS9900287	0.05	0.41	0.11	0.45	0.1	0.7	0.22	1.02	0.61	< 0.06		0.38	0.07	1.6	0.6	14.9	0.8
19900990	GS9900288	0.03	0.56	0.07	0.6	0.07	0.71	0.11	0.74	0.26	< 0.03		0.33	0.04	2.1	0.7	18.1	1
19900991	GS9900289	0.03	0.57	0.07	0.59	0.07	0.72	0.1	0.97	0.31	< 0.02		0.38	0.05	2.3	0.6	16.3	0.9
19900992	GS9900290	0.03	0.58	0.07	0.61	0.07	0.71	0.11	1.11	0.32	< 0.02		0.51	0.06	1.9	0.7	15.7	0.8
19900993	GS9900291	0.03	0.62	0.08	0.65	0.07	0.76	0.11	0.76	0.31	< 0.03		0.32	0.04	2.1	0.7	16.8	0.9
19900994	GS9900292	0.03	0.52	0.07	0.58	0.07	0.62	0.09	0.67	0.27	< 0.02		0.56	0.06	2.2	0.6	17.5	0.9
19900995	GS9900293	0.03	0.54	0.07	0.6	0.07	0.66	0.1	0.87	0.29	< 0.02		0.36	0.04	1.9	0.6	16.9	0.9
19900996	GS9900294	0.03	0.56	0.07	0.65	0.07	0.74	0.11	0.86	0.32	< 0.03		0.45	0.05	2.1	0.7	15.6	0.8
19900997	GS9900295	0.03	0.72	0.08	0.78	0.08	0.76	0.1	1	0.31	< 0.02		0.1	0.02	2	0.6	17.5	0.9
19900998	GS9900296	0.05	0.47	0.11	0.56	0.11	0.64	0.18	< 0.49		< 0.06		0.38	0.08	2.6	0.7	18	0.9
19900999	GS9900297	0.05	0.48	0.11	0.48	0.11	0.63	0.2	0.73	0.6	< 0.06		0.27	0.06	1.9	0.7	15.3	0.8
19901000	GS9900298	0.05	0.5	0.12	0.56	0.11	0.87	0.2	0.62	0.51	< 0.06				1.8	0.6	17.8	1
19901001	GS9900299	0.05	0.48	0.13	0.57	0.11	0.66	0.2	< 0.65		< 0.07				1.8	0.6	17.4	1
19901002	GS9900300	0.06	0.55	0.13	0.59	0.11	0.73	0.21	< 0.6		0.12	0.05	0.08	0.05	2	0.7	15.1	0.8
19901003	GS9900301	0.06	0.69	0.15	0.79	0.12	0.57	0.18	1.17	0.62	< 0.06				2.1	0.7	17.6	1
19901004	GS9900302	0.06	0.58	0.12	0.68	0.12	0.67	0.17	< 0.7		< 0.07		0.06	0.04	2.2	0.6	19.1	1
19901005	GS9900303	0.06	0.57	0.12	0.52	0.11	0.8	0.24	< 0.54		0.11	0.05	0.09	0.04	3	0.7	18	1
19901006	GS9900304	0.06	0.48	0.12	0.53	0.1	0.81	0.21	< 0.66		0.18	0.05			2.2	0.7	16.5	0.8
19901007	GS9900305	0.05	0.49	0.1	0.52	0.1	0.42	0.19	< 0.6		< 0.06		0.3	0.06	1.6	0.6	16.4	0.9
19901008	GS9900306	0.07	0.6	0.14	0.48	0.12	0.56	0.18	< 0.74		< 0.08		0.35	0.08	2.1	0.6	16.9	0.9
19901009	GS9900307	0.07	0.5	0.13	0.51	0.14	0.52	0.31	1	0.67	< 0.08		0.18	0.06	1.5	0.5	17.9	1
19901010	GS9900308	0.07	0.47	0.12	0.38	0.15	0.67	0.22	0.63	0.57	< 0.08		0.2	0.07	2.3	0.7	17.7	0.9
19901011	GS9900309	0.07	0.45	0.13	0.46	0.12	0.72	0.24	1.13	0.58	0.15	0.07	0.5	0.09	1.9	0.6	18.4	0.9
19901012	GS9900310	0.07	0.33	0.15	0.4	0.12	0.63	0.21	0.99	0.66	< 0.08		0.2	0.09	1.8	0.6	14.4	0.8

IERA/SDR	Base	Gamma Spectroscopy Analysis (pCi/g - Wet)													Gross Alpha		Gross Beta	
Sample	Sample	Am-241	Bi-214		Pb-214		Th-232		Th-234		U-235		Cs-137		pCi/g - Wet		pCi/g - Wet	
Number	Number	MDC*	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error
19901013	GS9900311	0.13	0.63	0.25	0.64	0.25	0.54		< 1.55		< 0.16				1.5	0.6	18	0.9
19901014	GS9900312	0.13	0.7	0.24	0.4	0.23	0.67	0.34	< 1.65		0.18	0.14	0.2	0.11	1.9	0.6	17.7	0.9
19901015	GS9900313	0.13	0.47	0.22	0.52	0.23	0.81	0.42	< 1.77		< 0.16		0.17	0.12	1.9	0.6	17.4	0.9
19901016	GS9900314	0.13	0.41	0.2	0.55	0.23	0.75	0.43	< 1.21		< 0.15		0.24	0.11	2	0.6	15	0.8
19901017	GS9900315	0.13	0.44	0.25	0.48	0.2	0.62	0.4	< 1.64		< 0.16		0.2	0.1	2.3	0.7	17.4	0.9
19901018	GS9900316	0.09	0.39	0.18	0.47	0.16	0.61	0.21	1.13	0.93	< 0.1		0.2	0.07	1.9	0.6	18.3	1
19901019	GS9900317	0.1	0.71	0.15	0.55	0.15	0.74	0.26	< 1.12		< 0.1		0.21	0.08	2.3	0.7	17.9	0.9
19901020	GS9900318	0.09	0.47	0.17	0.36	0.16	0.51	0.28	1.31	0.93	< 0.1		0.12	0.06	2.4	0.7	16.8	0.9
19901021	GS9900319	0.09	0.38	0.15	0.47	0.15	0.49	0.18	< 1.06		< 0.1		0.31	0.09	2.3	0.6	17.8	0.9
19901022	GS9900320	0.1	0.6	0.17	0.4	0.16	0.65	0.25	< 0.91		< 0.1		0.41	0.09	2.3	0.7	15.1	0.8
19901023	GS9900321	0.06	0.77	0.14	0.76	0.13	0.52	0.19	0.91	0.53	< 0.06		0.32	0.07	2.7	0.7	18.8	1
19901024	GS9900322	0.05	0.43	0.12	0.45	0.11	0.37	0.16	0.76	0.58	< 0.06		1.34	0.16	3.2	0.7	20.4	1
19901025	GS9900323	0.05	0.35	0.12	0.55	0.12	0.64	0.21	< 0.49		< 0.06		0.41	0.08	2.2	0.6	17.4	0.9
19901026	GS9900324	0.05	0.38	0.11	0.54	0.1	0.57	0.2	< 0.46		< 0.06		0.73	0.1	2.6	0.7	15.4	0.8
19901027	GS9900325	0.05	0.45	0.11	0.49	0.11	0.55	0.2	1.18	0.56	< 0.06		0.51	0.08	1.7	0.6	17.2	0.9
19901028	GS9900326	0.09	0.55	0.15	0.44	0.14	0.76	0.25	< 1.08		0.11	0.07	0.3	0.07	1.7	0.6	16.1	0.9
19901029	GS9900327	0.05	0.64	0.09	0.74	0.09	0.76	0.12	1.06	0.42	< 0.04		0.36	0.06	2.1	0.6	15.2	0.8
19901030	GS9900328	0.08	0.29	0.13	0.37	0.14	0.4	0.25	< 1.02		0.2	0.08	0.18	0.07	2.4	0.7	17.8	1
19901031	GS9900329	0.12	0.56	0.27	0.29	0.22	0.92	0.49	< 1.63		< 0.16		0.14	0.09	2.4	0.6	17.7	0.9
19901032	GS9900330	0.04	0.67	0.09	0.7	0.09	0.64	0.12	0.66	0.35	< 0.04		0.2	0.04	1.5	0.5	14.4	0.8
19901033	GS9900331	0.03	0.51	0.08	0.53	0.08	0.65	0.14	0.51	0.32	< 0.04		0.29	0.05	2	0.6	16.6	0.9
19901034	GS9900332	0.12	0.4	0.23	0.59	0.27	< 0.58		< 1.7		< 0.12		0.17	0.1	1.8	0.6	17.6	1
19901035	GS9900333	0.17	0.88	0.29	0.63	0.31	0.68	0.4	< 1.92		< 0.16		0.43	0.15	2.5	0.7	16.3	0.9
19901036	GS9900334	0.13	0.45	0.22	0.6	0.26	0.82	0.36	< 1.7		< 0.16		0.44	0.13	2.4	0.6	15.2	0.8
19901037	GS9900335	0.13	0.43	0.19	0.33	0.24	1.03	0.38	< 1.62		< 0.16		0.2	0.12	2.1	0.6	17	0.9
19901038	GS9900336	0.12	0.43	0.23	0.37	0.21	0.52	0.43	< 1.56		< 0.11		0.39	0.12	1.9	0.6	17.3	0.9
19901039	GS9900337	0.13	0.48	0.24	0.36	0.2	0.84	0.4	< 1.6		< 0.15		0.6	0.15	2.1	0.6	15	0.8
19901040	GS9900338	0.13	0.31	0.23	0.56	0.19	< 0.62		< 1.62		< 0.16				2.4	0.7	18	1
19901041	GS9900339	0.07	0.34	0.12	0.47	0.13	0.47	0.18	< 0.73		< 0.07		1.63	0.2	2.6	0.7	19.5	1
19901042	GS9900340	0.06	0.66	0.08	0.68	0.08	0.7	0.11	1.24	0.44	< 0.03		0.28	0.04	2.1	0.7	15.8	0.8
19901043	GS9900341	0.07	0.31	0.13	0.53	0.13	0.54	0.22	0.68	0.6	< 0.07		0.41	0.09	2.3	0.6	18.6	0.9
19901044	GS9900342	0.06	0.6	0.08	0.6	0.07	0.61	0.09	0.92	0.44	< 0.03		0.21	0.03	2.1	0.6	17	0.9
19901045	GS9900343	0.07	0.29	0.11	0.47	0.1	0.43	0.18	< 0.71		0.08	0.05	0.37	0.08	2.3	0.6	15.5	0.9
19901046	GS9900344	0.04	0.3	0.08	0.35	0.07	0.18	0.11	0.42	0.39	0.05	0.03	0.12	0.04	2	0.5	11.9	0.6

IERA/SDR	Base	Gamma Spectroscopy Analysis (pCi/g - Wet)													Gross Alpha		Gross Beta	
Sample	Sample	Am-241	Bi-214		Pb-214		Th-232		Th-234		U-235		Cs-137		pCi/g - Wet		pCi/g - Wet	
Number	Number	MDC*	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error
19901047	GS9900345	0.04	0.3	0.07	0.33	0.08	0.34	0.12	0.42	0.37	< 0.04		0.11	0.04	2	0.5	12.2	0.7
19901048	GS9900346	0.05	0.48	0.1	0.45	0.1	0.35	0.2	0.62	0.51	< 0.06		0.12	0.05	2.1	0.6	14.7	0.9
19901049	GS9900347	0.05	0.32	0.1	0.32	0.09	0.39	0.16	< 0.47		< 0.06		0.85	0.12	2.7	0.7	16.4	0.8
19901050	GS9900348	0.05	0.33	0.13	0.48	0.1	0.54	0.19	1.75	0.71	< 0.06		0.37	0.07	2.5	0.7	18.6	1
19901051	GS9900349	0.09	0.5	0.14	0.44	0.18	0.7	0.26	< 1.08		<0.1		0.33	0.07	2.3	0.6	17.7	0.9
19901052	GS9900350	0.04	0.62	0.08	0.65	0.07	0.7	0.11	0.84	0.31	< 0.03		0.34	0.05	2.1	0.6	15.1	0.8
19901053	GS9900351	0.09	0.42	0.14	0.51	0.15	0.68	0.21	1.09	0.95	0.14	0.09	0.2	0.06	2.4	0.7	17.5	0.9
19901054	GS9900352	0.04	0.59	0.08	0.67	0.07	0.68	0.1	0.72	0.32	< 0.03		0.2	0.03	2.5	0.7	17.8	1
19901055	GS9900353	0.04	0.54	0.08	0.62	0.07	0.74	0.1	0.77	0.32	< 0.03		0.55	0.07	1.2	0.5	16	0.9
19901056	GS9900354	0.09	0.41	0.13	0.49	0.14	0.4	0.21	< 1.04		< 0.1		0.33	0.1	2.6	0.7	14.2	0.8
19901057	GS9900355	0.04	0.58	0.08	0.58	0.07	0.71	0.1	0.65	0.32	< 0.03		0.37	0.05	2.5	0.7	17.2	0.9
19901058	GS9900356	0.04	0.54	0.08	0.58	0.08	0.64	0.1	0.42	0.35	< 0.04		1.96	0.24	1.6	0.5	17	0.9
19901059	GS9900357	0.04	0.69	0.09	0.76	0.08	0.82	0.11	1.35	0.39	< 0.03		0.6	0.08	2.4	0.6	15.9	0.8
19901060	GS9900358	0.04	0.64	0.09	0.75	0.08	0.81	0.11	1.31	0.4	< 0.03		0.43	0.06	2.5	0.7	18.3	1
19901061	GS9900359	0.07	0.42	0.11	0.45	0.13	0.65	0.21	0.67	0.48	< 0.07		0.72	0.11	1.7	0.5	16.1	0.9
19901062	GS9900360	0.06	0.65	0.08	0.72	0.08	0.8	0.12	1.19	0.54	< 0.03		0.18	0.03	2.1	0.6	15.9	0.8
19901063	GS9900361	0.07	0.67	0.09	0.7	0.08	0.85	0.13	1.22	0.49	< 0.03		0.69	0.09	2	0.6	18.6	1
19901064	GS9900362	0.21	0.53	0.18	0.62	0.15	0.6	0.3	1.53	1.39	< 0.1		0.8	0.13	1.7	0.5	15.7	0.8
19901065	GS9900363	0.07	0.62	0.08	0.61	0.07	0.69	0.11	1.23	0.51	< 0.03		0.66	0.08	2	0.6	15.4	0.8
19901066	GS9900364	0.07	0.41	0.11	0.4	0.12	0.66	0.17	< 0.65		< 0.08		0.38	0.07	2.4	0.6	13.9	0.8
19901067	GS9900365	0.06	0.66	0.09	0.71	0.08	0.71	0.1	0.93	0.49	< 0.03		0.55	0.07	2.3	0.6	17.3	0.9
19901068	GS9900366	0.07	0.39	0.12	0.44	0.11	0.57	0.21	0.72	0.5	< 0.07		0.94	0.13	2.3	0.6	16.2	0.9
19901069	GS9900367	0.06	0.6	0.08	0.63	0.07	0.66	0.11	0.95	0.5	< 0.03		0.79	0.1	1.9	0.6	13.9	0.8
19901070	GS9900368	0.08	0.44	0.14	0.41	0.14	0.59	0.23	1.31	0.76	< 0.08		0.57	0.1	2.3	0.7	17.9	1
19901071	GS9900369	0.05	0.42	0.1	0.47	0.1	0.59	0.19	0.6	0.5	< 0.06		0.51	0.09	2.5	0.6	16	0.9
19901072	GS9900370	0.04	0.69	0.08	0.72	0.08	0.82	0.12	1.43	0.38	< 0.06		0.72	0.08	1.7	0.5	16	0.8
19901073	GS9900371	0.04	0.58	0.07	0.64	0.07	0.68	0.1	4.92	0.6	< 0.03		0.83	0.09	2.9	0.7	20.5	1
19901074	GS9900372	0.04	0.63	0.08	0.65	0.07	0.73	0.11	4.05	0.54	< 0.03		0.59	0.07	2.2	0.6	20.7	1
19901075	GS9900373	0.08	0.44	0.11	0.41	0.11	0.57	0.24	17.96	1.99	0.4	0.08	0.66	0.1	4.4	0.8	46.4	1.4
19901076	GS9900374	0.04	0.61	0.07	0.67	0.07	0.73	0.11	10.66	1.15	< 0.03		0.56	0.06	2.8	0.7	23.3	1
19901077	GS9900375	0.03	0.61	0.08	0.74	0.08	0.73	0.11	0.85	0.3	< 0.03		0.64	0.07	2.6	0.7	17.2	0.9
19901078	GS9900376	0.03	0.6	0.07	0.69	0.08	0.73	0.11	0.81	0.32	0.14	0.03	0.61	0.07	2.5	0.7	17.8	1
19901079	GS9900377	0.04	0.61	0.08	0.71	0.08	0.86	0.12	8.3	0.95	< 0.03		0.71	0.08	2.6	0.7	17.4	0.9
19901080	GS9900378	0.03	0.6	0.07	0.66	0.07	0.77	0.11	2.72	0.44	< 0.03		0.92	0.1	1.8	0.6	20.8	1

IERA/SDR	Base	Gamma Spectroscopy Analysis (pCi/g - Wet)													Gross Alpha		Gross Beta	
Sample	Sample	Am-241	Bi-214		Pb-214		Th-232		Th-234		U-235		Cs-137		pCi/g - Wet		pCi/g - Wet	
Number	Number	MDC*	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error
19901081	GS9900379	0.14	0.41	0.23	0.51	0.29	0.54	0.38	< 1.77		< 0.16		0.24	0.15	1.8	0.6	17.1	0.9
19901082	GS9900380	0.04	0.66	0.09	0.64	0.09	0.72	0.14	1.21	0.4	< 0.04		0.53	0.07	2.1	0.6	15.5	0.8
19901083	GS9900381	0.05	0.69	0.1	0.67	0.09	0.77	0.14	0.88	0.4	< 0.04		0.52	0.07	2.8	0.7	17.6	0.9
19901084	GS9900382	0.13	0.55	0.25	0.5	0.21	< 0.57		< 1.67		< 0.16		0.46	0.14	1.8	0.6	18.3	1
19901085	GS9900383	0.05	0.63	0.1	0.75	0.09	0.88	0.15	0.65	0.4	< 0.04		0.78	0.1	1.8	0.6	18.3	0.9
19901086	GS9900384	0.03	0.58	0.08	0.65	0.07	0.64	0.09	0.52	0.29	< 0.03		0.36	0.05	2	0.6	15.7	0.8
19901087	GS9900385	0.05	0.62	0.09	0.7	0.08	0.67	0.11	2.32	0.49	0.16	0.03	0.6	0.08	2.3	0.6	18.4	0.9
19901088	GS9900386	0.05	0.62	0.09	0.68	0.08	0.83	0.12	1.83	0.51	0.16	0.04	0.63	0.08	2.6	0.7	20	1
19901089	GS9900387	0.1	0.65	0.15	0.57	0.15	0.46	0.25	< 1.14		< 0.1		0.27	0.08	2.5	0.7	15.8	0.8
19901090	GS9900388	0.04	0.72	0.1	0.77	0.09	0.83	0.13	1.15	0.41	< 0.04		0.69	0.09	1.9	0.6	19.4	1
19901091	GS9900389	0.05	0.36	0.1	0.56	0.11	0.48	0.18	0.74	0.38	< 0.06		0.5	0.08	2.2	0.6	16.6	0.9
19901092	GS9900390	0.03	0.67	0.08	0.74	0.08	0.81	0.12	0.84	0.35	< 0.03		0.5	0.06	2.2	0.6	15.5	0.8
19901093	GS9900391	0.04	0.62	0.08	0.7	0.08	0.68	0.11	4.41	0.61	< 0.03		0.64	0.07	3.3	0.7	19.6	1
19901094	GS9900392	0.05	0.58	0.12	0.55	0.1	0.47	0.19	0.56	0.49	< 0.06		0.4	0.07	2.4	0.6	18	0.9
19901095	GS9900393	0.03	0.59	0.07	0.64	0.07	0.72	0.1	1.25	0.31	< 0.03		0.9	0.1	2.7	0.7	16.6	0.9
19901096	GS9900396	0.05	0.51	0.07	0.57	0.06	< 0.09		0.71	0.39	< 0.03		0.54	0.07	2.4	0.7	13.9	0.8
19901097	GS9900397	0.06	0.71	0.09	0.67	0.07	< 0.1		1.78	0.51	< 0.03		0.34	0.05	2	0.6	19	1
19901098	GS9900398	0.07	0.49	0.13	0.46	0.14	< 0.31		< 0.76		< 0.08		0.56	0.1	2.1	0.6	18.3	1
19901099	GS9900399	0.08	0.55	0.08	0.65	0.08	0.72	0.14	6.6	0.93	< 0.04		0.85	0.1	2.5	0.7	20.6	0.9
19901100	GS9900400	0.11	0.35	0.12	0.42	0.15	< 0.34		14.64	1.86	< 0.11		0.69	0.12	3.6	0.8	42.9	1.5
19901101	GS9900401	0.07	0.65	0.13	0.66	0.12	0.7	0.22	8.16	1.17	0.28	0.07	0.34	0.08	3.3	0.8	35.3	1.3
19901102	GS9900402	0.07	0.62	0.13	0.59	0.13	0.52	0.21	7.76	1.2	< 0.08		0.15	0.06	3.4	0.8	29	1.1
19901103	GS9900403	0.07	0.64	0.13	0.69	0.13	0.81	0.21	6.52	0.96	0.21	0.06	0.3	0.06	3.7	0.8	30.5	1.2
19901104	GS9900404	0.04	0.65	0.08	0.74	0.08	0.75	0.11	11.06	1.18	0.28	0.03	0.37	0.04	3.6	0.8	32.7	1.3
19901105	GS9900405	0.06	0.6	0.14	0.67	0.13	0.86	0.21	3.17	0.74	0.17	0.06			2.7	0.7	22.7	1.1
19901106	GS9900406	0.08	0.61	0.14	0.6	0.12	0.57	0.23	10.74	1.36	0.28	0.07	0.25	0.06	3.9	0.9	30.1	1.1
19901107	GS9900407	0.07	0.67	0.14	0.73	0.12	0.83	0.27	4.18	0.84	< 0.08				3	0.7	25.2	1.1
19901108	GS9900408	0.07	0.57	0.14	0.62	0.12	0.94	0.23	4.47	0.89	0.2	0.06			4	0.9	30.9	1.3
19901109	GS9900409	0.1	0.47	0.12	0.44	0.12	0.56	0.18	34.58	3.61	0.65	0.09	0.4	0.07	7.1	1.1	64.8	1.6
19901110	GS9900410	0.08	0.72	0.14	0.71	0.14	0.54	0.34	17.82	2.03	0.51	0.08	0.09	0.04	5.3	1	53.9	1.6
19901111	GS9900411	0.11	0.69	0.17	0.79	0.19	0.7	0.26	2.26	1.07	< 0.12				3.2	0.8	22.5	1.1
19901112	GS9900412	0.1	0.6	0.14	0.75	0.17	0.52	0.28	2.5	1.06	< 0.11		0.48	0.08	2	0.6	18	0.9
19901113	GS9900413	0.11	0.83	0.17	0.88	0.19	0.71	0.24	1.59	1.01	0.31	0.1			3.4	0.8	20.4	1
19901114	GS9900414	0.1	0.57	0.16	0.68	0.15	0.63	0.26	2.07	1.31	< 0.11				3	0.8	18.4	1

IERA/SDR	Base	Gamma Spectroscopy Analysis (pCi/g - Wet)												Gross Alpha		Gross Beta	
Sample	Sample	Am-241	Bi-214		Pb-214		Th-232		Th-234		U-235		Cs-137		pCi/g - Wet		pCi/g - Wet	
Number	Number	MDC*	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error	Value	Error
19901115	GS9900415	0.1	0.52	0.14	0.6	0.17	0.61	0.24	< 1.1		< 0.1		0.34	0.09	2.4	0.7	17.8	1
19901116	GS9900416	0.11	0.45	0.17	0.51	0.18	0.71	0.27	1.31		< 0.12				1.5	0.6	15.3	0.8
19901117	GS9900417	0.1	0.49	0.15	0.55	0.14	0.68	0.23	1.52	0.97	< 0.1		0.33	0.08	2.7	0.7	17.4	0.9
19901118	GS9900418	0.1	0.62	0.14	0.55	0.16	0.98	0.28	1.25	0.94	0.13	0.08	0.31	0.1	3.1	0.8	18.1	1
19901119	GS9900419	0.09	0.43	0.16	0.5	0.15	0.63	0.23	1.01	0.91	< 0.09				2.8	0.7	15	0.8
19901120	GS9900420	0.1	0.41	0.15	0.46	0.17	< 0.35		< 0.87		< 0.1		0.27	0.09	2.6	0.7	19.7	1
19901121	GS9900421	0.08	0.58	0.15	0.46	0.13	1.04	0.23	0.75	0.6	< 0.09		< 0.08		2.5	0.7	18.3	1
19901122	GS9900422	0.06	0.71	0.09	0.74	0.08	0.8	0.11	1.26	0.51	< 0.09		0.08	0.02	2.6	0.7	15.9	0.8
19901123	GS9900423	0.08	0.56	0.14	0.53	0.17	< 0.31		< 0.78		< 0.08				2	0.6	17.8	1
19901124	GS9900424	0.08	0.57	0.15	0.4	0.14	0.65	0.3	0.79	0.54	< 0.09				2.8	0.7	19.5	1
* All Values Less Than MDC			All Error Values are Reported at the 95 % Confidence Level															

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Appendix 3

Site Map with Soil Sampling and In-Situ Measurements Data

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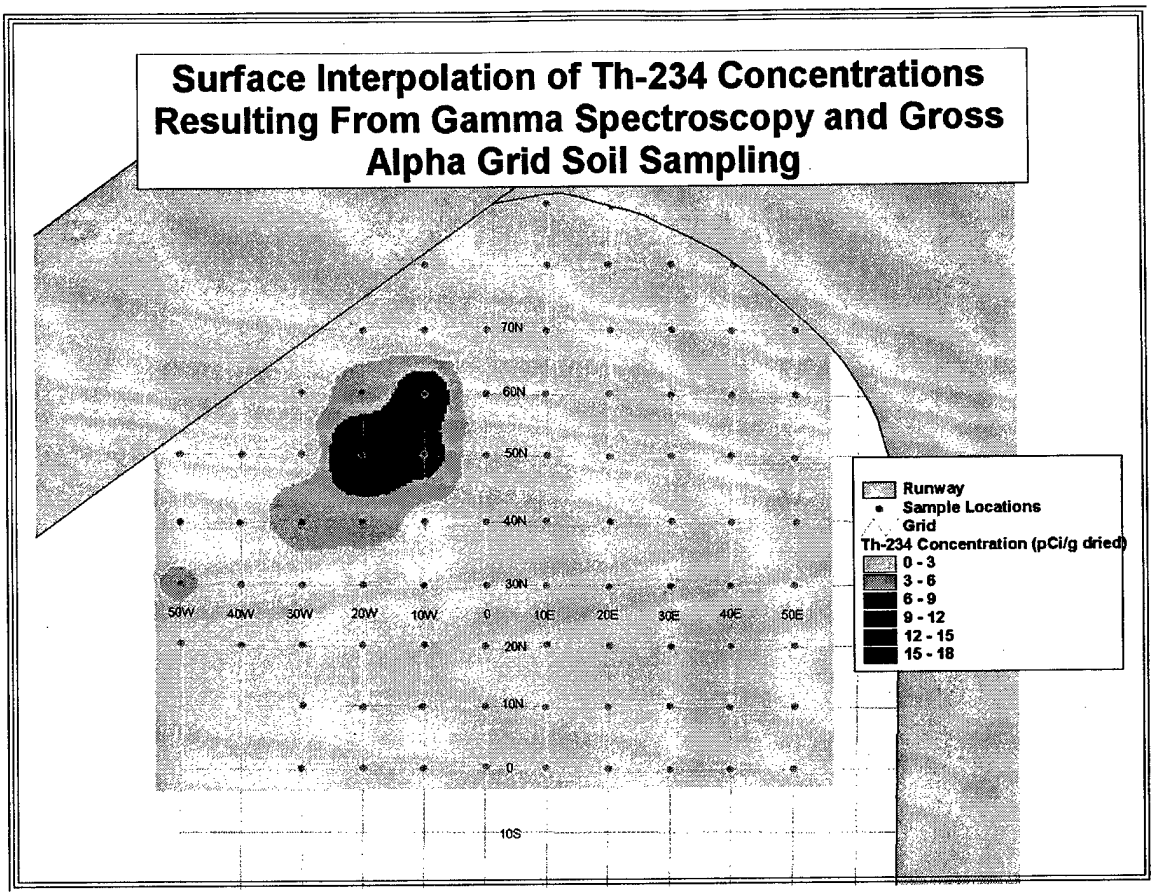
Surface Interpolation of Th-234 Concentrations Resulting From Gamma Spectroscopy and Gross Alpha Grid Soil Sampling
70N
60N
50N
40N
30N
20N
10N
0
10S
50W
40W
30W
20W
10W
0
10E
20E
30E
40E
50E
Runway
Sample Locations
Grid
Th-234 Concentration (pCi/g dried)
0 - 3
3 - 6
6 - 9
9 - 12
12 - 15
15 - 18

3D Interpretation of In-Situ Gamma Measurements in Investigation Area