Nevada
Environmental
Restoration
Project

DOE/NV-484
UC-700

RECEIVED

AUG 05 1997

OSTI

Double Tracks Test Site
Characterization Report

May 1996

MASTER

Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

DOUBLE TRACKS TEST SITE CHARACTERIZATION REPORT

DOE Nevada Operations Office
Las Vegas, Nevada

May 1996

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

A handwritten signature in black ink, appearing to be 'nj', is located at the bottom right of the page.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

**DOUBLE TRACKS TEST SITE
CHARACTERIZATION REPORT**

Submitted by: Monica Sanchez
Monica L. Sanchez, Manager
Soils Media Operable Unit Subproject

Date: 5/16/96

Approved by: David S. Shafer
David S. Shafer, Acting Project Manager
Nevada Environmental Restoration Project

Date: 5/16/96

Table of Contents

List of Figures	iii
List of Tables	iv
List of Acronyms and Abbreviations	vi
1.0 Introduction	1-1
1.1 Purpose	1-1
1.2 Site Description and History	1-1
1.3 Physical Characteristics of the Site	1-4
1.4 Previous Investigations	1-4
2.0 Site Characterization Activities	2-1
2.1 Characterization Event 1	2-1
2.2 Characterization Event 2	2-2
2.2.1 Surface Radiation Measurements	2-3
2.2.2 Hot Spot Investigations	2-3
2.2.3 Depth Profile Samples	2-4
2.2.4 Passive Alpha Detector Measurements	2-4
2.3 Characterization Event 3	2-5
2.3.1 Radiological Surveys	2-5
2.3.1.1 All-Terrain Vehicle-Mounted FIDLER Survey	2-5
2.3.1.2 Suburban-mounted Sodium-Iodide Detector Survey	2-5
2.3.1.3 Suburban Mast-Mounted HPGe Detector Survey	2-6
2.3.1.4 Jeep-mounted Scintillation Detector Survey	2-6
2.3.2 Hot Spot Mining	2-6
2.3.3 Ground Zero Characterization	2-6
2.4 Characterization Event 4	2-7
3.0 Nature and Extent of Soil Contamination	3-1
3.1 Radiological Constituents	3-1
3.1.1 Identification of Radiological Constituents of Concern	3-1
3.1.2 Plutonium/Americium Isotopic Ratio	3-11

Table of Contents (Continued)

3.1.3 Radiological Hot Spots	3-15
3.2 Nonradiological Constituents	3-15
3.2.1 Metals	3-15
3.2.2 Toxicity Characteristic Leaching Procedure Results	3-17
3.3 Horizontal Extent of Contamination	3-20
3.4 Vertical Extent of Contamination	3-21
3.5 Ground Zero Characterization	3-23
3.6 Soil Particle-size and Volume Reduction Testing	3-23
3.7 Contaminated Soil Volume	3-31
 4.0 Summary and Conclusions	 4-1
4.1 Summary	4-1
4.2 Conclusions	4-2
 5.0 References	 5-1
 Appendix A - IT Field Sampling Instructions	 A-1
Appendix B - EG&G Remote-Sensing Mission Plans	B-1
Appendix C - Soil Sample Analytical Data	C-1
Appendix D - Bechtel Nevada, Remote Sensing Laboratory Report on the Second and Third Characterization Events	 D-1
Appendix E - Vertical Profile Plots for Americium and Plutonium in Soil	E-1
Appendix F - Soil Particle-Size and Volume Reduction Data	F-1
Appendix G - Passive Alpha Detector Data Summaries and Result Discussions	G-1

List of Figures

Number	Title	Page
1-1	Location of Double Tracks Test Site	1-2
1-2	Nevada Applied Ecology Group Soil Sampling Locations and Results	1-6
1-3	EG&G 1977 Aerial Radiological Survey of the Double Tracks Test Site	1-8
1-4	EG&G 1993 Aerial Radiological Survey of the Double Tracks Test Site	1-10
3-1	Location of Soil Samples Collected During the First Characterization Event	3-2
3-2	Location of Hot Spot Soil Profile Samples Collected During the Second Characterization Event	3-5
3-3	Uranium Isotope Versus Plutonium-239/240 Activity in Double Tracks Surface Soil	3-10
3-4	Activity Ratio of Plutonium-239/240 to Americium-241 in Double Tracks Surface Soil (Assuming Negligible Initial Americium-241 Ingrowth)	3-12
3-5	Americium-241 Versus Plutonium-239/240 Activity in Double Tracks Surface Soil	3-13
3-6	Total Transuranic Isotope Activity of Double Tracks Soil, Based on the 1995 EG&G Ground Survey	3-22
3-7	Location of Soil Borings in Ground Zero Area of the Double Tracks Test Site ..	3-25
3-8	Location of Soil Samples Collected During the Fourth Characterization Event	3-26

List of Tables

Number	Title	Page
1-1	Isotopic Composition of Plutonium and Uranium Used in the Double Tracks Test Device	1-3
1-2	Estimated Size of Areas Exceeding Specified Concentrations of Plutonium at the Double Tracks Test Site	1-7
3-1	Radionuclide Activity in Surface Soil at the Double Tracks Test Site	3-3
3-2	Radionuclide Activities in Surface Soil Samples Collected from Hot Spot Locations	3-6
3-3	Background Radioactivity in Surface Soil	3-8
3-4	Source of Radionuclides in Double Tracks Surface Soil	3-11
3-5	Field Collimated HPGe Detector Measurements of Metal Fragments and Hot Spot Soil	3-16
3-6	Metal Concentrations in Surface Soil at the Double Tracks Test Site	3-18
3-7	Toxicity Characteristic Leaching Procedure Results for Surface Soil Samples from the Double Tracks Test Site	3-19
3-8	<i>In Situ</i> Radiological Measurements of Depth Profiles at the Double Tracks Test Site	3-24
3-9	<i>In Situ</i> Radiological Measurements in Ground Zero Soil Borings	3-27
3-10	Grain-Size Analysis of Treatability Study Samples	3-29

List of Tables (Continued)

- 3-11 Summary of Gamma Spectroscopy and Isotopic Analysis of Treatability Study
Samples 3-30
- 3-12 Estimates of Area and Volume of Soil Exceeding 200 Picocuries per Gram
of Total Transuranic Isotope Activity at the Double Tracks Test Site 3-32

List of Acronyms and Abbreviations

ATD	Alpha Track Detector(s)
ATV	All-terrain vehicle
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
cm	Centimeter(s)
cpm	Count(s) per minute
DOE	U.S. Department of Energy
DRI	Desert Research Institute
EIC	Electrode Ionization Chamber(s)
EPA	U.S. Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low-Energy Radiation
ft	Foot (feet)
GPS	Global positioning system
HPGe	High-purity germanium
in.	Inch(es)
IT	IT Corporation
ITPDL	IT Process Development Laboratory
kg	Kilogram(s)
km	Kilometer(s)
lb	Pound(s)
m	Meter(s)
m ³	Cubic meter(s)
MAL	Minimum activity level
mg/kg	Milligram(s) per kilogram
mg/L	Milligram(s) per liter
mi	Mile(s)
NAEG	Nevada Applied Ecology Group
NAFR	Nellis Air Force Range
NaI	Sodium iodide
NAS	National Academy of Sciences
NTS	Nevada Test Site
pCi/g	Picocurie(s) per gram
ppm	Part(s) per million

List of Acronyms and Abbreviations (Continued)

RCRA	Resource Conservation and Recovery Act
SAFER	Streamlined Approach for Environmental Restoration
TAL	Target analyte list
TCLP	Toxicity characteristic leaching procedure
TNT	Trinitrotoluene
TTR	Tonopah Test Range
TRU	Transuranic
yd ³	Cubic yard(s)
μCi	Microcurie(s)
μCi/g	Microcurie(s) per gram
μg/g	Microgram(s) per gram

1.0 Introduction

This report presents the results of site characterization activities performed at the Double Tracks Test Site, located on Range 71 North, of the Nellis Air Force Range (NAFR) in southern Nevada. Site characterization activities included reviewing historical data from the Double Tracks experiment, previous site investigation efforts, and recent site characterization data. The most recent site characterization activities were conducted in support of an interim corrective action to remediate the Double Tracks Test Site to an acceptable risk to human health and the environment. Site characterization was performed using a phased approach. First, previously collected data and historical records were compiled and reviewed. Generalized scopes of work were then prepared to fill known data gaps. Field activities were conducted and the collected data were then reviewed to determine whether data gaps were filled and whether other areas needed to be investigated. Additional field efforts were then conducted, as required, to adequately characterize the site. Characterization of the Double Tracks Test Site was conducted in accordance with the U.S. Department of Energy's (DOE) Streamlined Approach for Environmental Restoration (SAFER).

1.1 Purpose

This report presents the data and conclusions derived from the characterization activities that were conducted at the Double Tracks Test Site. Because characterization was conducted in support of an interim corrective action, field activities focused on adequately characterizing the site to a level so that interim corrective action could be determined. The characterization included determining the nature and extent of contamination, estimating the volume of contaminated soil and debris, and adequately characterizing the soil to meet disposal criteria.

1.2 Site Description and History

The Double Tracks test site is located in Stonewall Flat on Range 71 North, of the NAFR, northwest of the Nevada Test Site (NTS) (Figure 1-1). The nearest town is Goldfield, Nevada, located approximately 22 kilometers (km) (14 miles [mi]) west of the site. By existing road (through the Tonopah Test Range [TTR] and U.S. Highways 6 and 95), Goldfield is approximately 132 km (82 mi), and Mercury, Nevada, is approximately 362 km (224 mi) from the Double Tracks Test Site.

Double Tracks was the first of four experiments that constituted Operation Roller Coaster. On May 15, 1963, plutonium, depleted uranium, and trace amounts of other isotopes were placed on

Figure 1-1
Location of Double Tracks Test Site

a 2.4- by 2.4-meter (m) (8- by 8-foot [ft]) steel plate that was supported by a 6.1- by 6.1-m (20- by 20-ft), 0.3-m (1-ft)-thick reinforced concrete pad. The radioactive material was dispersed using 54 kilograms (kg) (118 pounds [lbs]) of trinitrotoluene (TNT) explosive (Church, 1969; Shreve, 1965). The explosion occurred in the open, 0.3 m (1 ft) above the steel plate (Menker et al., 1966). No fission yield was detected from the test, and the total amount of plutonium deposited on the steel plate, concrete slab, and ground surface was estimated to be between 980 and 1,600 grams (Shreve, 1965). Table 1-1 lists the isotopic composition of plutonium and uranium used in the device (Menker et al., 1966). The test device was composed primarily of uranium-238 (U-238) and plutonium-239 (Pu-239). Menker et al. (1966) reported that the weight ratio of uranium to plutonium in the device was 4.35.

Table 1-1
Isotopic Composition of Plutonium and Uranium Used
in the Double Tracks Test Device^a

Isotope	Weight Percent	Activity Percent ^b
Plutonium-238	0.00387	0.30
Plutonium-239	97.314	27.53
Plutonium-240	2.530	2.62
Plutonium-241	0.1487	69.55
Plutonium-242	0.00310	0.0000554
Total Plutonium	100	100
Uranium-234	0.00074	12.00
Uranium-235	0.165	0.93
Uranium-238	99.834	87.08
Total Uranium	100	100

^a Menker et al. (1966)

^b Converted from weight percent, using specific activity

The objectives of the Double Tracks experiment were to evaluate the dispersal of radionuclides in the environment and the uptake and fate of plutonium in several animal species. The experiment scattered radioactive material, earth, and other material (concrete and metal) into the air. The debris and most of the dirt fell to earth at relatively short distances from the GZ area.

However, some of the finer grained material was spread over a larger area downwind, to the south of ground zero. The debris in the vicinity of ground zero and identified fragments to distances of 90 to 120 m (300 to 800 ft) were collected and buried near ground zero.

Contaminated surface soil in the vicinity of ground zero reportedly was scraped to a depth of several inches and mounded, covered with clean dirt, and compacted. The steel plate was buried in the clean slates radiation disposal pit, but was later exhumed and transported to the NTS for analysis and disposal. Except for these postevent activities, no decontamination of the site was reported. Postevent sampling and surveying were conducted to determine contamination levels and distribution and are summarized in Section 1.4.

1.3 Physical Characteristics of the Site

The Double Tracks Test Site is located on Stonewall Flat, an alluvial basin that is bordered by the Cactus Range to the east, the Goldfield Hills to the north, and Stonewall Mountain to the south (Ekren et al., 1972). The depth of the alluvial material beneath the site is not accurately known but is suspected to be deeper than 250 m (800 ft). Groundwater in the vicinity of the Double Tracks Test Site is at an elevation of approximately 1,400 m (4,500 ft), or approximately 150 m (500 ft) below ground surface (Thomas et al., 1986). This first occurrence of groundwater is in the alluvial material.

The Double Tracks Test Site is relatively flat, with surface runoff toward the southwest. The elevation of the site is approximately 1,524 m (5,000 ft) above mean sea level. Average annual precipitation at Goldfield for the years 1948 to 1989 was 11.8 centimeters (cm) (4.6 inches [in.]) (unpublished, Office of the Nevada State Climatologist). Major plant species found on the site are shadscale (*Atriplex confertifolia*), budsage (*Artemisia spinescens*), winterfat (*Ceratoides lanata*), greasewood (*Sarcobatus vermiculatus*), burrobrush (*Hymenoclea salsola*), and Indian ricegrass (*Oryzopsis hymenoides*). Soils are predominantly gravelly, sandy loams and gravelly loams (Leavitt, 1974), and blow-sand mounds are common beneath shrubbery.

1.4 Previous Investigations

Periodic alpha radiation surveys of the Double Tracks test site were conducted for several years following the event (Gloria and Brown, 1964; Gloria and Aoki, 1966). Leavitt (1974) conducted a soil classification survey of the Double Tracks Test Site and characterized the soil as gravelly, sandy loam and gravelly loam. Leavitt also reported that plant density is 5 to 15 percent.

In the 1970s, the Nevada Applied Ecology Group (NAEG) performed a systematic survey of suspected surface-contaminated sites on the NTS, TTR, and NAFR. The following activities

were conducted at the Double Tracks Test Site as part of the NAEG investigation (Gilbert et al., 1975):

- An *in situ* radiological survey using a Field Instrument for the Detection of Low-Energy Radiation (FIDLER)
- Collection of surface soil samples (0- to 5-cm [0- to 2-in.] depth) using a stratified random sampling scheme based on FIDLER survey results. Laboratory analyses were performed on 53 samples for Pu-239/240 and 33 samples for americium-241 (Am-241)
- Collection of vegetation samples and laboratory analysis of 48 samples for Pu-239/240 and 40 samples for Am-241
- Collection of five vertical soil profile samples consisting of ten 2.5-cm (1.0-in.) incremental samples collected to a depth of 25 cm (10 in.) and analysis of samples for Pu-239/240 and Am-241.

Figure 1-2 shows the locations and Pu-239/240 concentrations of the surface soil samples collected by the NAEG. Most of the samples were collected near ground zero and may not represent undisturbed fallout from the experiment because much of the soil was reworked during postevent activities. The soil data indicate that the concentration of plutonium in surface soil is highly variable over relatively small distances. From the NAEG surface soil data, Gilbert (1977) estimated the inventory of Pu-239/240 in the upper 5 cm (2 in.) of Double Tracks soil to be 3.6 curies, with a 95 percent confidence interval of 1.7 to 5.5 curies. Kinnison and Gilbert (1982) calculated that using a 160-picocurie per gram (pCi/g) cleanup level and removing the top 15 cm (6 in.) of soil at Double Tracks would yield a soil volume of 9,200 cubic meters (m^3) (12,030 cubic yards [yd^3]). With an average density of 1,100 kilograms per cubic meter for Double Tracks soil (Martin and Bloom, 1977), the mass of soil removed would be 1.0×10^7 kg (2.2×10^7 lbs).

Using the 1974 NAEG surface soil data, the average Pu-239/240 to Am-241 activity ratio was estimated to be 24, with a standard error of 0.64 (Gilbert et al., 1975). Kinnison and Gilbert (1982) reported that the average ratio for Double Tracks soil is 20, with a standard deviation of 4, based on more recent (1977) data from the NAEG. Kinnison and Gilbert also reported an average Pu-239/240 to Pu-238 activity ratio of 100, with a standard deviation of 26. This ratio is consistent with the ratio of these isotopes reported for the Double Tracks device (Table 1-1).

Figure 1-2
Nevada Applied Ecology Group Soil Sampling Locations and Results

Essington et al. (1975) presented the results of NAEG vertical soil profile sampling at Double Tracks. When the Pu-239/240 activity of the top 5-cm (2-in.) soil sample was compared with the activity of the 5- to 25-cm (2- to 10-in.) interval, they found that the proportion ranged from 48 to 99 percent. These results may indicate that the soil has either been disturbed by site activities or the plutonium has moved downward at some locations. Essington et al., suggested that plutonium may move down the soil profile to caliche layers or layers where lime lenses are in the process of forming. The plutonium may be accumulating in these layers by cation exchange. Essington et al. (1975) also indicated that Am-241 moved more readily into the soil profile, based on changes in the Pu-239/240 to Am-241 ratio with depth. NAEG studies also have shown that plant uptake of americium is greater than that of plutonium (Friesen, 1992).

A study by the DOE (1995a) used the 1974 NAEG surface soil data to estimate the Double Tracks Test Site surface areas that exceed specified plutonium concentrations. These estimates are shown in Table 1-2.

Table 1-2
Estimated Size of Areas Exceeding Specified
Concentrations of Plutonium at the Double Tracks Test Site^a

	Area, A (hectares) exceeding X picocuries per gram of plutonium						
X =	1,000	400	200	150	100	40	10
A =	1	1	3	4	7	8	11

^aDOE, 1995a

These volume estimates have been revised using site characterization data collected in preparation of the interim corrective action. The new volume estimates are presented in Section 3.7.

An aerial radiological survey of the Double Tracks Test Site was conducted in 1977 by EG&G for the NAEG (Jobst, 1979). The survey was conducted from a helicopter at an altitude of 30 m (100 ft). A gamma ray from Am-241 was measured with sodium iodide (NaI) detectors, and the Pu-239/240 to Am-241 ratio determined by Gilbert et al. (1975) was used to estimate the Pu-239/240 activity of the surface soil. Figure 1-3 shows the isopleth map of americium and plutonium activity determined by the EG&G aerial survey. There appears to be an error on the conversion of count rates to activity for this survey. The activity should be about a factor of

Figure 1-3
EG&G 1977 Aerial Radiological Survey of the Double Tracks Site

10 less than reported. The Double Tracks Test Site was resurveyed in 1993 by EG&G, again from an altitude of 30 m (100 ft), with NaI detectors mounted on a helicopter (Hendricks, 1995). The results of this survey are shown in Figure 1-4. Please note that the results presented in Figure 1-4 are large-area averaged, which at the time this investigation was conducted appeared to best represent the extent of contamination.

Figure 1-4
EG&G 1993 Aerial Radiological Survey of the Double Tracks Test Site

2.0 Site Characterization Activities

To fill identified data gaps, additional site characterization activities were conducted at Double Tracks Test Site on four separate occasions from October 1994 to August 1995. The characterization phases are referred to as events in this report because the term "phase" has regulatory connotations that do not apply.

The four characterization events consisted of the following:

- During the first characterization event, discrete vertical soil profile samples were collected for analysis of radionuclides and metals.
- During the second characterization event, various radiological surveying systems and techniques were evaluated, hot spots (areas of anomalously elevated radioactivity) were identified and sampled, and additional depth profiles were sampled.
- During the third characterization event, systematic radiological surveys of the Double Tracks Test Site were performed, along with some additional characterization of the ground zero area.
- During the fourth characterization event, soil samples were collected from previously identified contaminated areas for treatability testing.

These characterization events were conducted in accordance with the *Soils Media Operable Unit Quality Assurance Project Plan* (DOE, 1995b). The characterization activities for each event are discussed in more detail in the following sections.

2.1 Characterization Event 1

The first characterization event at the Double Tracks Test Site was conducted in October 1994. The goal of this characterization field effort was to collect discrete soil samples to confirm the NAEG sample and EG&G aerial survey results. In addition, samples were collected for toxicity characteristic leaching procedure (TCLP) testing to evaluate disposal requirements and determine whether mixed waste was present. The laboratory analytical results were expected to be used in the accurate determination the Pu-239/240 to Am-241 ratio.

Discrete soil samples were collected from 12 locations within the exclusion zone. The sampling locations were selected based on the 1977 and 1993 aerial surveys and NAEG sample results. At

each sample location, vertical profile soil samples were collected from the following depth intervals:

- 0 to 5 cm (0 to 2 in.)
- 5 to 10 cm (2 to 4 in.)
- 10 to 15 cm (4 to 6 in.)
- 22.5 to 30 cm (9 to 12 in.)

Samples from the three upper intervals were submitted to a laboratory for analysis of isotopic americium, plutonium, and uranium. The uppermost sample intervals were also analyzed for gamma-emitting radionuclides and total target analyte list (TAL) metals. The TAL is a list of analytes specified in Resource Conservation and Recovery Act (RCRA) to characterize waste and waste streams. Because previous investigations indicated that most of the contaminants were in the top several centimeters, the lowest interval sample from each location was archived and not analyzed. If contaminants were detected in the sample immediately above the archived sample, then the archived sample was to be analyzed. This sample analysis strategy follows the SAFER approach of collecting and analyzing the minimum number of samples required for the adequate characterization of a site.

In addition to the analyses described, soil from the uppermost interval (0 to 5 cm [0 to 2 in.]) at three sample locations was submitted for TCLP testing and the extract was analyzed for RCRA metals to provide information on soil waste disposal requirements. Appendix A presents additional details on the sampling and analysis performed during the first site characterization event.

2.2 Characterization Event 2

Results of the first characterization event indicated that the spatial distribution of radiological contamination in surface soil was highly variable and that the extent of soil contamination at the Double Tracks Test Site was not as uniform as previously assumed. As a result, it is difficult to accurately delineate the extent of soil contamination based only on soil sample results. Because of this, the second characterization event focused on evaluating the use of *in situ* radiological survey equipment and methods to delineate the extent of contamination and characterize the Double Tracks Test Site. In addition, because hot spots were thought to be biasing the aerial survey measurements, experiments were conducted to determine the size and depth of the hot spots and whether they could be removed. Several hot spot removal methods were tried to determine the most cost-effective approach. Finally, additional soil samples were collected from areas with elevated activities to determine the Pu-239/240 to Am-241 ratio more accurately.

The second characterization event was conducted in April 1995. Additional details on the field activities performed are presented in Appendices A, B, and D. Specific activities conducted during the second characterization event are discussed in the following sections.

2.2.1 Surface Radiation Measurements

A small-scale radiation survey was conducted over a limited area at the Double Tracks Test Site. The area selected for this survey was known to have elevated radioactivity, as determined from aerial radiological surveys conducted by EG&G (Section 1.4). The objective of the survey was to obtain data from several surface *in situ* detector systems and compare them with laboratory results. The following detector systems were used:

- A Suburban-mounted collimated high-purity germanium (HPGe) detector
- A tripod-mounted collimated HPGe detector
- A hand-held FIDLER

A tripod-mounted collimated system was placed near ground zero for approximately 1 to 2 hours to measure radioactivity with suitable accuracy to determine the Pu-238/239 to Am-241 ratio. In addition, the Suburban-mounted HPGe system was used outside the immediate ground zero area to evaluate the uniformity of the radiation field by taking measurements from different heights at the same location.

2.2.2 Hot Spot Investigations

Hot spots identified during the small-scale radiological survey (Section 2.2.1) were investigated further to determine the nature of the elevated radioactivity and to evaluate the feasibility of removing the hot spots. Once located by *in situ* surveying, hot spots were physically removed using a combination of methods, and the area was resurveyed. This process was continued until approximately 80 to 90 percent of the radioactivity, determined by field instrument count rates, had been removed.

To assist in determining the nature and size of the hot spot material, several hot spot soil samples were split in the field by passing the soil through a Jones splitter device. After a single sample was split into two equal-sized subsamples, the FIDLER instrument was used to survey the subsamples. This activity was designed to provide information on the distribution of radioactive particles in the hot spot soil. For each split sample, the subsample with the highest measured radioactivity was retained for laboratory analysis. If relatively large metallic fragments were found in a hot spot soil sample, the fragments were removed from the sample and stored at the

Double Tracks Test Site within the exclusion zone. Six hot spot soil samples (some of which were also depth profile samples; Section 2.2.3) were submitted to a laboratory for analysis of americium, isotopic plutonium and total uranium. Four hot spot samples were submitted for TCLP testing of RCRA metals to provide information on soil waste disposal requirements. In addition, a particle-size analysis/separation was performed on one hot spot soil sample, and the separated fractions were analyzed for gross alpha and beta activity, to support the evaluation of a volume reduction alternative.

2.2.3 Depth Profile Samples

To assess the vertical distribution of contamination, depth profile sampling experiments were performed at four locations of elevated radioactivity. A tripod-mounted collimated HPGe detector or hand-held FIDLER detector was used to measure the radioactivity of the undisturbed sample location. After this measurement, a layer of soil (approximately 1 to 2 cm) was physically removed from the location starting at ground surface, and the radioactivity was remeasured. This process was continued until approximately 80 to 90 percent of the radioactivity had been removed. The first (uppermost) layer of soil from three of the four hot spot locations was submitted to a laboratory for analysis of americium, isotopic plutonium, and total uranium.

2.2.4 Passive Alpha Detector Measurements

Two types of passive alpha detectors were field tested to evaluate their effectiveness for screening alpha-emitting contaminated soil at the Double Tracks Test Site. Electrete Ionization Chambers (EICs) measure air ionization due to alpha emission from the soil surface. Alpha Track Detectors (ATDs) measure alpha particles as microscopic emission from the soil surface. Each of the detectors tested was deployed in several types of arrays in areas of known contamination. The deployment times ranged from 5 minutes to 5 days. Surface deployment consisted of laying the detectors directly on the contaminated soil and covering them to protect the detectors from airborne (dust) contamination and adverse weather. Depth profiles were also conducted by driving a small diameter stake 20 cm into the ground, removing the stake, and then inserting the detectors into the open hole. To correlate these detectors with other *in situ* measurements, several experiment locations were also surveyed with the tripod- and boom-mounted HPGe detector.

Results from the EIC and ATD detector experiments indicated that these types of detectors cannot cost effectively be used to characterize the Double Tracks Test Site. The disadvantage of these detectors is that they were very susceptible to airborne (dust) contamination and they could not systematically identify hot spots over a relatively large area. The advantages of these detectors is that they were relatively inexpensive, responded well to contamination levels

encountered at the Double Tracks Test Site, and can provide immediate on-site readout. During this experiment the detection limits ranged from 100 nCi/g (Pu+Am) to 22 pCi/g (total alpha).

The depth profile experiment did not yield usable results and therefore will not be discussed any further in this document. A more in-depth discussion of results from these detector experiments is presented in Appendix G.

2.3 Characterization Event 3

The third characterization event at the Double Tracks Test Site was conducted in June 1995. The goal of this field effort was to remove all hot spots from the areas to be surveyed and then survey the site to determine the extent of radiological contamination with accuracy. In addition, several pieces of metal from the hot spots were weighed and counted using a sensitive collimated detector to determine whether transuranic (TRU) material was present. Several *in situ* radiation field instruments were used to cross-correlate the results in the field to determine whether the site was being accurately characterized. Appendices A and B present additional details on the field activities performed during this stage of characterization.

2.3.1 Radiological Surveys

Several radiological surveys were conducted concurrently to cross-correlate results. These surveys are discussed individually in the sections that follow.

2.3.1.1 All-Terrain Vehicle-Mounted FIDLER Survey

This measurement system consisted of three FIDLERs mounted on the front of an all-terrain vehicle (ATV). The FIDLERs were mounted approximately 1 m (3 ft) above ground surface. The combined field of view of the three detectors was approximately 1.5 m (5 ft). The ATV was used to conduct a systematic survey of the contaminated area for hot spots. Traverses were made on approximately 1.5-m (5-ft) centers. The ATV operator dropped a flag at locations where hot spots were detected. The intent of this survey was to remove fragments and hot spots prior to conducting additional instrument surveys.

2.3.1.2 Suburban-Mounted Sodium-Iodide Detector Survey

This measurement system consisted of three pods of NaI detectors mounted on the rear bumper of a specially designed Suburban vehicle (named the Kiwi). The system was combined with a differential global positioning system (GPS) to provide both an *in situ* radioactivity measurement and an accurate location. Sets of NaI detectors were previously used in the aerial (helicopter) system. Because the detectors are closer to the ground, spatial resolution and sensitivity were

increased relative to the previous aerial surveys. At an aboveground distance of 0.8 m (2.5 ft), the array of NaI detectors produced a field of view of approximately 3 m (10 ft). The positional uncertainty of the differential GPS was approximately 1 m (3 ft). The Kiwi was used to perform a systematic survey of the Double Tracks Test Site to establish with accuracy the extent of contamination. This survey was performed after most known hot spots had been removed, but the Kiwi surveyed part of the area before the ATV could locate and remove all of the metallic material or hot spots.

2.3.1.3 Suburban Mast-Mounted HPGe Detector Survey

This measurement system consisted of a collimated HPGe detector mounted on an extendable mast attached to a Suburban vehicle. When the mast was fully extended, the field of view covered an approximately 13-m (43-ft)-diameter area. The system was used to make *in situ* radioactivity measurements in and around Double Tracks contaminated areas. Outside these areas, measurements were made to determine background. Inside the exclusion zone, the HPGe detector system was used to confirm the measurements made by the Kiwi system. Although the boom mounted collimated HPGe detector was shown to provide the most reliable *in situ* measurements, the measurements require relatively long count times (5 to 10 minutes).

2.3.1.4 Jeep-Mounted Scintillation Detector Survey

To cross-check the other *in situ* radiological survey results, a scintillation detector system mounted on the bumper of a Jeep Cherokee was used to survey the contaminated areas at the Double Tracks Test Site. This survey was also used to assist in the location of hot spots. Results indicated that this system was not as sensitive as the other instrument systems used. The scintillation detector system will not be discussed again in this document.

2.3.2 Hot Spot Mining

As previously stated, relatively large, highly radioactive metallic fragments were discovered at hot spot locations during the second characterization event. During the third characterization event, hot spot materials were identified and the fragments were removed and taken to a central location. Several of the fragments were then characterized by measuring radioactivity using a collimated HPGe detector, weighing the samples, and photographing them.

2.3.3 Ground Zero Characterization

Historical records indicate that debris and contaminated soil in the immediate vicinity of ground zero were removed, scraped, and mounded up at ground zero (Section 1.2). *In situ* radiological surveys could not be performed at ground zero because of elevated activities, at times exceeding

5,000 pCi/g. Therefore, all of the ground zero mound was assumed to be contaminated even though clean fill was documented as having been placed on top of the mound.

To provide for a better understanding of the nature and extent of contamination in the ground zero area, several field activities were conducted to measure the volume of the mound and characterize its contents. To determine the vertical extent of contamination, 17 shallow boreholes were advanced in the ground zero area using manual and power augers. The depths of the boreholes ranged from less than 1.5 m (5 ft) to approximately 2.5 m (8 ft). Downhole radiation measurements were recorded using a NaI detector to determine the bottom of the mound. Several of the boreholes intercepted a hard layer that was assumed to be the concrete pad used in the Double Tracks test.

2.4 Characterization Event 4

The fourth characterization event was conducted on July 25, 1995. The objective of this field effort was to collect contaminated soil samples for treatability testing. The goal of the treatability analysis was to determine if a physical separation process (grain-size separation) is a cost-effective option to reduce the volume of soil requiring disposal during site remediation.

Soil sample locations were chosen so that a representative suite of samples could be collected from contaminated areas at the Double Tracks Test Site, excluding ground zero, that adequately represent soil that will require remediation. The sampling locations were selected based on previous ground survey results. The first sample location was approximately 61 m (200 ft) south of ground zero, in the approximate center of the contaminant plume. Samples were then collected every 30 m (100 ft) south along the axis of the contaminant plume. To reduce the potential of cross contamination, samples were collected from least to most contaminated locations (south to north).

Based on previous soil sampling experience, as well as previous analytical results, it was known that the contaminants at the Double Tracks Test Site are not homogeneous. Therefore, the sampling procedures included mechanically splitting the soil sample several times with a Jones splitter to achieve a more representative sample at each location. The soil splitting consisted of the following:

- Two soil samples were collected from the upper 2 to 4 cm at each sample location. Each soil sample was approximately 2 liters.

- Each of these samples was mechanically split with half of each sample discarded and the second half from each sample combined. The combined sample was then mechanically split a second time.
- Each of the second sample splits was retained. One split sample was sent to Desert Research Institute (DRI) for analysis at the NTS and the other was sent to the IT Corporation (IT) Process Development Laboratory (ITPDL) in Knoxville, Tennessee.

The IT laboratory analysis consisted of wet screening approximately 1,000 to 1,500 grams of soil from each sample to develop a bulk soil characterization profile. The coarse fraction, i.e., soil plus 100 mesh (149 microns), was then dried and submitted for gamma spectroscopy analysis. This coarse fraction was then subjected to attrition scrubbing for 15 minutes at approximately 70 to 75 percent solids. The attrition scrubbing consisted of violent agitation of the coarse fraction, forcing finer material to separate from more coarse material. The attrition scrubbed soil was then wet sieved again. The coarse fraction was dried and submitted for gamma spectroscopy analysis. The final coarse fraction as well as the combined fine fractions, initial wet sieving and wet sieving after attrition scrubbing, were sent to another laboratory for americium and isotopic plutonium analysis. For a more complete discussion of this sampling effort, see the fourth Sampling Instruction Characterization Event presented in Appendix A.

The DRI laboratory program consisted of grain-size analysis (wet sieving) of each sample, followed by gamma spectroscopy analysis. The intent of the DRI laboratory program was to confirm the ITPDL results. This confirmation was required because of the variability of the results previously experienced during site characterization. Note that the DRI soils were not attrition scrubbed prior to wet sieving, and gamma spectroscopy analysis was the only analysis conducted. The DRI wet sieving was conducted with a vibrating type of sieving system, which agitates the sample more than the ITPDL sieving system. This additional agitation may liberate more of the fine fraction than the ITPDL sieving system and less than the attrition scrubbing process. Smaller volumes of soil were wet sieved and analyzed at DRI than at the ITPDL, so the variability of the results may be slightly greater.

3.0 Nature and Extent of Soil Contamination

Historical records indicate that during the Double Tracks experiment the only materials known to have been released were radioactive materials. There are no historical records indicating that significant amounts of RCRA constituents were either present or released at the Double Tracks Test Site. Therefore, this section focuses primarily on the nature and extent of radiological soil contamination at the Double Tracks Test Site. This section also describes the contaminant plume as it currently exists and demonstrates that the plume has not changed significantly since the experiment was conducted. In addition, identified contaminants of concern, estimates of the volume of contaminated soil, and a summary of isotopic ratios calculated are presented.

This section is organized as follows:

- Contaminants of concern are identified.
- Horizontal extent and vertical extent of contamination are delineated.
- Nature and extent of contamination at the ground zero area are defined.
- Results of soil volume reduction studies are presented.
- Volume of contaminated soil at the Double Tracks Test Site is estimated.

3.1 Radiological Constituents

This section discusses radiological constituents of concern, the Pu/Am ratio, and hot spots.

3.1.1 Identification of Radiological Constituents of Concern

Figure 3-1 shows the location of soil samples collected and analyzed for radionuclides during the first Double Tracks Test Site characterization event, and Table 3-1 summarizes the activities of detected radioisotopes. Surface soil samples were collected from the uppermost 5 cm (2 in.) of the soil profile (Section 2.1) and were analyzed by gamma spectroscopy using Method HASL 300 (DOE, 1992), with the exception of Am-241, isotopic plutonium, and isotopic uranium, which were analyzed by Methods NAS-NS-3006, NAS-NS-3058, and NAS-NS-3050, respectively (National Academy of Sciences [NAS], 1960, 1965, and 1962, respectively).

Figure 3-2 shows the location of hot spot sampling experiments conducted during the second characterization event, and Table 3-2 lists the radiological results for the hot spot soil samples.

Figure 3-1
Location of Soil Samples Collected During the First Characterization Event

Table 3-1
Radionuclide Activity in Surface Soil at the Double Tracks Test Site
 (Page 1 of 2)

Radionuclide	Ac-227	Am-241	Bi-214	Cs-137	Co-60	Eu-155	Pb-210	Pb-212	Pu-238	Pu-239 and Pu-240	K-40	Pa-234	Ra-226	Tl-208	Th-232	U-234	U-235 and U-236	U-238
Location 1 Soil Sample DT00002	< 0.24	0.056 ± 0.021	1.40 ± 0.14	0.54 ± 0.08	< 0.059	0.12 ± 0.07	1.60 ± 0.55	1.97 ± 0.23	0.008 ± 0.011	0.12 ± 0.04	33.6 ± 3.6	< 0.10	1.32 ± 0.09	0.59 ± 0.07	1.93 ± 0.020	0.92 ± 0.20	0.073 ± 0.046	0.80 ± 0.18
Location 1 Soil Sample DT00002 Lab Duplicate	1.41 ± 0.34	0.020 ± 0.012	1.28 ± 0.14	0.53 ± 0.08	< 0.070	< 0.26	< 113	2.03 ± 0.22	-0.004 ± 0.010	0.063 ± 0.035	35.2 ± 3.8	< 0.21	1.27 ± 0.10	0.64 ± 0.08	1.80 ± 0.23	0.82 ± 0.18	0.043 ± 0.034	0.51 ± 0.13
Location 2 Soil Sample DT00006	< 0.23	0.28 ± 0.15	1.16 ± 0.13	1.06 ± 0.13	< 0.052	0.13 ± 0.07	1.77 ± 0.58	1.77 ± 0.15	0.15 ± 0.06	6.92 ± 1.16	29.6 ± 3.1	< 0.11	1.24 ± 0.09	0.58 ± 0.07	1.68 ± 0.20	1.11 ± 0.26	0.049 ± 0.044	0.92 ± 0.23
Location 3 Soil Sample DT00010	2.31 ± 0.44	0.089 ± 0.036	1.22 ± 0.16	1.09 ± 0.16	< 0.078	< 0.23	< 10.9	1.86 ± 0.20	0.012 ± 0.010	0.68 ± 0.13	29.3 ± 3.4	< 0.21	1.23 ± 0.11	0.68 ± 0.09	1.48 ± 0.22	1.20 ± 0.27	0.089 ± 0.059	1.16 ± 0.26
Location 4 Soil Sample DT00014	< 0.20	0.009 ± 0.011	1.24 ± 0.12	1.34 ± 0.15	0.061 ± 0.031	< 0.11	1.66 ± 0.48	1.77 ± 0.20	-0.004 ± 0.004	0.066 ± 0.19	31.9 ± 3.3	< 0.093	1.19 ± 0.08	0.60 ± 0.06	1.63 ± 0.17	0.94 ± 0.29	0.11 ± 0.09	1.28 ± 0.36
Location 4 Field Blank ^a DT00018	< 0.079	0.009 ± 0.018	0.060 ± 0.027	< 0.015	< 0.016	< 0.034	< 0.26	< 0.028	-0.001 ± 0.001	0.012 ± 0.019	< 0.18	< 0.033	0.060 ± 0.027	< 0.018	< 0.078	0.28 ± 0.19	0.07 ± 0.10	0.23 ± 0.17
Location 5 Soil Sample DT00019	< 0.23	0.21 ± 0.07	1.31 ± 0.14	0.38 ± 0.06	< 0.052	0.14 ± 0.07	1.43 ± 0.51	1.92 ± 0.15	0.021 ± 0.032	1.42 ± 0.33	31.3 ± 3.3	< 0.11	1.29 ± 0.09	0.59 ± 0.07	1.72 ± 0.20	1.12 ± 0.33	0.074 ± 0.077	0.92 ± 0.29
Location 6 Soil Sample DT00024	1.35 ± 0.29	8.96 ± 1.56	1.26 ± 0.13	0.26 ± 0.05	< 0.048	< 0.22	< 110	1.86 ± 0.19	0.47 ± 0.61	80.0 ± 15.3	32.5 ± 3.5	0.20 ± 0.11	1.28 ± 0.09	0.59 ± 0.07	1.69 ± 0.20	0.90 ± 0.28	0.10 ± 0.09	0.84 ± 0.26
Location 7 Soil Sample DT00028	2.34 ± 0.45	0.007 ± 0.017	1.34 ± 0.17	0.31 ± 0.07	< 0.077	< 0.23	< 10.8	1.90 ± 0.21	0.004 ± 0.018	0.077 ± 0.053	31.9 ± 3.6	< 0.21	1.38 ± 0.11	0.64 ± 0.09	1.73 ± 0.23	0.72 ± 0.24	0.000 ± 0.000	0.68 ± 0.23
Location 8 Soil Sample DT00032	4.46 ± 0.68	0.076 ± 0.059	1.09 ± 0.16	0.29 ± 0.05	< 0.053	< 0.17	< 2.34	1.88 ± 0.19	-0.012 ± 0.007	0.66 ± 0.19	30.8 ± 3.5	< 0.17	1.12 ± 0.10	0.61 ± 0.07	1.72 ± 0.28	1.13 ± 0.31	0.077 ± 0.070	1.07 ± 0.30

Refer to footnotes at end of table.

Table 3-1
Radionuclide Activity in Surface Soil at the Double Tracks Test Site
 (Page 2 of 2)

Radionuclide	Ac-227	Am-241	Bi-214	Cs-137	Co-60	Eu-155	Pb-210	Pb-212	Pu-238	Pu-239 and Pu-240	K-40	Pa-234	Ra-226	Tl-208	Th-232	U-234	U-235 and U-236	U-238
Location 9 Soil Sample DT00036	1.52 ± 0.31	2.27 ± 0.45	1.29 ± 0.13	0.41 ± 0.06	< 0.049	< 0.21	< 104	1.88 ± 0.19	0.18 ± 0.06	29.3 ± 4.6	32.6 ± 3.5	< 0.18	1.36 ± 0.09	0.62 ± 0.07	1.74 ± 0.21	0.81 ± 0.19	0.046 ± 0.039	0.82 ± 0.19
Location 10 Soil Sample DT00040	4.34 ± 0.67	17.1 ± 3.1	1.15 ± 0.17	0.33 ± 0.06	< 0.060	< 0.19	17.4 ± 6.1	1.98 ± 0.20	2.40 ± 1.38	341 ± 58	32.1 ± 3.7	0.33 ± 0.13	1.18 ± 0.11	0.69 ± 0.08	1.95 ± 0.31	1.11 ± 0.25	0.080 ± 0.050	0.86 ± 0.20
Location 11 Soil Sample DT00045	< 0.24	0.081 ± 0.052	1.24 ± 0.16	0.29 ± 0.05	< 0.057	< 0.11	1.66 ± 0.55	1.69 ± 0.17	0.007 ± 0.016	2.33 ± 0.47	32.0 ± 3.3	< 0.11	1.28 ± 0.09	0.67 ± 0.08	1.84 ± 0.20	1.15 ± 0.39	0.57 ± 0.28	1.11 ± 0.38
Location 12 Soil Sample DT00049	< 0.25	0.053 ± 0.052	1.38 ± 0.14	0.46 ± 0.07	< 0.046	< 0.12	1.39 ± 0.49	1.94 ± 0.15	0.034 ± 0.026	2.23 ± 0.39	33.5 ± 3.3	0.17 ± 0.09	1.34 ± 0.09	0.61 ± 0.07	1.75 ± 0.19	1.11 ± 0.24	0.11 ± 0.06	0.94 ± 0.21

^a Field blank is sea sand.

Notes:

All soil samples collected from a depth interval of 0 to 5 cm (0 to 2 in.)

See Figure 3-1 for soil sample locations.

All activities are in pCi/g (picocuries per gram) followed by the uncertainty reported as the 2 sigma error.

All activities were determined by gamma spectroscopy (Method HSL300), except the following:

AM-241 by Method NAS-NS-3006

Pu238, Pu239, Pu240 by Method NAS-NS-3058

U-238 by Method NAS-NS-3050

< = A less than symbol "<" indicates that the analyte was present above the instrument detection limit at an activity levels less than the value shown.

Figure 3-2
Location of Hot Spot Soil Profile Samples
Collected During the Second Characterization Event

Table 3-2
Radionuclide Activities in Surface Soil Samples Collected from Hot Spot Locations

Radionuclide	Hot Spot 1 Soil Sample DT00100	Hot Spot 1 Soil Sample Lab. Dup. DT00100	Hot Spot 2 Soil Sample DT00101	Hot Spot 3 Soil Sample DT00102	Hot Spot 4 Soil Sample DT00103	Hot Spot 5 Soil Sample DT00104	Hot Spot 6 Soil Sample DT00105
Americium-241 (pCi/g)	734 ± 163	656 ± 154	567 ± 133	64.6 ± 25.0	783 ± 172	29.6 ± 12.1	10.1 ± 7.3
Plutonium-238 (pCi/g)	90.0 ± 22.5	101 ± 27	95.0 ± 28.5	9.45 ± 7.51	91.0 ± 23.8	10.9 ± 8.2	6.1 ± 6.7
Plutonium-239/240 (pCi/g)	12,000 ± 2,030	10,600 ± 1,870	10,800 ± 2,010	998 ± 200	11,900 ± 2,060	775 ± 158	183 ± 48
Total Uranium (µg/g)	3.50 ± 0.37	3.59 ± 0.38	2.63 ± 0.27	3.92 ± 0.41	3.41 ± 0.36	2.55 ± 0.27	2.12 ± 0.22
Plutonium-238/240 to Americium-241 Ratio	16.3	16.2	19.0	15.4	15.2	26.2	18.1

Notes:

See Figure 3-2 for hot spot locations.

All activities are reported in picocuries per gram except total uranium which is reported in micrograms per gram (µg/g) or parts per million (ppm).

All values followed by the uncertainty reported as a 2 sigma error

The uppermost 2.5 cm (1 in.) of soil was collected at each location for analysis of Am-241, isotopic plutonium, and total uranium. Any metallic fragments found in the soil were removed before the soil was placed into sample containers. The analytical methods for americium and plutonium were as specified above, and American Society for Testing and Materials (ASTM) Method 5174-91 (ASTM, 1991) was used for the total uranium analysis.

The following are potential sources of radionuclides in the soil at the Double Tracks Test Site:

- The Double Tracks experiment
- Fallout from nuclear weapons atmospheric testing
- Natural terrestrial sources

Naturally occurring radionuclides in soil include potassium-40 (K-40), uranium isotopes (e.g., U-234, U-235, and U-238), thorium isotopes (e.g., Th-232), and decay products of uranium and thorium (e.g., radium-226 [Ra-226]). These radionuclides generally have very long half-lives and have been present since the formation of the earth. Man-made radionuclides are ubiquitous in surface soil because of fallout from atmospheric testing of nuclear weapons that began in the 1940s and continued into the 1960s. Examples of these radionuclides are cesium-137 (Cs-137), cobalt-60 (Co-60), and europium-155 (Eu-155). Although the Double Tracks Test Site is not directly downwind of most of the NTS atmospheric testing, it was downwind of a few and did receive a minor component of fallout from the NTS, as well as global fallout.

Table 3-3 lists background levels of radionuclides in surface soil derived from two studies. The first study evaluated background activities of several radionuclides in the uppermost 5 cm (2 in.) of surface soil at selected undisturbed sample locations in south-central Nevada and southeastern California (McArthur and Miller, 1989). Most of the sample locations were within 160 km (100 mi) of the Double Tracks Test Site. The activity range, mean activity, upper 95 percent confidence limit for the mean, and the standard deviation are given for each radionuclide. Lognormal-distributions are assumed. The second study was a statistical evaluation of historical background data for samples collected at Sandia National Laboratories/New Mexico in Albuquerque, New Mexico (IT, 1994). The activity range and geometric mean soil activity are listed for each radionuclide. Mean activities are given as arithmetic means of lognormal distributions for the first background study and as geometric means of lognormal distributions for

Table 3-3
Background Radioactivity in Surface Soil

Radionuclide	South-Central Nevada and Southeastern California ^a				Sandia National Laboratories, Albuquerque, New Mexico ^b	
	Range (pCi/g)	Mean (pCi/g)	Standard Deviation (pCi/g)	Upper 95 percent Confidence Limit for the Mean (pCi/g)	Range (pCi/g)	Geometric Mean (pCi/g)
Bismuth-214	ND	ND	ND	ND	0.43 to 1.3	0.62
Cesium-137	0.203 to 0.605	0.369	0.114	0.448	0.004 to 1.8	0.191
Lead-210	ND	ND	ND	ND	0.5 to 12	3.5
Lead-212	ND	ND	ND	ND	0.5 to 1.4	0.69
Plutonium-239/240	0.013 to 0.092	0.034	0.026	0.090	ND	ND
Potassium-40	10.6 to 29.3	19.3	5.0	22.6	0.19 to 31	17.6
Radium-226	ND	ND	ND	ND	0.51 to 2.46	1.13
Thorium-232	0.61 to 1.51	1.24	0.37	1.49	0.23 to 1.16	0.79
Uranium-234	ND	ND	ND	ND	0.8 to 1.0	0.9
Uranium-235	ND	ND	ND	ND	0.108 to 0.156	0.125
Uranium-238	0.94 to 2.08	1.40	0.34	1.62	0.7 to 1.1	0.9
Total Uranium	ND	ND	ND	ND	0.005 to 4.66	0.992

^a Background from six locations in south-central Nevada and southeastern California (McArthur and Miller, 1989)

^b Background from samples collected at Sandia National Laboratories/New Mexico, Albuquerque, New Mexico (IT, 1994)

Notes:

All values are in picocuries per gram except total uranium which is in $\mu\text{g/g}$ ppm.

ND = No data available

All statistical results assume a lognormal distribution.

the second study. Although these are different statistical measures, they are comparable for background data. For some of the naturally occurring radioisotopes listed in Table 3-3 (e.g., bismuth-214 [Bi-214] and lead-210 [Pb-210]), the wide activity range is indicative of the wide variety of geologic parent materials.

Double Tracks surface soil radionuclide sample results (Tables 3-1 and 3-2) were compared with background (Table 3-3). With the exception of americium and plutonium, the radionuclides detected in Double Tracks surface soil are similar to background and are either naturally occurring or due to fallout.

The observed activity of K-40, Th-232, and Pb-212 in Double Tracks surface soil slightly exceeds background. These isotopes occur naturally and the elevated activity is likely due to differences in the composition of the soil parent material. Rocks that are silica-rich, such as those present at Double Tracks, are enriched in potassium, thorium, and uranium relative to other rock types (Faure, 1986; Krauskopf, 1979).

The ratio of intermediate daughter radioisotopes to their parent isotopes strongly suggests that some radionuclides detected in soil from Double Tracks are naturally occurring. Assuming no other source of isotopes, the activity ratios for the previously identified radionuclides detected in Double Tracks soil should be as follows:

- The activity of daughters U-234, Ra-226, Bi-214, and Pb-210 should be approximately equal to the activity of parent isotope U-238.
- The activity of U-235 and actinium-227 (Ac-227) should be approximately equal.
- The activity of daughter Pb-212 should be approximately equal to that of parent isotope Th-232, and the activity of daughter thallium-208 (Tl-208) should be approximately 36 percent of Th-232.

Evaluation of the data listed in Table 3-1 shows that, in general, considering the 2-standard-deviation counting errors, the isotopic activity relationships discussed above are approximated in Double Tracks soil samples and, thus, daughter radioisotopes are generally in equilibrium with naturally occurring parent isotopes. Although uranium reportedly was present in the test device (Section 1.2), a comparison with background and evaluation of isotopic ratios (e.g., uranium versus Pu-239/240, Figure 3-3) indicates that uranium contamination either is not present or is not distinguishable from background levels (Figure 3-3).

The data in Tables 3-1 and 3-2 indicate that surface soil at some sample locations at the Double Tracks Test Site is contaminated with Pu-238, Pu-239/240, and Am-241. This is consistent with the results of previous investigations discussed in Section 1.4. Also consistent with the results of previous investigations, the contamination was found to be highly variable over relatively small distances based on an analysis of discrete soil samples. In general, the sample locations south of

Figure 3-3
Uranium Isotope Versus Plutonium-239/240 Activity in
Double Tracks Surface Soil

ground zero and the sample locations closest to ground zero should be the most contaminated. For the first characterization event, samples from Locations 6, 9, and 10 exhibited the highest plutonium and americium levels (Table 3-1 and Figure 3-1).

Table 3-4 summarizes the information presented above and shows the most probable source of each radioisotope detected in Double Tracks soil samples. Laboratory analytical data for soil samples from characterization events 1 and 2 are presented in Appendix C.

Table 3-4
Source of Radionuclides in Double Tracks Surface Soil

Source	Radionuclides
Double Tracks test event	americium-241, plutonium-238, plutonium-239/240
Fallout from atmospheric nuclear testing	cesium-137, cobalt-60, europium-155
Natural terrestrial radioactivity	potassium-40
	thorium-232 and decay products: lead-212, thallium-208
	uranium-235 and decay product: actinium-227
	uranium-238 and decay products: uranium-234, protactinium-234, radium-226, bismuth-214, lead-210

3.1.2 Plutonium/Americium Isotopic Ratio

Figure 3-4 shows the calculated Pu-239/240 to Am-241 activity ratio, using known decay rates of plutonium and americium, starting with the known initial experiment isotopic ratios (Table 1-1). Based on these calculations, the theoretical isotopic ratio of Pu-239/240 to Am-241 should be between 17 and 18 in 1995. Based on laboratory results from soil samples collected during the first characterization event, the Pu-239/240 to Am-241 activity ratio was calculated to be 17.8. The Am-241 versus Pu-239/240 activities for these samples are shown in Table 3-5. This ratio is suspect because many of the isotopic results were at or near the laboratory detection limit. The linear regression standard deviation was calculated to be 12.4 which also indicated that the activity ratio is variable between sampling locations.

Figure 3-4
Activity Ratio of Plutonium-239/240 to Americium-241 in
Double Tracks Surface Soil (Assuming Negligible Initial Americium-241 Ingrowth)

Figure 3-5
Americium-241 Versus Plutonium-239/240 Activity in Double Tracks Surface Soil

One of the goals of the second characterization event was to more accurately determine the isotopic ratio. To accomplish this, additional soil samples were collected from areas that were known to have relatively high activities based on *in situ* field measurements (Section 2.2.2). The rationale behind this was to have the soil samples contain enough plutonium and americium so the results would not be near the laboratory detection limit. It was assumed that these samples would yield more accurate activities and consequently more accurate isotopic ratios could be calculated. The isotopic laboratory results are presented in Table 3-2. As presented in this table, only three of the six samples indicate significant activities. The Pu-239/240 to Am-241 ratios ranged from 15.2 to 26.2 and averaged 18.6, with a standard deviation of 4.0. Excluding one high activity ratio, which may be an outlier, the Pu-239/240 to Am-241 ratio is 16.7 with a standard deviation of 1.5. While the second characterization event soil sample results, and isotopic ratios, are more reasonable and closer to the theoretically calculated isotopic ratio, it was determined that the isotopic ratio was still not known to a high enough accuracy using only soil sample isotopic laboratory analysis.

After the first soil sampling event it had become apparent that soil sample laboratory analytical results were inconsistent. Therefore, *in situ* isotopic radiation measurements were also made during the second characterization event to assist in determining the isotopic ratios. An in depth discussion of the measuring equipment and techniques as well as the results are presented in Appendix B, in the report titled "In Situ Radiological Surveying at the Double Tracks Site," in Section 6.2 titled "Experiment #2 - Pu: Am Ratio Measurements" (Riedhauser and Tipton, 1996). In this section the theoretical Pu-239/240 to Am-241 ratio was calculated to be 13.71 which, when adding the Am-241 yields a total transuranic (TRU) to Am-241 ratio of 14.71. *In situ* measurements were made at locations identified to have elevated activities, using two independent methods and two sets of instruments. The rationale for the duplication was to cross check the measurements and isotopic ratio calculations. There was general agreement between the independent methods and the theoretical isotopic ratio calculated. This agreement is notable because different detectors, counting times and methods were used to reduce the data. Results of the *in situ* measurements yielded similar isotopic ratios with relatively low standard deviations. The *in situ* measurements discussion contained in Appendix B concludes by stating that the isotopic ratio of 16 is recommended to determine the activity of plutonium at the site given the Am-241 measurement. This is approximately 10 percent higher than the theoretical prediction and provides a reasonable, conservative, margin of error. An isotopic ratio of 16 was used in the contaminant analysis at the Double Tracks Test Site presented in this document.

3.1.3 Radiological Hot Spots

Hot spots are discrete areas within the Double Tracks exclusion zone that exhibited elevated radioactivity relative to the surrounding area. During the second and third characterization events, *in situ* radiological surveys were conducted at the Double Tracks Test Site to identify hot spots. To reduce potential bias in the systematic *in situ* radiological survey, metallic fragments (derived from the test device or other materials) were located and removed before conducting the systematic survey. The fragments were also removed from hot spot locations prior to collection of the hot spot soil samples discussed (Section 3.1.1). When soil samples were split in the field, the activity of both sample splits was generally similar (Section 2.2.2). However, in one instance the radioactive contamination did not split equally and the difference in the activity of the splits was significant. This was probably due to the presence of a small, highly radioactive particle.

As part of the third characterization event effort, metallic fragments and hot spot soil were weighed and the metal fragments were photographed. The Am-241 activity was measured in the field using a collimated HPGe detector. Table 3-5 presents the resulting data for the fragments and hot spot soil. Following characterization, the metallic fragments and soil were placed in a secure container inside the Double Tracks exclusion zone. Using the definition set forth in Title 40, Code of Federal Regulations (CFR), Part 191.02 (U.S. Environmental Protection Agency [EPA], 1993), the fragments were classified as TRU material because the activity exceeds 100 nanocuries (0.100 microcuries) per gram.

3.2 Nonradiological Constituents

This section addresses the nonradiological constituents detected in the Double Tracks Test Site surface soil.

3.2.1 Metals

Nine surface soil samples collected during the first characterization event were analyzed for TAL metals using the EPA Contract Laboratory Program statement of work for inorganics (EPA, 1990a). The samples were collected from the uppermost vertical profile interval (0 to 5 cm [0 to 2 in.]) at Locations 1 through 8 and Location 12 (Figure 3-1). Table 3-6 lists the concentrations of metals in these soil samples.

Table 3-5
Field Collimated HPGe Detector Measurements of
Metal Fragments and Hot Spot Soil

Sample Number	Sample Type	Activity One Side Am-241 (μCi) ^b	Activity Other Side Am-241 (μCi)	Total Activity Am-241 (μCi)	Weight (grams)	Activity/mass Am-241 ($\mu\text{Ci/g}$) ^c	TRU ^a Activity/mass ($\mu\text{Ci/g}$)
1	Metal Fragment	143.7	179.5	323.2 ^d	33.25	9.700	156.000
2	Metal Fragment	71.4	89.0	160.4 ^d	30.68	5.200	84.000
3	Metal Fragment	357.1	255.5	612.6 ^d	254.01	2.400	39.000
4	Metal Fragment	318.3	366.1	684.4 ^d	316.40	2.200	35.000
5	Metal Fragment	167.0	144.5	311.5 ^d	124.12	2.500	40.000
6	Metal Fragment	157.8	211.3	369.1 ^d	58.87	6.300	100.000
7	Metal Fragment	54.2	54.2	108.4 ^d	13.41	8.100	130.000
8	Hot Spot Soil ^e	2.5	3.8	6.3 ^d	796.62	0.008	0.127
9	Hot Spot Soil ^e	8.2	6.0	14.2 ^d	746.97	0.019	0.304
10	Metal Fragment	106.2	120.4	226.6 ^d	95.55	2.400	38.000
11	Metal Fragment	17.7	17.6	35.3 ^d	21.33	1.700	27.000
12	Metal Fragment	49.6	54.8	104.4 ^d	2.40	43.500	696.000
13	Metal Fragment	87.7	74.3	162.0 ^f	107.36	1.500	24.000
14	Metal Fragment	123.3	123.3	246.6 ^f	39.78	6.200	99.000
15	Metal Fragment	38.5	47.7	86.2 ^f	17.38	5.000	80.000
S1	Hot Spot Soil ^g	2.3	2.4	4.7 ^f	588.41	0.008	0.128
S2	Hot Spot Soil ^h	5.9	6.3	12.2 ^f	240.87	0.051	0.816
S3	Hot Spot Soil ⁱ	4.6	5.0	9.6 ^f	297.77	0.032	0.512
S4	Hot Spot Soil ^j	5.8	5.7	11.5 ^f	345.86	0.033	0.528

^a Assumed a transuranic (TRU) ratio of 16 (Pu-239 + Pu-240 + Pu-241 + Am-241/Am-241)

^b Microcurie

^c Microcurie per gram

^d Subtracted background equivalent to 5.4 μCi from each side of metal fragment/soil

^e Ground zero mound vicinity (surface soil)

^f Subtracted background equivalent of 1.3 μCi from each side of metal fragment/soil

^g Approximately 18 meters northeast of ground zero (surface soil)

^h From ground zero boring 1, approximately 1.6-meter depth

ⁱ Approximately 30 meters east of ground zero (surface soil)

^j Approximately 46 meters east of ground zero (surface soil)

Note: For samples of hot spot soil, an actual activity will be closer to that from only one side based on sample geometry. This will be approximately half the transuranic activity/mass quoted in the table.

TRU material, as defined by DOE Order 5820.2A, is 0.1 $\mu\text{Ci/g}$ (10^5 pCi/g).

Predominant metals (exceeding 1,000 milligrams per kilogram [mg/kg]) in Double Tracks surface soil are the typical rock-forming elements: calcium, aluminum, iron, magnesium, and potassium. Secondary elements (exceeding 100 mg/kg) are barium, manganese, and sodium. Trace elements (less than 100 mg/kg) are arsenic, beryllium, chromium, cobalt, copper, lead, nickel, vanadium, and zinc. Antimony, cadmium, selenium, silver, and thallium concentrations are all below detection limits; mercury is below the detection limit in all but one sample (Table 3-6).

The Double Tracks metal results are typical of desert soil developed from siliceous and intermediate volcanic parent material. To determine if any metal concentrations were anomalous, an outlier test was performed on the data set. The test method used is from the EPA guidance document *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (EPA, 1989) and is based on an ASTM method (ASTM, 1975). A lognormal distribution was assumed, and the upper 5 percent significant level was used. Only two outliers were found, as follows:

- The mercury concentration (0.065 mg/kg) for Sample DT00002 from Location 1 was an outlier because all other reported concentrations were below the detection limit.

However, the mercury concentration of a laboratory duplicate of Sample DT00002 was below the detection limit of 0.051 mg/kg.

- The sodium concentration (1,110 mg/kg) for Sample DT00024 from Location 6 was an outlier. The concentration was approximately twice that of the other soil samples. The reason for this high concentration is not known. Sodium is a component of salt, which typically occurs in a desert environment, such as at Double Tracks.

Concentrations of metals detected in subsurface soils are within the normal range of background and are not associated with the Double Tracks experiment.

3.2.2 Toxicity Characteristic Leaching Procedure Results

Three surface soil samples collected during the first characterization event were submitted for TCLP analysis of extractable metals. The samples were collected from the uppermost vertical profile interval (0 to 5 cm [0 to 2 in.]) at Locations 9, 10, and 11, near the ground zero area (Figure 3-1). As part of the second characterization event, surface soil samples from four hot spot locations were submitted for TCLP analysis of RCRA metals. The uppermost 2.5-cm (1-in.) soil interval from each location was collected for analysis. Concentrations of metals in the TCLP extracts are listed in Table 3-7, along with the toxicity characteristic regulatory levels. The

Table 3-6
Metal Concentrations in Surface Soil at the Double Tracks Test Site

Metal	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Ni	K	Se	Ag	Na	Tl	V	Zn
CAS Number	7429-90-5	7440-36-0	7440-38-2	7440-39-3	7440-41-7	7440-43-9	7440-70-2	7440-47-3	7440-48-4	7440-50-8	7439-89-6	7439-92-1	7439-95-4	7439-96-5	7439-97-6	7440-02-0	7440-09-7	7782-49-2	7440-22-4	7440-23-5	7440-28-0	7440-62-2	7440-66-6
Location 1 DT00002	8,830	9.3 U	2.2	172	0.73 B	0.75 U	11,600	4.1	4.5 B	7.7	9,970	8.9	3,550	409	0.065 B	5.7 B	5,360	0.34 U	0.77 U	523 B	0.30 U	16.6	30.4
Location 1 DT00002 Lab Duplicate	6,390	9.3 U	2.7	140	0.64 B	0.75 U	11,700	3.3	4.1 B	6.9	8,220	9.5	3,090	385	0.051 U	4.8 B	3,800	0.34 U	0.77 U	386 B	0.30 U	12.4	25.5
Location 2 DT00006	9,050	9.3 U	2.1	182	0.73 B	0.75 U	12,300	4.2	4.3 B	6.2	11,000	11.8	3,520	447	0.051 U	5.6 B	3,600	0.35 U	0.77 U	385 B	0.30 U	19.2	33.5
Location 3 DT00010	9,460	9.3 U	3.1	151	0.73 B	0.75 U	11,100	5.1	4.9 B	7.3	12,200	10.7	3,880	416	0.050 U	5.5 B	4,090	0.34 U	0.77 U	446 B	0.30 U	19.2	35.40
Location 4 DT00014	8,660	9.3 U	2.2	128	0.76 B	0.75 U	19,800	5.0	5.3 B	7.4	13,000	11.0	4,200	394	0.051 U	7.3 B	3,960	0.34 U	0.77 U	476 B	0.30 U	23.1	38.0
Location 4 Field Blank ^a DT00018	21.2 B	9.2 U	0.36 U	0.56 B	0.060 U	0.74 U	242 B	1.1 U	0.68 U	1.5 U	36.6	0.72	39.2 B	2.3 B	0.050 U	3.1 U	389 U	0.34 U	0.76 U	70.5 B	0.30 U	1.9 U	3.3 B
Location 5 DT00019	7,090	9.3 U	1.7 B	123	0.62 B	0.75 U	12,000	4.4	4.2 B	7.1	10,300	9.9	3,650	358	0.050 U	6.3 B	3,290	0.34 U	0.77 U	524 B	0.30 U	15.3	33.4
Location 6 DT00024	8,330	9.3 U	3.2	143	0.73 B	0.75 U	16,900	5.2	5.4 B	9.8	11,200	8.2	4,830	431	0.051 U	7.9 B	4,790	0.34 U	0.77 U	1,110	0.30 U	17.70	41.3
Location 7 DT00028	9,360	9.3 U	3.2	159	0.76 B	0.75 U	14,200	5.6	5.0 B	8.4	12,100	10.3	4,720	453	0.051 U	8.0 B	4,430	0.34 U	0.77 U	598 B	0.30 U	18.7	35.9
Location 8 DT00032	8,710	9.3 U	2.8	144	0.66 B	0.75 U	15,600	4.7	3.7 B	9.6	10,100	13.8	3,940	374	0.051 U	7.0 B	4,040	0.34 U	0.77 U	479 B	0.30 U	14.7	34.1
Location 12 DT00049	10,300	9.3 U	3.0	167	0.76 B	0.75 U	13,300	6.3	5.2 B	9.0	13,500	10.1	4,760	487	0.051 U	7.5 B	4,130	0.34 U	0.77 U	523 B	0.30 U	20.8	38.6

^aField blank is sea sand.

Notes:

All concentrations are in milligrams per kilogram (mg/kg) or parts per million (ppm).
Surface soil samples collected from depth interval of 0 to 5 centimeters (0 to 2 inches)
See Figure 3-1 for soil sample locations.

Data Qualifiers:

B = Reported value is less than the contract-required detection limit but greater than or equal to the instrument detection limit.
U = Compound was analyzed for but not detected. The value listed is the instrument detection limit.

Table 3-7
Toxicity Characteristic Leaching Procedure Results for
Surface Soil Samples from the Double Tracks Test Site

Metal	CAS Number^a	Location 9 Soil Sample DT00036 (mg/L)	Location 10 Soil Sample DT00040 (mg/L)	Location 11 Soil Sample DT00045 (mg/L)	Hot Spot 1 Soil Sample DT00100 (mg/L)	Hot Spot 3 Soil Sample DT00102 (mg/L)	Hot Spot 4 Soil Sample DT00103 (mg/L)	Hot Spot 5 Soil Sample DT00104 (mg/L)	Regulatory Level (mg/L)
Arsenic	7440-38-2	0.011	0.004	0.014	0.0078	0.0074	0.0092	0.0061	5.0
Barium	7440-39-3	0.45	0.200 U	0.42	0.40	0.43	0.39	0.44	100.0
Cadmium	7440-43-9	0.005 U	0.005 U	0.005 U	0.0024 U	0.0024 U	0.0024 U	0.0024 U	1.0
Chromium	7440-47-3	0.020 U	0.020 U	0.020 U	0.0047 U	0.0047 U	0.0047 U	0.0047 U	5.0
Lead	7439-92-1	0.008	0.003 U	0.003 U	0.0077	0.0050	0.0020 B	0.0022 B	5.0
Mercury	7439-97-6	0.002 U	0.002 U	0.002 U	0.00010 U	0.00029	0.00012 B	0.00016 B	0.2
Selenium	7782-49-2	0.007	0.004	0.006	0.0096	0.0096	0.0091	0.0096	1.0
Silver	7440-22-4	0.010 U	0.010 U	0.01 U	0.0041 U	0.0041 U	0.0041 U	0.0041 U	5.0

^aChemical Abstracts Service Number.

Notes:

See Figure 3-1 for soil sample locations.

All concentrations are in milligrams per liter.

Data Qualifiers:

B = Reported value is less than the contract-required detection limit but greater than or equal to the instrument detection limit.

U = Compound was analyzed for but not detected. The stated activity is the instrument detection limit.

extract was analyzed using EPA SW-846 Method 6010 and Method 7470 for mercury (EPA, 1990b).

The samples selected for TCLP analysis were collected from areas suspected of being impacted by the Double Tracks test event. As discussed in Section 3.1.1, the highest activities of plutonium identified during the first characterization event were found at Location 10 and relatively high levels were also observed at Location 9. During the second characterization event, hot spot soil samples were collected from areas of plutonium contamination (Section 3.1.1). Table 3-7 shows that concentrations of RCRA metals in TCLP extracts are orders of magnitude lower than the regulatory levels. This, combined with the knowledge that the soil samples were collected from areas impacted by the Double Tracks experiment, strongly indicates that Double Tracks soil does not exhibit toxicity characteristics as defined in Title 40 CFR 261.24 (EPA, 1994); therefore, the soil from the Double Tracks Test Site cannot be classified as mixed waste based on the toxicity characteristics.

3.3 Horizontal Extent of Contamination

Previous characterization activities have shown that data from the collection and analysis of soil samples cannot effectively be used to delineate the horizontal extent of contamination at the Double Tracks Test Site (Sections 1.4 and 3.1.1). This is because contamination levels are highly variable on the spatial scale represented by discrete soil samples. Thus, to evaluate the horizontal extent of contamination, *in situ* radiological surveys were conducted. *In situ* techniques allowed more coverage of the potentially contaminated area and provided data that are "averaged" over the field of view of the detector. These features of *in situ* techniques provide for better estimates of contaminated soil volume relative to those made using discrete soil sample data.

During the second characterization event, the performance of various *in situ* survey equipment and methods was evaluated (Section 2.2). Systematic *in situ* radiological surveys were performed during the third characterization event (Section 2.3). In general, the *in situ* surveys measured gamma radiation from Am-241, and information obtained from the analysis of discrete soil samples was used to convert the *in situ* Am-241 measurements into the total TRU isotope activity of the soil. The details of the *in situ* radiological survey work are presented in *In Situ Radiological Surveying at the Double Tracks Test Site* (Riedhauser and Tipton, 1996), which is included as Appendix D of this report. Although several different *in situ* radiological surveys were performed, only the results of the systematic survey conducted using the Suburban-mounted NaI detector (Kiwi system; Section 2.3.1.2) are discussed here. Appendix D provides

information on the other surveys and *in situ* measurements performed to characterize the Double Tracks test site.

Figure 3-5 shows the total TRU isotope activity of soil at the Double Tracks Test Site, as derived from *in situ* measurements obtained using the Kiwi system. The radioactivity measurements were collected into 9.1-m (30-ft) averages and centered on a 9.1-m (30-ft) grid. Comparing this survey to 1977 and 1993 aerial surveys (Figures 1-3 and 1-4) shows that the extent of contamination in the east-west direction (across the plume) is less than indicated by the older aerial surveys. This is anticipated because the Kiwi spatial resolution is much smaller than that of the aerial systems. The highest levels of plutonium and americium are located in and around ground zero, and a relatively narrow plume of total TRU activity exceeding 100 pCi/g extends to the south of ground zero, almost to the southern end of the exclusion zone (Figure 3-5). Small areas of high activity in the vicinity of ground zero may represent hot spots that were not removed. The small area of elevated activity at the edge of the exclusion zone, southeast of ground zero, is the container holding the radioactive fragments discussed in Section 3.1.3.

3.4 Vertical Extent of Contamination

Along with the surface soil samples discussed in Section 3.1.1, vertical profile soil samples were collected from the 12 locations shown in Figure 3-1. In addition to the 0- to 5-cm (0- to 2-in.) interval, discrete soil samples were also collected from the 5- to 10-cm (2- to 4-in.) and 10- to 15-cm (4- to 6-in.) depth intervals. These samples were analyzed for Am-241, isotopic plutonium, and isotopic uranium by the methods listed in Section 3.1.1. Results from the first characterization event indicated that plutonium and americium concentrations generally were not consistent with what was anticipated. This was the case with both the horizontal and vertical soil sampling results. Only one sampling location (E-10) detected significant radiological contamination above 200 pCi/g. The other nine depth profile locations depth profile results were inconclusive, especially when contaminants were detected at or near the laboratory detection limit. The depth profile results are presented in Appendix E for completeness.

Realizing that laboratory soil results were inconsistent, part of the second characterization event included the vertical distribution of contamination *in situ* measurements at selected hot spot locations. The rationale for this approach was to determine depth of contamination in areas where significant contamination were known to be present. A tripod-mounted collimated HPGe detector or a hand-held FIDLER was used to measure the radioactivity of the undisturbed sample location. After the measurement was taken, a 2.5-cm (1-in.) layer of soil was removed and the

Figure 3-6
Total Transuranic Isotope Activity of Double Tracks Soil,
Based on 1995 EG&G Ground Survey

activity of the sample location was again measured. This process was repeated until approximately 80 to 90 percent of the initial radioactivity had been removed (Section 2.2.3).

Table 3-8 presents the results of the *in situ* radiological depth profiles. These results indicated that 80 to 90 percent of the radioactivity was generally in the top 5 cm (2 in.) of the soil at the locations measured. During the second characterization event, the vertical distribution of contamination was also investigated using adhesive-backed tiles to remove thin layers of soil (less than 1 cm) from a hot spot sample location. An *in situ* radiological survey of the location was conducted before and after soil removal, and the results were compared. The results indicate that most of the radioactivity is contained within the uppermost 0.3 to 1.3 cm (0.1 to 0.5 in.) of the soil profile; however, the data from this technique are considered semiquantitative.

3.5 Ground Zero Characterization

As part of the third characterization event, 17 shallow boreholes were drilled in the ground zero area, and *in situ* radiation measurements were taken using a downhole NaI detector (Section 2.3.3). Figure 3-6 shows the approximate location of each boring, and Table 3-9 lists the radioactivity measured at each boring. The depth of the ground zero borings ranged from 0.5 to 1.4 m (1.6 to 4.5 ft). Several of the borings intercepted the suspected concrete pad on which the Double Tracks test was conducted (Figure 3-6). The suspected concrete pad is covered by a soil mound that is approximately 0.5 to 0.9 m (1.6 to 3.0 ft) high. Levels of activity greater than 1×10^4 counts per minute were found at depth in the borings (Table 3-9), confirming that contaminated soil and possibly metallic material from the test are present in the ground zero mound.

3.6 Soil Particle-Size and Volume Reduction Testing

Several observations were made that require discussion before the grain-size and analytical results can be presented. The first observation is that the measured plutonium activity of the samples did not generally and uniformly decrease with distance from ground zero, as shown on Figure 3-7. It is not known whether this was caused by variability of the experiment fallout, varied distribution of the contaminants in the soil, or the presence of hot particles at the sample locations. The second observation is that the plutonium content of the coarse soil fraction determined by gamma spectroscopy analysis in the ITPDL and by isotopic analysis in the radiological laboratory were not always similar. It is anticipated that, while the analytical methods are different, the results should be comparable because the same soil sample was being analyzed. These analyses do not agree for 3 of the 10 sample locations, which may indicate that

Table 3-8
In Situ Radiological Measurements of Depth Profiles at the Double Tracks Test Site

Location	Surface Measurement	Measurement after Removal of Uppermost 2.5 cm of Soil		Measurement after Removal of Uppermost 5.1 cm of Soil		Measurement Units	In Situ Measurement Device
		Measurement	Percent Activity Removed	Measurement	Percent Activity Removed		
Hot Spot 2	60,000	9,000	85	8,000	87	counts per minute	FIDLER
		14,000	77				
Hot Spot 4	5,820	4,510	23	4,232	27	total counts, 10 minute count time	HPGe Detector
	1,123	47	96	0	100	net americium-241 counts, 10 minute count time	HPGe Detector
Hot Spot 5	30,000	5,400	82	5,000	83	counts per minute	FIDLER
Hot Spot 6	90,000	8,000	91	7,400	92	counts per minute	FIDLER

Notes:

Measurement locations are shown in Figure 3-2.

Measurement made at undisturbed hot spot location, after removal of any large metallic fragments

At Hot Spot 2, duplicate values indicated count rates were measured in samples split with a Jones type soil splitter.

At Hot Spot 4, two measurements were made of the same soil. The first was total counts and the second was net americium-241 counts.

FIDLER = Field Instrument for the Detection of Low Energy Radiation. Measurements were made until a consistent count rate was obtained, typically this was less than one minute.

HPGE = High purity germanium (Ge)

Figure 3-7
Location of Soil Borings in Ground Zero Area of the Double Tracks Test Site

Figure 3-8
Location of Soil Samples Collected During
the Fourth Characterization Event

Table 3-9
In Situ Radiological Measurements in Ground Zero Soil Borings

Depth Below Ground Surface (meters)	Boring 1 ^a (1,000 count per minute)	Boring 2 (1,000 count per minute)	Boring 4 (1,000 count per minute)	Boring 5 (1,000 count per minute)	Boring 7 (1,000 count per minute)	Boring 8 (1,000 count per minute)	Boring 9 (1,000 count per minute)	Boring 10 (1,000 count per minute)	Boring 11 (1,000 count per minute)	Boring 12a (1,000 count per minute)	Boring 14 (1,000 count per minute)	Boring 15 (1,000 count per minute)	Boring 16 (1,000 count per minute)	Boring 17 (1,000 count per minute)
0.0 (surface)	9	8	5.6	5	6	5	6.1	6.5	8.5	14	20	50	35	180
0.15	20	16	6.3	6	6	5.6	12	15	13	7.7	100	25	10	6
0.30	25	22	8.7	7	6.5	7	10	17	13	12	200	8	8	5.5
0.46	40	14	16	7	17	14	10	19	12	11	90	7.5	6	10
0.61	52	14 ^{b,c}	11	6.6	17	7	8.4 ^b	25	10	9.5	38	6.7	9	12 ^d
0.76	80		16 ^{b,e}	6	10	6		16 ^b	10	13	37	5.3	16 ^f	
0.91	200			6.2	28 ^b	5.5			9	8 ^b	50 ^g	5.4		
1.07	620			5.5 ^h		6			14 ^h			5.7		
1.22	600					6						7.3		
1.37	600											16 ⁱ		

^a See Figure 3-7 for boring locations.

^b Boring refusal, concrete slab

^c Bottom of boring is at 0.48 meters below ground surface.

^d Bottom of boring is at 0.51 meters below ground surface.

^e Bottom of boring is at 0.66 meters below ground surface.

^f Bottom of boring is at 0.69 meters below ground surface.

^g Bottom of boring is at 0.84 meters below ground surface.

^h Bottom of boring is at 1.02 meters below ground surface.

ⁱ Bottom of boring is at 1.32 meters below ground surface.

Note: Radiological measurements not collected in borings 3, 6, 12b, and 13

Average background ranged between 200 to 400 counts per minute (0.2 to 0.4 1,000 counts per minute).

hot particles are present. This heterogeneity within soil analysis has been reported by previous investigators.

Results of the grain-size analysis were that the attrition scrubbing effectively removed the fine material from the coarse material. Grain-size analysis results are summarized on Table 3-10 and the data presented in Appendix F. Average grain-size analysis indicated that 84 percent of the soil was coarser than 100 mesh, larger than fine sand before attrition scrubbing. Attrition scrubbing removed on the average an additional 19 percent more fine-grained material from the coarse-grained material.

Gamma spectroscopy analysis and laboratory isotopic analyses indicated that generally, the contaminants did concentrate in the fine fraction before and after attrition scrubbing (Table 3-11). Based on gamma spectroscopy analysis before attrition scrubbing, 4 of the coarse fractions had activities below 100 pCi/g total transuranics, and seven had activities below 200 pCi/g. Based on gamma spectroscopy analysis after attrition scrubbing, all but Sample 7 (256 pCi/g total transuranics) had activities less than 200 pCi/g. Sample 7 had an activity of 18.5 pCi/g plutonium 239/240 in the fine fraction based on more precise isotopic analysis. Note that Sample 5 had an increase after attrition scrubbing of 107 pCi/g.

Isotopic analysis after attrition scrubbing indicated that for most of the samples the contaminants were generally concentrated in the fine fraction (Table 3-11). Exceptions to this are the coarse fractions of Samples 3 and 5, which had unanticipated high activities. Sample 5 had 1,040 pCi/g plutonium 239/240 in the coarse fraction and 1,880 pCi/g in the fine fraction. Sample 3 had 413 pCi/g plutonium 239/240 in the coarse fraction and 304 pCi/g in the fine fraction. The Sample 5 and 3 results indicate that some contaminants larger in size than fine sand are present, since high activities were detected in the coarse fraction. Sample three was reanalyzed with no significant activity changes. This demonstrates that larger than anticipated contaminated material was present in two of the soil samples.

The results of the treatability testing are that, for eight of the ten soil samples tested, the use of volume reduction will work at Double Tracks Test Site. This represents 80 percent of the samples tested. Technically, it is inconclusive if volume reduction via grain size separation will work at the Double Tracks Test Site. Because of the relative small volume of soil requiring corrective action, volume reduction is probably not economically feasible. Analysis of volume reduction options will continue during remediation of the Double Tracks Test Site and characterization of the Clean Slate Test Sites. It is anticipated that volume reduction may be

Table 3-10
Grain-Size Analysis of Treatability Study Samples

Sample Location ^b	ITPDL ^a Before Attrition Scrubbing		DRI ^b No Attrition Scrubbing		ITPDL ^a After Attrition Scrubbing	
	Fine Fraction ^c	Coarse Fraction	Fine Fraction ^d	Coarse Fraction	Fine Fraction ^c	Coarse Fraction
1	22	78	25	75	35	65
2	17	83	21	79	30	70
3	8	92	19	81	23	77
4	12	88	30	70	38	62
5	22	78	36	64	43	57
6	23	77	27	73	38	62
7	25	75	23	77	39	61
8	9	91	14	86	24	76
9	24	76	31	69	41	59
10	2	98	29	71	39	61
Average	16	84	26	74	35	65

^a IT Corporation Process Development Laboratory located in Knoxville, TN

^b Desert Research Institute Laboratory located at the Nevada Test Site

^c Fine fraction is smaller than #100 Mesh, 149 microns.

^d Fine fraction is smaller than #125 Mesh, 125 microns.

Notes:

All values are in weight percent.

See Figure 3-8 for soil sample location.

Table 3-11
Summary of Gamma Spectroscopy and Isotopic Analysis of Treatability Study Samples

Sample Location	Gamma Spectroscopy ^a				Isotopic Analysis ^b					
	Coarse Fraction Before Attrition Scrubbing		Coarse Fraction After Attrition Scrubbing		Coarse Fraction After Attrition Scrubbing			Fine Fraction After Attrition Scrubbing		
	Am-241	Transuranics ^c	Am-241	Transuranics	Am-241	Pu-238	Pu-239/240	Am-241	Pu-238	Pu-239/240
1	17 ± 1	272	3 ± 4	48	1.86 ± 0.58	1.3 ± 5.8	30.8 ± 19.8	9.2 ± 19.9	36.6 ± 36.4	1460 ± 54
1 Duplicate ^d								51.5 ± 36.4	19 ± 25.5	1260 ± 273
1 Reanalyze ^e								35.6 ± 28.2		
1 Reanalyze Duplicate								141 ± 54		
2	5.12 ± 2	82	6.5 ± 6	104	0.55 ± 0.27	0.08 ± 0.35	4.69 ± 1.98	4.6 ± 11.3	5.6 ± 10.2	334 ± 76
2 Reanalyze								-1.8 ± 4.9		
3	2.4 ± 6	38	2.6 ± 8	42	18 ± 5.4	2.8 ± 1.58	413 ± 72	12.8 ± 6.0	2.66 ± 2.2	304 ± 54
3 Reanalyze									1.69 ± 1.23	294 ± 51
4	16.2 ± 1	259	6.4 ± 6	102	2.19 ± 0.65	<1.76 ± 0.49	43.2 ± 9.9	14.5 ± 6.8	5.86 ± 3.08	491 ± 84
4 Reanalyze									3.85 ± 1.68	661 ± 110
5	1.5 ± 7	24	8.2 ± 5	131	43.4 ± 13.9	8.04 ± 2.38	1040 ± 167	93.5 ± 22.2	12.7 ± 4.4	1880 ± 307
6	10.9 ± 4	174	6.6 ± 6	106	1.05 ± 0.41	-0.19 ± 0.08	19 ± 5.4	35.2 ± 22.9	-7.3 ± 11.1	957 ± 218
7	19.7 ± 1	315	16 ± 4	256	0.55 ± 0.25	-0.07 ± 0.04	18.5 ± 4.9	1.6 ± 14.0	-1.1 ± 8.2	724 ± 158
7 Reanalyze								19.1 ± 13.3		
8	1.91 ± 4	31	0.7 ± 20	11	0.25 ± 0.16	0.30 ± 0.56	2.79 ± 1.59	1.75 ± 1.53	0.25 ± 0.66	68 ± 12.7
8 Reanalyze								2.75 ± 2.19		
9	6.7 ± 2	107	4.96 ±	78	0.32 ± 0.20	0.33 ± 0.54	11.7 ± 3.6	2.19 ± 2.04	-0.12 ± 0.3	59.4 ± 11.2
9 Reanalyze								3.38 ± 1.94		
10	7.4	118	0.9 ± 24	14	0.56 ± 0.26	0.4 ± 0.51	12.1 ± 3.3	9.96 ± 3.48	2.37 ± 1.25	346 ± 58

^a Gamma spectroscopy performed at the IT Process Development Laboratory (Knoxville, TN)

^b Isotopic analysis performed at the radiologic laboratory (St. Louis, MO)

^c Total Transuranic Isotopes, assuming a total transuranics to Am-241 ratio of 16

^d Duplicate analyses were for quality control.

^e Selected samples were reanalyzed because of relatively large two-sigma errors.

Note:

Negative values (-) are values less than the minimum detection activity (MDA).

All values reported in pCi/g

See Figure 3-8 for sample locations.

implemented during the remediation of the Double Tracks Test Site, if different physical conditions are encountered than are currently anticipated. After Clean Slate I Test Site characterization, more site characterization treatability testing and data will be examined to determine if volume reduction can be implemented.

3.7 Contaminated Soil Volume

Table 3-12 presents an estimate of the surface area and volume of contaminated soil at the Double Tracks Test Site exceeding 200 pCi/g plutonium 239/240 of total activity. The surface area estimates are based on the results of the EG&G Kiwi system radiological survey conducted during the third characterization event (Section 3.3 and Appendix D). To provide more flexibility in the estimates of the soil volume to be remediated, the area of contamination was divided into the ground zero mound and north area and south areas (Table 3-12). The ground zero mound was defined as the topographically elevated area at ground zero investigated during the third characterization event (Section 3.5). The north area was defined as the area of contaminated soil immediately around the ground zero area, and the south area was defined as the long, narrow strip of contamination extending south of ground zero (Figure 3-6). An estimated 219 m³ (286 yd³) of contaminated soil is present in the mound at ground zero (Table 3-12). The average height of the mound is 0.5 m (1.7 ft). This assumption is based on information obtained from the ground zero soil borings discussed in Section 3.5. The other soil volumes calculated for the ground zero mound area assume that, in addition to the mound itself, a uniform thickness of soil will be removed. Estimates are given for uniform soil thicknesses ranging from 15 to 46 cm (6 to 18 in.).

Based on *in situ* ground-based radiation survey data, the total surface area at Double Tracks containing activity greater than 200 pCi/g plutonium 239/240 is approximately 8,780 square meters (94,500 square feet), approximately 1 hectare. For estimating the volume of soil requiring remediation, it was assumed a 30-cm (12-in.) layer of soil beneath the mound, a 15-cm (6-in.) layer of soil in the north area, and an 8-cm (3-in.) layer of soil in the south area will require remediation. The estimated total soil volume to be remediated is approximately 1,240 m³ (1,620 yd³). Approximately 28 percent of this soil is from the ground zero mound area, 39 percent is from the north area, and 33 percent is from the south area. The soil volume estimates do not take into account soil expansion that occurs during excavation. Soil of the type found at the Double Tracks Test Site typically will expand 20 to 25 percent during dry excavation. However, the soil will be wetted during site remediation as part of the dust suppression activities. This may significantly reduce the soil expansion percent, possibly to less than 10 percent.

Table 3-12
Estimates of Area and Volume of Soil Exceeding 200 Picocuries per Gram
of Total Transuranic Isotope Activity at the Double Tracks Test Site

Location	Depth		Surface Area ^a		Soil Volume	
	centimeters	inches	square meters	square feet	cubic meters	cubic yards
Ground Zero Mound	Soil in Mound		420	4,500	219	286
	15	6			282	369
	23	9			314	411
	30	12			346	453
	46	18			412	536
North Area	8	3	3,260	35,100	261	341
	15	6			489	640
	23	9			750	981
	30	12			978	1,279
South Area	8	3	5,100	54,900	408	534
	15	6			765	1,001
	23	9			1,173	1,534
	30	12			1,530	2,001

^aSurface area is based on 1995 ground survey radiation measurements (Figure 3-6).

Shaded volumes were the values used to calculate the volume of soil requiring disposal at the Double Tracks Test Site (346 + 489 + 408 = 1,243 cubic meters).

4.0 Summary and Conclusions

The summary and conclusions derived from the site characterization efforts at the Double Tracks Test Site are described in this section.

4.1 Summary

Previous investigations of the Double Tracks Test Site provided considerable information on the nature and extent of contamination. Aerial radiological surveys provided an estimate of the extent of the radiological contamination at the site, and discrete soil sample results indicated that plutonium and americium were present in surface soil. Data gaps identified before this site characterization started included the possibility of other radiological and nonradiological contamination, the depth distribution of contamination, and a more precise estimate of the area contaminated. The characterization activities discussed in this report were designed to address these data gaps using a phased approach that expedited gathering of the required information.

Four separate characterization events were conducted at the site from October 1994 to July 1995. During the first event, discrete soil samples were collected and analyzed for radionuclides and metals. The TCLP was also performed on several of the soil samples and the extracts were analyzed for RCRA metals. Discrete depth profile soil samples were also collected as part of the first characterization event, and these samples were analyzed for Am-241, isotopic plutonium, and isotopic uranium. Results of the first event were to identify the contaminants of potential concern and provided information on the depth of contamination in soil. The first characterization event laboratory results did not yield anticipated results. The sample results did indicate that the collection and analysis of discrete soil samples cannot cost-effectively characterize the contaminants at the site. RCRA constituents were not detected so mixed waste material is not present at the Double Tracks Test Site.

The performance of several *in situ* radiation measurement systems was evaluated as part of the second characterization event. During the *in situ* survey work, localized areas of elevated radiation "hot spots" were located and investigated by conducting *in situ* radiation measurements at several depths and by collecting discrete soil samples. Relatively-large, highly-radioactive metallic fragments were found at most hot spot locations. These fragments, which appear to be fragments from the Double Tracks experiment, were the primary source of radioactivity at the hot spots. When the fragments were removed and the area resurveyed, the hot spot activity generally decreased. At several sites, the surrounding soil still exhibited relatively-high levels of

radioactivity possibly due to material spilling off the hot particle over time. Typically, this contamination was also removed by excavating a small amount of soil with the hot particle. Hot spot soil samples were collected and analyzed for Am-241, isotopic plutonium, and total uranium. In addition, several samples underwent the TCLP for RCRA metals analysis.

A systematic *in situ* radiological survey of the Double Tracks Test Site was performed during the third characterization event. The measurement system consisted of three pods of NaI detectors mounted on a Suburban vehicle. This system was combined with a GPS to provide both radiation measurements and locations. Prior to the survey, hot spots were identified and the highly-radioactive metallic fragments were removed and placed in a central storage location at the site. The radioactivity of the fragments was measured before storage. Several shallow soil boreholes were advanced near the Double Tracks ground zero to assess the extent of contamination in a soil mound at ground zero. Downhole radiation measurements were taken in several soil borings and indicated that radiological contamination was present within the soil mound.

The focus of the fourth characterization event was to collect soil known to be contaminated for treatability testing. Ten soil surface samples were collected in the approximate center of the contaminant plume south of ground zero. Treatability testing consisted of grain size analysis, bench scale attrition scrubbing, and gamma spectroscopy and isotopic analysis.

4.2 Conclusions

This report presents the results of characterization activities performed at the Double Tracks Test Site. Historical data combined with recent characterization data provided the information necessary to adequately characterize the nature and extent of contamination at Double Tracks. The interim corrective action currently planned for Double Tracks consists of removing contaminated soil and disposing of it at a permanent disposal site. The characterization data required for planning the interim corrective action included the horizontal and vertical extent of contamination, the volume of contaminated soil to be removed, waste classification data, and information to satisfy disposal criteria.

Specific conclusions on the nature and extent of contamination at the Double Tracks Test Site are as follows:

- Contaminants of potential concern in soil at the Double Tracks Test Site are Am-241 and plutonium. Uranium and other non-radiologic metals are present only in background concentrations.
- *In situ* measurements indicate that typically most of the total transuranic activity is present within the top 2.5 cm (1 in.) of the soil profile. Where significant amounts of plutonium (greater than 1,000 pCi/g) are present, it can be assumed that the uppermost 5 cm (2 in.) of the soil profile is contaminated. In the ground zero area, radiologically-contaminated soil and possibly test debris are buried. The depth of contamination in the mound may be as thick as 0.9 m (3.0 ft).
- The contamination of surface soil at Double Tracks appears to have been caused by local fallout and debris from the experiment. Superimposed on this contamination pattern were relatively-large metallic fragments. These metallic fragments were the source of most of the radioactive hot spots activity identified during characterization.
- The surface area with total transuranic activity greater than 200 pCi/g is approximately 8,780 square meters (95,400 square feet), based on an *in situ* radiological survey.
- The best estimate of the volume of contaminated soil to be removed from Double Tracks is 1,243 m³ (1,611 yd³), based on a clean-up level of 200 pCi/g. This estimate does not take into account soil expansion during excavation.
- Based on the contaminants present, soil from the Double Tracks Test Site would be classified as low-level radioactive waste and not mixed low-level waste. Soil contaminated with Am-241 and plutonium did not exhibit toxicity characteristics, based on TCLP data.
- The metallic fragments outside of ground zero are containerized inside the exclusion zone and represent a very small volume of transuranic material.
- Results of the treatability testing were that when the soil was separated via grain size, the contamination also separated, going into the finer fraction. After attrition scrubbing, 80 to 90 percent of the radioactive contamination is contained in the fine fraction. The fine fraction is 20 to 40 percent of the total soil mass. However, two of the ten samples had radioactive contamination present in the coarse fraction. This indicates that some of the radioactive contaminants present, outside of ground zero, are larger than fine sand. Based on this bench scale testing, volume reduction appears to be feasible with the current understanding of site characteristics. However, volume reduction does not appear to be cost effective for the Double Tracks Test Site because of the relatively small amount of soil requiring corrective action. If during the site corrective action it is determined that site conditions change, volume reduction via grain size separation may be reexamined. If volume reduction is implemented, the volume of soil requiring transportation to the disposal site will be reduced, as will the associated transportation risks.

5.0 References

- American Society for Testing and Materials. 1991. *Trace Uranium in Water by Pulsed-Laser Fluorimetry*, 5174-91. Philadelphia, PA.
- American Society for Testing and Materials. 1975. *Standard Recommended Practice for Dealing with Outlying Observations*, E178-75. Philadelphia, PA.
- ASTM, see American Society for Testing and Materials.
- Church, H.W. Sandia National Laboratories. 1969. *Cloud Rise from High-Explosives Detonations*, SC-RR-68-903. Albuquerque, NM.
- DOE, see U.S. Department of Energy.
- Ekren, C.B., R.E. Anderson, C.L. Rogers, and D.C. Noble. 1971. U.S. Atomic Energy Commission. *Geology of Northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada*. Geological Survey Professional Paper 651.
- EPA, see U.S. Environmental Protection Agency.
- Essington, E.H., R.O. Gilbert, L.L. Eberhardt, and E.B. Fowler. U.S. Energy Research and Development Administration, Nevada Operations Office. 1975. *Plutonium, Americium, and Uranium Concentrations in Nevada Test Site Soil Profiles*, LA-UR-75-1770, IAEA-SM-199/76.
- Faure, G. 1986. *Principles of Isotope Geology*, 2nd ed., John Wiley and Sons. New York, NY.
- Friesen, H.N. U.S. Department of Energy, Nevada Field Office. 1992. *Summary of the Nevada Applied Ecology Group and Correlative Programs*, DOE/NV-357. Las Vegas, NV.
- Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold Company, Inc. New York, NY.
- Gilbert, R.O. U.S. Department of Energy, Nevada Operations Office. 1977. "Revised Total Amounts of $^{239,240}\text{Pu}$ in Surface Soil at Safety-Shot Sites," in *Transuranics in Desert Ecosystems*, NVO-181. M.G. White, P.B. Dunaway, and D.L. Wireman, eds. Las Vegas, NV.
- Gilbert, R.O., L.L. Eberhardt, E.B. Fowler, E.M. Romney, E.H. Essington, and J.E. Kinnear. U.S. Energy Research and Development Administration, Nevada Operations Office. 1975. "Statistical Analysis of $^{239,240}\text{Pu}$ and ^{241}Am Contamination of Soil and Vegetation on NAEG Study Sites," in *The Radioecology of Plutonium and Other Transuranics in Desert Environments*, NVO-153. M.G. White and P.B. Dunaway, eds. Las Vegas, NV.

Gloria, M.A. and I. Aoki. Reynolds Electrical & Engineering Co., Inc. 1966. *Radiological Conditions at Project Rollercoaster Sites - 1965*, NVO-162-19. Radiological Sciences Department. Mercury, NV.

Gloria, M.A. and B.L. Brown. Reynolds Electrical & Engineering Co., Inc. 1964. *Project Roller Coaster Quarterly Resurvey, June 1964*, NVO-162-17. Radiological Sciences Department. Mercury, NV.

Hendricks, T.J. EG&G Energy Measurements Group. 1995. *An Aerial Radiological Survey of the Double Track Site and Surrounding Area, Central Nevada*, EGG 11265-1466, Draft. Las Vegas, NV.

IT, see IT Corporation.

IT Corporation. 1994. *Background Concentrations of Constituents of Concern to the Sandia National Laboratories/New Mexico Environmental Restoration Project, Phase II: Interim Report*. Albuquerque, NM.

Jobst, J.E. EG&G Energy Measurements Group. 1979. *An Aerial Radiological Survey of Clean Slates 1, 2, and 3, and Double Track, Tonopah Test Range, Central Nevada*, EGG-1183-1737. Las Vegas, NV.

Kinnison, R.R. and R.O. Gilbert. U.S. Department of Energy, Nevada Operations Office. 1982. "Estimates of Amounts of Soil Removal for Cleanup of Transuranics at NAEG Off-Site Safety-Shot Sites," in *The Radioecology of Transuranics and Other Radionuclides in Desert Ecosystems*, NVO-224. W.A. Howard, P.B. Dunaway, and R.G. Fuller, eds. Las Vegas, NV.

Krauskopf, K.B. 1979. *Introduction to Geochemistry*, 2nd ed., McGraw-Hill Book Company. New York, NY.

Leavitt, V.D. U.S. Environmental Protection Agency. 1974. *Soil Surveys of Five Plutonium Contaminated Areas on the Test Range Complex in Nevada*, NERC-LV-539-28, Monitoring Systems Research and Development Laboratory, National Environmental Research Center. Las Vegas, NV.

Martin, W.E. and S.G. Bloom. U.S. Energy Research and Development Administration, Nevada Operations Office. 1977. "Nevada Applied Ecology Group Model for Estimating Plutonium Transport and Dose to Man," in *Transuranics in Natural Environments*, NVO-178. M.G. White and P.B. Dunaway, Eds. Las Vegas, NV.

McArthur, R.D. and F.L. Miller, Jr. Desert Research Institute. 1989. *Off-Site Radiation Exposure Review Project, Phase II Soils Program*, DOE/NV/10384-23, Water Resources Center, University of Nevada System. Las Vegas, NV.

- Menker, H.E., J.C. Armstrong, E.J. Forslow, and B.H. Sorensen. Hazleton-Nuclear Science Corporation. 1966. *Operation Roller Coaster, Project Officers Report - Project 5.2/5.3a, Radiochemical Analysis of Biological and Physical Samples*, POR-2515. Palo Alto, CA.
- NAS, see National Academy of Sciences.
- National Academy of Sciences. 1965. *The Radiochemistry of Plutonium*, NAS-NS-3058. Washington, DC.
- National Academy of Sciences. 1962. *The Radiochemistry of Uranium*, NAS-NS-3050. Washington, DC.
- National Academy of Sciences. 1960. *The Radiochemistry of Americium and Curium*, NAS-NS-3006. Washington, DC.
- Riedhauser, S.R. and W.J. Tipton. Bechtel Nevada, Remote Sensing Laboratory. 1996. *In Situ Radiological Surveying at the Double Tracks Site, Nellis Air Force Range, Tonopah, Nevada*, Draft. Las Vegas, NV.
- Shreve, J.D., Jr. Sandia Corporation. 1965. *Operation Roller Coaster, Scientific Director's Summary Report*, DASA-1644. Albuquerque, NM.
- Thomas, J.M., J.L. Mason, and J.D. Crabtree. U.S. Geological Survey. 1986. Ground-Water Levels in the Great Basin Region of Nevada, Utah, and Adjacent States [MAP].
- U.S. Department of Energy, Nevada Operations Office. 1995a. *Cost/Risk/Benefit Analysis of Alternative Cleanup Requirements for Plutonium-Contaminated Soils On and Near the Nevada Test Site*, DOE/NV-399. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1995b. *Soils Media Operable Unit Quality Assurance Project Plan*, DOE/NV-376. Las Vegas, NV.
- U.S. Department of Energy. 1992. *Environmental Measurements Laboratory Procedures Manual*, HASL-300, 27th ed. New York, NY.
- U.S. Environmental Protection Agency. 1994. *Title 40 - Protection of Environment, Part 261 - Identification and Listing of Hazardous Waste, Subpart C - Characteristics of Hazardous Waste, Toxicity Characteristic (40 CFR 261.24)*. Washington, DC.
- U.S. Environmental Protection Agency. 1993. *Title 40 - Protection of Environment, Part 191 - Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, Subpart A - Environmental Standards for Management and Storage, Definitions (40 CFR 191.02)*. Washington, DC.

U.S. Environmental Protection Agency. 1990a. *USEPA Contract Laboratory Program Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration*, ILM01.0. Washington, DC.

U.S. Environmental Protection Agency. 1990b. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*, 3rd ed., Final Update 1. Washington, DC.

U.S. Environmental Protection Agency. 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, EPA/530-SW-89-026, Interim Final Guidance, Office of Solid Waste, Waste Management Division. Washington, DC.

Appendix A

IT Field Sampling Instructions

FIELD SAMPLING INSTRUCTION DOUBLE TRACKS SITE SCOPING STUDY

Prepared for

DOE Nevada Operations Office
Las Vegas, Nevada

Prepared by

IT CORPORATION
4330 South Valley View Boulevard, Suite 114
Las Vegas, Nevada

Work Performed Under Contract No.
DE-AC08-92NV10972

October 1994

This report has been reproduced from the best available copy. For availability contact:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831 (615) 576-8401

DISCLAIMER

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, makes a warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

FIELD SAMPLING INSTRUCTION
DOUBLE TRACKS SITE
SCOPING STUDY

Approved by:

Dick McKinley
Dick McKinley
Project Manager

Date:

10/24/94

Approved by:

Steve Mergenmiller for Cheryl Prince
Cheryl Prince
Quality Assurance Office

Date:

10/24/94

Table of Contents

1.0 Introduction	1-1
2.0 General Sampling Procedures	2-1
2.1 Sample Locations	2-1
2.2 Sampling Methods	2-1
2.3 Sample Handling, Packaging, and Shipping	2-3
2.4 Quality Control Samples	2-4
2.4.1 Equipment Rinsate Blank Samples	2-5
2.4.2 Field Blank Samples	2-5
2.4.3 Duplicate Samples	2-6
2.4.4 Matrix-Spike Analysis	2-6
2.5 Sample Custody	2-6
2.6 Field Documentation	2-7
2.7 Decontamination	2-8
2.8 Waste Disposal	2-8
3.0 Analytical Methods	3-1
3.1 Resource Conservation Recovery Act Metals	3-1
3.2 Gamma Spectroscopy	3-1
3.3 Isotopic Plutonium and Uranium	3-1
4.0 Data Analysis	4-1
4.1 Ratios	4-1
4.2 Depth Distribution	4-1
5.0 Health and Safety Plan	5-1
6.0 References	6-1
Appendix A - Site Specific Health and Safety Plan	A-1

List of Figures

<i>Number</i>	<i>Title</i>	<i>Page</i>
2-1	Approximate Sample Locations for Scoping Study Double Tracks, Nellis Air Force Range	2-2

List of Tables

<i>Number</i>	<i>Title</i>	<i>Page</i>
2-1	Sample Container, Preservation, and Holding-Time Requirements for Soil Samples and Field Blank Samples	2-3
2-2	Sample Container, Preservation, and Holding-Time Requirements for Equipment Rinsate	2-5
3-1	Analytical Methods and Quality Assurance Criteria	3-2
3-2	Practical Quantitation Limits for the Analysis of Metals by the Toxicity Characteristic Leaching Procedure	3-3
3-3	Target Detection Limits for Radionuclides by Gamma Spectroscopy in Soil and Water Samples	3-4

List of Acronyms and Abbreviations

AR/COC	Analysis Request and Chain of Custody Form
cm	centimeter
DOE	U.S. Department of Energy
FADL	Field Activity Daily Log
in.	inch
ml	milliliter
NAFR	Nellis Air Force Range
NV ERP	Nevada Environmental Restoration Project
oz	ounce
pCi/g	picocuries per gram
PQL	practical quantitation limits
Pu	plutonium
QC	quality control
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
SMOU	Soils Media Operable Unit
SQP	Standard Quality Practice
SSHASP	Site-Specific Health and Safety Plan
TAL	Target Analyte List
TCLP	Toxicity Characteristic Leaching Procedure
U	uranium

1.0 Introduction

The Double Tracks site located on Stonewall Flat in Subrange 71 of the Nellis Air Force Range (NAFR) was used for one of four safety-shot tests performed for the Operation Roller Coaster testing series in 1963. Plutonium (Pu) and uranium (U) were used in the four tests to study the mechanisms of dispersal, transport, and deposition of the radioactive elements from nonnuclear detonations of plutonium-bearing devices (Shreve, 1965). No nuclear yield resulted from these tests, but large land areas were contaminated with plutonium and uranium. This contamination is primarily within the top 3 centimeters (cm) to 5 cm (1.2 inches [in.] to 2 in.) of soil (SNL, 1982).

The Double Tracks safety test consisted of a one-point detonation of a plutonium-uranium device. The test was conducted at the land surface on a concrete and metal pad. The detonation threw weapons material, earth, and other material into the air. The debris and most of the dirt fell to earth at relatively short distances from the detonation point; however, some of the material was spread downwind over larger areas. No decontamination or clean-up activities occurred at the test site (Martin, 1989).

This field instruction for the collection of scoping samples at the Double Tracks site is designed for collecting and analyzing an adequate number of samples to provide sufficient information for Double Tracks characterization scoping activities. Analysis of scoping samples will facilitate designing characterization sampling activities by providing information relative to selection of sampling methodology and the vertical distribution of radiological and nonradiological parameters.

This field instruction shall be used only in conjunction with, and as a supplement to, the Soils Media Operable Unit (SMOU) Quality Assurance Project Plan (QAPjP). Each field worker's familiarity with this plan and instructions shall be documented by the completion of a Required Reading Checklist, which shall include the QAPjP, the Site-Specific Health and Safety Plan, this field instruction, and any Standard Quality Practices (SQPs) referenced herein.

2.0 General Sampling Procedures

This section outlines the sampling methods that will be used at the Double Tracks site for scoping surveys.

Sampling equipment shall be decontaminated before mobilization to the field, using procedures given in SQP ITLV-0405, Sampling Equipment Decontamination. Soil samples must be collected and packaged in accordance with the SMOU QAPjP: SQP ITLV-0605, Vertical Profile Soil Sampling; and SQP ITLV-0403, Sample Handling, Packaging and Shipping.

2.1 Sample Locations

Sampling locations are outlined on Figure 2-1. Three transects will be used for the sample locations that will run west to east downwind of ground zero. Sample locations were chosen to bias sample results for higher radiological and metal parameter levels.

2.2 Sampling Methods

Radiological contamination is relatively widespread in surface soil at the Double Tracks site. However, a limited investigation performed by the Nevada Applied Ecology Group showed that the contamination is limited to the uppermost soil profile. To determine the vertical migration of the Pu, vertical-profile soil samples shall be collected and analyzed at all sample locations.

To collect soil samples, the sampling team shall approximately locate and mark with a wooden stake each sample site shown in Figure 2-1. Sample locations may change if it is determined by the Field Supervisor that the location is inadequate for sampling. Sample locations shall be thoroughly documented in the Field Activity Daily Log (FADL) and will be surveyed to determine Nevada grid coordinates at a later date. Samples shall be collected in accordance with SQP ITLV-0605. Four separate intervals (subsamples) shall be collected from each soil-sample site. These vertical intervals are as follows:

- 0 cm to 5 cm (0 in. to 2 in.)
- 5 cm to 10 cm (2 in. to 4 in.)
- 10 cm to 15 cm (4 in. to 6 in.)
- 22.5 cm to 30 cm (9 in. to 12 in.).

N 1,075,000 —

N 1,074,500 —

N 1,074,000 —

Fenced area

LEGEND

== == == Road

- - - - - Drainage

— 5000 — Topographic contour,
feet above mean sea level

Ground zero

Approximate sample location

Surface sample will be
analyzed for TCLP metals

SCALE

0 250 500 Feet

0 80 160 Meters

FIGURE 2-1
APPROXIMATE SAMPLE LOCATIONS
FOR DOUBLE TRACKS SCOPING STUDY,
NELLIS AIR FORCE RANGE

4101A01

10/13/94

CHECKED BY	<i>[Signature]</i>	10/24/94	DRAWING
APPROVED BY	<i>[Signature]</i>	12/27/94	NUMBER

At each sample location and for each depth interval enough soil shall be collected to fill two containers: one 1,000-milliliter (ml) container and one 8 ounce (oz) container. These sample containers shall be submitted for analysis of the parameters listed in Table 2-1 and explained in Section 3.0. The fourth interval samples will not be sent to the lab for analysis. They will be archived until laboratory analysis results are received from the upper interval samples.

Table 2-1
Sample Container, Preservation, and
Holding-Time Requirements for Soil Samples and Field Blank Samples

Parameter	Container Type/ Sample Volume	Preservation ^a	Maximum Holding Time ^b
Radionuclides: Gamma Spec	1,000-milliliter (ml) glass or polyethylene, wide- mouth	none required	180 days
Total TAL ^c Metals, - TCLP ^d Metals, and Isotopic U, Pu, and Am ^e	8-ounce amber glass	cool, 4°C	180 days ^f

^aTemperature Note: All samples requiring temperature preservation stated at 4°Celsius (C) will be acceptable within the range of 4°C ± 2°C. The laboratory should note on the sample Chain-of-custody Form that temperature requirements were met by noting the receipt temperature. For all samples received outside the range of 4°C ± 2°C, the sample(s) and the temperature (in 1°C increments) will be noted on the Chain-of-custody Form, and the Project Manager shall be notified immediately.

^bHolding times are calculated from time of sample collection.

^cTarget Analyte List.

^dToxicity Characteristic Leaching Procedure.

^eUranium, plutonium, and americium.

^fFor TCLP, except for mercury, holding time from field collection to extraction is 180 days, and holding time from extraction to analysis is 180 days (360 days total elapsed time). For TCLP mercury, corresponding holding times are 28 and 28 days (56 days total elapsed time).

At sample locations where the surface is armored with gravel (desert pavement), the gravel shall be removed prior to sample collection. Also, cobbles and coarse gravel (diameter ≥ 2 cm [0.8 in.]) shall be removed from samples, regardless of the depth at which they occur. The total sample depth, 30 cm (12 in.), is assumed to be sufficient because downward transport of metals and radionuclides in soil under arid and semiarid conditions has been shown by other similar studies to be minimal.

2.3 Sample Handling, Packaging, and Shipping

Soil samples shall be handled, packaged, and shipped in accordance with SQP ITLV-0403. The required sample containers and volumes, preservation procedures, and holding times for the analysis of soil samples are given in Table 2-1. Sample containers shall be obtained from

an approved laboratory and certified clean as per U.S. Environmental Protection Agency protocol. The containers shall remain sealed until they are used.

Immediately after collection, the sample containers shall be labeled with black waterproof markers with, at a minimum, the following information:

- Unique identification number (assigned by program sample coordinator)
- Project name and number
- Date and time (military) of the sample collection
- Sample location
- Sample depth interval (e.g., 0 in. to 2 in.)
- Sample medium
- Requested analyses
- Preservation
- Bottle number
- Name(s) of the initial sample custodians (collectors).

Filled sample containers shall be packaged in a shipping container as described in SQP ITLV-0403. The shipping container and the outside surface of filled sample bottles shall be screened for radiological contamination either in the field or at a designated location by qualified IT or contractor personnel. Radiological screening procedures used shall be in compliance with U.S. Department of Energy (DOE) requirements and U.S. Department of Transportation regulations.

Documentation of sample handling, packaging, and shipping shall be completed daily, in ink, by the soil sampling team in accordance with SQP ITLV-0401, Field Activities Documentation.

2.4 Quality Control Samples

Field and laboratory investigation activities shall include the collection and analysis of quality control (QC) samples to determine whether data generated meet the data quality criteria of this scoping survey. These samples shall be introduced into the analytical process in order to assess the overall quality of the sampling and analysis program. Samples will be collected in compliance with the QAPjP and SQP ITLV-0404, Collection of Field Quality Control Samples. This section describes the QC samples that will be generated from the scoping survey field activities.

2.4.1 Equipment Rinsate Blank Samples

To assess the overall cleanliness of the sampling system and the effectiveness of sampling-equipment decontamination procedures, a minimum of one equipment rinsate blank shall be submitted to the laboratory for each day of sampling activity requiring equipment decontamination. The blanks shall be prepared by pouring deionized water through or over a decontaminated sampling device prior to the use of the device for environmental sample collection. Enough rinsate must be generated to fill four 1,000-ml containers. Equipment rinsates shall be analyzed for the parameters in Table 2-2. If rinsate blank analytical results indicate possible contamination of samples, environmental sample results shall be reviewed to determine whether qualifiers should be assigned to the data or corrective action would be required.

Table 2-2
Sample Container, Preservation, and Holding-Time Requirements
for Equipment Rinsate

Parameter	Container Type/ Sample Volume	Preservation ^a	Maximum Holding Time ^b
Radionuclides: Gamma Spec	1,000-milliliter (ml) polyethylene	cool, 4°C; pH ≤ 2 with HNO ₃	180 days
Total TAL ^c Metals	1,000-ml amber glass	cool, 4°C; pH ≤ 2 with HNO ₃	180 days
Isotopic Uranium	1,000-ml polyethylene	cool, 4°C; pH ≤ 2 with HNO ₃	180 days
Isotopic Plutonium, and Americium	1,000-ml polyethylene	cool, 4°C; pH ≤ 2 with HNO ₃	180 days

^aTemperature Note: All samples requiring temperature preservation stated at 4°Celsius (C) will be acceptable within the range of 4°C ± 2°C. The laboratory should note on the sample Chain-of-custody Form that temperature requirements were met by noting the receipt temperature. For all samples received outside the range of 4°C ± 2°C, the sample(s) and the temperature (in 1°C increments) will be noted on the Chain-of-custody Form, and the Project Manager shall be notified immediately.

^bHolding times are calculated from time of sample collection.

^cTarget Analyte List.

2.4.2 Field Blank Samples

Field blanks shall be collected at a minimum of one per day. If weather conditions change significantly during sampling, an additional field blank shall be collected. Field blanks shall be collected and analyzed to determine if contamination in the air during sample collection and packaging may have contaminated the samples. The field blanks shall be prepared by

pouring certified clean sand into clean sample containers in the field near the sampling locations. Field blanks shall be analyzed for the parameters in Table 2-1. If field blank analytical results indicate possible contamination of associated samples, environmental sample results shall be reviewed to determine whether qualifiers should be assigned to the data or corrective action is required.

2.4.3 Duplicate Samples

To assess sample variability, duplicate samples shall be collected at a minimum of 1 per group of 20 samples. The duplicates shall be obtained from the same depth horizon and approximately the same horizontal position as the original sample. A unique sample number shall be assigned to the duplicate sample. The duplicate sample number shall not indicate that it is a QC sample to minimize handling, analysis, and data-evaluation bias. Duplicates shall be analyzed for the parameters in Table 2-1.

2.4.4 Matrix-Spike Analysis

For metal analysis, a sample shall be designated on an Analysis Request and Chain of Custody (AR/COC) Form for matrix-spike analysis for each matrix. One matrix spike will be designated per 20 samples collected. The sample will be spiked with the analytes of interest at the laboratory and analyzed with each batch of samples. Matrix-spike samples shall be analyzed to determine interferences of the sample matrix on the analytical methods.

2.5 Sample Custody

The validity of environmental measurement data is dependent upon the ability to demonstrate that samples have been obtained from the locations stated and that they have reached the laboratory without alteration except by required preservation. The procedures for initiating, maintaining, and documenting sample chain of custody are defined by SQP ITLV-0402, Chain of Custody. An AR/COC Form shall be used to record custody transfers by field personnel responsible for transporting samples. The term "chain of custody" refers to the method by which the sample history is tracked and continuous possession of a sample by approved personnel (custodian) is documented. The AR/COC Form makes the sample a legally defensible entity. Chain of custody shall be initiated in the field by the person collecting samples. Use of the AR/COC Form is required without exception to create a written record of sample custody from the time of collection through laboratory analysis. All samples, including field QC samples, shall be recorded on the AR/COC Form. Samples will not be analyzed by the laboratory without a correctly prepared AR/COC Form. Materials that

shall be used in the chain-of-custody process for sample tracking and field activities are as follows:

- Sample Identification Label
- AR/COC Form
- Custody Seal Tape.

Examples of these forms and instructions for their use are presented in SQPs ITLV-0401, ITLV-0402, and ITLV-0403.

2.6 Field Documentation

Field activities and sample collection shall be documented in accordance with SQP ITLV-0401. At a minimum, field documentation for the soil sampling effort shall be comprised of the following:

- FADL
- Tailgate Safety Briefing Form
- Equipment Calibration Form (for health and safety monitoring instruments)
- Sample Collection Log.

Sample collection logs shall be completed immediately after sample collection and contain the following information, at a minimum:

- Unique identification number (assigned by program sample coordinator)
- Project name and number
- Date and time (military) of the sample collection
- Sample location (e.g., BM-YF-1-1), with a drawing if appropriate
- Sample depth interval (e.g., 0 in. to 2 in.)
- Sample type (e.g., duplicate or rinsate)
- Physical description of sample
- Background area name
- Amount of sample collected and container type
- Signature(s) of the sample collectors.

If duplicate samples are collected, the unique identification number of the second sample shall be recorded on the sample collection log. The physical description of the sample should include the following, as applicable:

- Overall sample grain size
- Soil color
- Lithology of float at the sample site

- Removal of surface gravel or desert pavement prior to sampling
- Sedimentary environment (e.g., active wash, channel, inactive surface, and desert varnish)
- Presence of distinct or unusual soil layers or horizons
- Suspected contamination
- Disturbed sample site.

All field documentation shall be completed daily, in ink, by the soil sampling team. Field records shall be collected and maintained by the IT Project Manager or designee until completion of the field program or until they are submitted to the project files.

2.7 Decontamination

Decontamination of sampling equipment shall be performed according to SQP ITLV-0405. Sampling equipment shall be decontaminated in the field between collection of samples, and waste from decontamination shall be disposed according to the procedure discussed in Section 2.8. Personnel decontamination requirements are specified in the Nevada Environmental Restoration Project (NV ERP) Health and Safety Plan (DOE, 1994) and the Site-Specific Health and Safety Plan (SSHASP) that is included as an attachment to this field instruction.

2.8 Waste Disposal

This subproject will result in the generation of investigation-derived waste. The waste shall be categorized as sanitary, hazardous, radioactive, or mixed (a combination of radioactive and hazardous). Waste shall be categorized through process knowledge and/or sampling analysis.

Disposal of field-derived waste from the NAFR shall be in accordance with written, approved operating procedures. These procedures ensure that field-derived waste shall be managed in accordance with applicable federal and state of Nevada regulations, as well as DOE requirements. Field-derived waste shall be minimized to the greatest extent possible through process controls, control of hazardous materials, and segregation of waste.

If waste is shown to be low-level radioactive waste, solid (i.e., nonliquid) field-derived waste (e.g., personal protective and sampling equipment and disposable wipes) shall be appropriately segregated into items which are amenable to decontamination and which are not. Items amenable to decontamination, such as cloth coveralls, shall be transported to the NTS Area 6 Decontamination Facility. Items not amenable to decontamination shall be managed in accordance with the approved Reynolds Electrical & Engineering Co., Inc., low-level

compactable trash waste stream. Liquid waste, such as decontamination rinsate, shall be containerized and left on site pending additional sampling activities and the construction of an on-site decontamination facility.

Sanitary, nonradioactive solid waste shall be disposed in an approved sanitary landfill; liquids will be evaporated or discharged to an approved sanitary sewer.

Mixed waste, if generated, shall be transported to the NTS Area 5 Transuranic Waste Storage Pad in accordance with the provisions of the consent order between DOE and the state of Nevada. Hazardous waste, if generated, shall be accumulated on site pending accumulation of 55 gallons. Upon accumulation of 55 or more gallons of hazardous waste, the waste shall be held for less than 90 days pending transport to a permitted off-site treatment, storage, and disposal facility in accordance with federal and state regulations.

3.0 Analytical Methods

Table 3-1 lists the analytical methods and equipment and the acceptance criteria for precision, accuracy, and completeness. While acceptance criteria are also presented in the QAPjP, more detailed criteria are presented in this field instruction.

3.1 Resource Conservation Recovery Act Metals

The soil samples shall be analyzed for total target analyte list (TAL) metals using inductively coupled-atomic emission spectroscopy and cold vapor atomic absorption spectrometry for mercury. Three surface samples, as shown in Figure 2-1, will also undergo toxicity characteristic leaching procedure (TCLP) analysis for Resource Conservation Recovery Act (RCRA) metals (Title 40 CFR Appendix II) to provide information relative to future soil waste disposal requirements. The list of RCRA metals and practical quantitation limits (PQL) are shown in Table 3-2. The PQLs are sufficient to quantify the concentration of RCRA metals in the TCLP extract.

3.2 Gamma Spectroscopy

A gamma spectroscopic method from the *Environmental Measurements Laboratory Procedures Manual* (HASL-300) (DOE, 1992a) shall be used to analyze the soil samples for radiological parameters. Radiological analytes and target detection limits are presented in Table 3-3. In general, target detection limits were selected to provide enough sensitivity to ensure that soil samples were not contaminated by testing-related radionuclides. The target detection limits were selected so that global fallout levels of Cesium-137, 0.2 picocuries per gram (pCi/g) to 0.4 pCi/g (EG&G, 1985), and naturally-occurring levels of other radionuclides, (e.g., 0.3 pCi/g to 1.3 pCi/g U-238 [EG&G, 1985]), shall be quantified in soil samples.

3.3 Isotopic Plutonium, Uranium, and Americium

Soil samples analysis for isotopic uranium and plutonium and americium-241 shall be performed in accordance with the National Academy of Science Nuclear Series procedure 3050 (1962) for uranium, 3058 for plutonium (1965), and 3006 for americium. Soil aliquots will undergo several stages of dissolution using nitric, hydrofluoric, and hydrochloric acids and hydrogen peroxide. The solution will be introduced onto an ion exchange column, and the elements of concern will be eluted from the column with an acid solution. This solution will undergo further treatment so that the elements of concern form a precipitate that will be filtered and mounted on a stainless-steel disk for alpha counting.

Table 3-1
Analytical Methods and Quality Assurance Criteria

Parameters	Medium	Analytical Methods	Analytical Equipment	Precision Criteria (RPD) ^a	Accuracy Criteria (Percent Recovery)	Completeness (Percent)
Total TAL Metals ^b	soil	EPA 6010, ^c EPA 7470 for Mercury	ICP ^d , CVAA ^e	± 35 ^f	LCS ^g : 80 - 120 (except for antimony and silver) MS ^h : 75 - 125	90
	water	EPA 6010, EPA 7470 for Mercury	ICP, CVAA	± 20 ^f	LCS: 80 - 120 (except for antimony and silver) MS: 75 - 125	90
Radionuclides	soil	HASL-300 ⁱ 4.5.2.3	gamma spectrometer	± 1.5 x 2σ error of sample ^k	± 3σ mean recovery from control tables ^k	90
	water	HASL-300 4.5.2.3	gamma spectrometer	± 1.5 x 2σ error of sample ^k	± 3σ mean recovery from control tables ^k	90
TCLP ^l RCRA Metals	soil	Extraction: EPA 1311	NA ^m	NA	NA	90
	extract	EPA 6010, EPA 7060 for arsenic, EPA 7421 for lead, EPA 7470 for mercury, EPA 7740 for selenium	ICP, CVAA, GFAA ⁱ	± 20 ⁿ	LCS: 80 - 120 MS: 75 - 125	90
Isotopic U	water	NAS NS ^o 3050	alpha spectrometer	± 20	LCS: 75 - 125	90
	soil	NAS NS 3050	alpha spectrometer	± 20	LCS: 75 - 125	90
Isotopic Pu	water	NAS NS 3058	alpha spectrometer	± 25	LCS: 75 - 125	90
	soil	NAS NS 3058	alpha spectrometer	± 35	LCS: 75 - 125	90
Am-241	water	NAS NS 3006	alpha spectrometer	± 50	LCS: 75 - 125	90
	soil	NAS NS 3006	alpha spectrometer	± 50	LCS: 75 - 125	90

^aRelative percent difference.

^bTarget Analyte List.

^cU.S. Environmental Protection Agency, 1992.

^dInductively coupled argon plasma spectroscopy.

^eCold vapor atomic absorption spectroscopy.

^fRPD for sample values greater than five times the Contract Required Detection Limit (CRDL). For sample values less than five times the CRDL, the criterion is ± CRDL for water and ± 2 times the CRDL for soil.

^gLaboratory control sample.

^hMatrix spike sample

ⁱGraphite furnace atomic absorption spectroscopy

^jU.S. Department of Energy, 1992a.

^kExpressed in the same units as analytical results (e.g., picocuries per gram)

^lToxicity Characteristic Leaching Procedure.

^mNot applicable

ⁿApplicable only to sample values greater than 10 times the instrument detection limit.

^oNational Academy of Science Nuclear Series

Table 3-2
Practical Quantitation Limits for the Analysis of Metals
by the Toxicity Characteristic Leaching Procedure^a

Element ^b	CAS ^c Number	Practical Quantitation Limits ($\mu\text{g}/\ell$) ^d
Arsenic ^e	7440-38-2	3
Barium	7440-39-3	10
Cadmium	7440-43-9	10
Chromium	7440-47-3	25
Lead ^e	7439-92-1	3
Mercury ^f	7439-97-6	0.2
Selenium ^e	7782-49-2	3
Silver	7440-22-4	20

^aIT, 1993.

^eAnalyzed by inductively coupled argon plasma spectroscopy, unless noted.

^cChemical Abstract Service.

^dMicrograms per liter.

^fAnalyzed by graphite furnace atomic absorption spectroscopy.

^gAnalyzed by cold vapor atomic absorption spectroscopy.

Table 3-3
Target Detection Limits for Radionuclides by Gamma Spectroscopy
in Soil and Water Samples

Radionuclide	Target Detection Limit for Soil Samples (pCi/g) ^a	Target Detection Limit for Water Samples (pCi/l) ^b
Actinium-227	0.6	NA ^c
Antimony-125	0.2	25
Americium-241	0.6	NA
Barium-133	0.1	10
Bismuth-214	0.2	25
Cobalt-60	0.1	10
Cesium-137	0.1	10
Europium-152	0.2	25
Europium-154 ^c	0.2	25
Europium-155	0.4	25
Lead-210	5	NA
Lead-212	0.1	25
Potassium-40	1	NA
Protactinium-231	3	NA
Protactinium-234	18	NA
Radium-223	0.6	50
Radium-226	0.2	25
Thallium-208	0.1	10
Thorium-232	0.6	NA
Uranium-234	0.6	NA
Uranium-235	0.6	NA
Uranium-238	0.6	NA

^aPicocuries per gram.

^bPicocuries per liter.

^cNot applicable. Detection limits in water are relatively high and are not applicable to QC samples.

4.0 Data Analysis

Analytical data will be reviewed by the project manager for completeness and accuracy prior to conducting data analysis. The following will be calculated and reported for the Double Tracks site for use in the characterization report.

4.1 Ratios

The average ratios of $^{239,240}\text{Pu}$ to ^{241}Am and $^{239,240}\text{Pu}$ to ^{238}U shall be computed using:

$$b = \frac{\sum_{i=1}^n y_i}{\sum_{i=1}^n x_i}$$

where y_i is the $^{239,240}\text{Pu}$ (pCi/g) concentration, and x_i is the ^{241}Am (pCi/g) or ^{238}U (pCi/g) concentration for the i^{th} soil sample collected at Double Tracks. All ratios will be determined from analysis of the same aliquot from the soil sample.

4.2 Depth Distribution

Sample results for the upper three depth intervals shall be analyzed for the parameters in Table 2-1. If results indicate radioactivity concentrations that are not decreasing with increasing depth, are inconsistent or otherwise questionable, then the archived lower depth intervals shall be analyzed for the same parameters to determine the depth distribution.

5.0 Health and Safety Plan

The health and safety protocols for the field activities related to the implementation of this field instruction are delineated in the SSHASP presented in Appendix B. The SSHASP sets forth the specific requirements and procedures that shall be followed while performing operations under the field instruction. In addition, all requirements of the NV ERP Health and Safety Plan (DOE, 1994) shall be observed.

The SSHASP includes the following information:

- Protective measures, engineering and administrative
- Monitoring for site-specific contaminants, chemical and radiological
- Personal protective equipment and its use
- Site control
- Emergency communications
- Emergency reporting protocol
- Decontamination
- Site characterization
- Training.

All field activities shall be performed in accordance with the SSHASP. A copy of the SSHASP shall be maintained on site by the field coordinator during all field activities. All field personnel involved in these activities shall be cognizant of the SSHASP. All visitors to the work sites shall be required to abide by these procedures.

The objective of the SSHASP is the protection of workers during NV ERP activities. This shall be accomplished through compliance with DOE Orders, Occupational Safety and Health Administration regulations, the DOE/NV NVIYMP *Radiological Control Manual* (1992b), the NV ERP Health and Safety Plan (DOE, 1994), and the SSHASP.

6.0 References

DOE. see U.S. Department of Energy.

EG&G. see EG&G Energy Measurements.

EG&G Energy Measurements. 1985. *An Aerial Radiological Survey of the Feed Materials Production Center and Surrounding Area*. EGG-10282-1084. Fernald. OH.

EPA. see U.S. Environmental Protection Agency.

IT Corporation. 1993. *Operation Specific Quality Assurance Manual Management Plan*. Earth City, MO.

Martin, B.W.. 1989. "Interview with Mr. Harold L. Rarrick. Albuquerque. New Mexico. March 16, 1989." History Associated Incorporated. Rockville. MD. p. 33.

NAS. see National Academy of Science.

National Academy of Science. 1965. *The Radiochemistry of Plutonium*. NAS-NS-3058. Washington, DC.

National Academy of Science. 1962. *The Radiochemistry of Uranium*. NAS-NS-3050. Washington, DC.

Sandia National Laboratories. 1982. *1981 Environmental Summary*. Albuquerque. NM. and Livermore. CA.

Shreve, J.D.. Department of Defense. 1965. *Operation Roller Coaster-Scientific Director's Summary Report*. DASA-1644. Washington DC.

SNL. See Sandia National Laboratories.

U.S. Department of Energy. Nevada Operations Office. 1994. *Nevada Environmental Restoration Project Health and Safety Plan*. Las Vegas, NV.

U.S. Department of Energy. 1992a. *Environmental Measurements Laboratory Procedures Manual*. HASL-300. New York, NY.

U.S. Department of Energy. Yucca Mountain Project Office. 1992b. *NV/YMP Radiological Control Manual*. Las Vegas, NV.

U.S. Environmental Protection Agency. 1992. *Test Methods for Evaluating Solid Waste. Physical Chemical Methods*. SW-846. 3rd edition. Final Update I. Washington, DC.

Double Tracks

Field Sampling Instructions

Prepared By

IT CORPORATION

4330 South Valley View Boulevard, Suite 114

Las Vegas, Nevada 89103

Work Performed Under Contract No.

DE-AC08-92NV10972

April 1995

Double Tracks
Field Sampling Instruction

Approved by:

J. Richard McKinley

Double Tracks Project Manager

Date:

4/7/95

Approved by:

Cheryl Prince

Quality Assurance Officer

Date:

4/7/95

1.0 Introduction

This Field Sampling Instruction document is intended to fulfill the Sampling Plan requirements for the Double Tracks field effort that will be conducted the week of April 10, 1995, as well as describe the activities that will be required by the field team. The overall strategy of this field effort is not to characterize the extent of radiological contamination at the site, but rather to test radiation instrument surveying applicability, determine radiological contaminants physical properties (and how the contaminants are entrained in the soil matrix) and collection of duplicate samples for laboratory analysis. The data and results for the field activities described in this document should not be used in a risk assessment. Results from this field effort will be used to streamline and focus site characterization and possible remediation efforts. Many field activities will be conducted during this field trip, with several that are unrelated to the tasks described in this document. However, the field crews, while having different agendas and goals, will work as a team to insure that all tasks are completed in a timely manner.

2.0 General Scope of Work

The field effort described in this document will concentrate on surface radiological measurements and soil sampling in the upfield area. Additional field activities will be conducted by other contractors in the downfield areas and are not discussed. Field tasks to be completed include "hot spot" mining to determine the feasibility of removing identified hot spots from specific areas and depth profile measurements, to evaluate the depth that plutonium and americium have migrated. Field radiological measuring instruments that will be used during these tasks include the following.

- Suburban mounted sodium-iodine (NaI) detector with a approximately a 13 meter diameter field of view
- FIDLER hand held instrument

- Tripod mounted germanium (Ge) detector collimated to view approximately a one meter area.
- Tripod mounted germanium detector collimated to view approximately a 0.3 meter (one foot) area

To evaluate hot spot mining, field radiological measurements will be conducted in areas that have been previously identified by EG&G in aerial flyovers to have an activity of between 200 to 400 pCi/g. The Suburban mounted detector will be used first to measure several areas of elevated activity. Next, the walk over surveys, using a FIDLER will identify hot spots within the Suburban mounted detector's field of view and mark the hot spots with either flagging or dye. The hot spots will be physically mined (picked-up) and taken out of the detectors field of view. After the material has been removed, the area will be re-measured with the FIDLER to determine if the hot spot activity has been adequately removed. Hot spot removal will continue until approximately 80 to 90 percent of the activity from the identified hot spots has been eliminated. The suburban mounted detector will then be re-employed to measure the activity of the same area.

At other locations depth profile evaluations will be conducted after several areas of high activity have been identified, some distance from the Suburban detector areas. At selected hot spots, a tripod mounted collimated instrument will be used to collect more precise radiological measurements. After the one or 0.3 meter collimated instrument has collected a measurement, a thin layer of soil will be physically removed and additional measurements taken, with the same instrument. The removed material will be taken to an area removed from the instrument area of view. By continually removing material to greater depths, and taking field measurements it can be estimated how deep the contamination has migrated. The depth profile will also be used by EG&G to refine their formulas for determining total activity from surface americium gamma radiation.

During this task, soil will be removed in approximately one centimeter layers. Some of the

removed soil will be retained, placed in sample containers, with chain of custody, and transported to Las Vegas. Details of how samples are to be collected and retained, as well as field documentation are discussed in the following section.

In addition, two relatively new approaches to field measurements will be explored. The insitu measurement of alpha energy using standard radon gas detection systems has been explored at Oak Ridge National Laboratory (ORNL) Health and Science Research Division. A three person (ORNL) team will be included for part of this field effort and will have a preplanned program. There will be time, however, to work with IT to evaluate the comparative efficiency of the just acquired, newly developed, SAIC AP-2 Alpha Analyzer. This instrument will first be evaluated to determine if it can "measure" americium and plutonium using its 128 channel Multi-channel Analyzer (MCA). The first effort will be to put a thin layer of contaminated soil into the bottom of a petri dish such that the MCA can be supported by the rim of the dish and left in place for a period of time. This type of measurement can then be compared to the measurements derived from the same sample by the ORNL system.

The ORNL effort is directed toward development of a relatively inexpensive, and perhaps immediate field result, system. Obviously, if the AP-2 can approximate these results, cost and speed would both be improved. This effort will be research in nature and thus evolutionary.

Other field tasks will include surveying both previous sample locations and selected locations from this field effort. Selected soil samples will be collected at locations of elevated activity and submitted to the laboratory for isotopic analysis. These soil samples will be collected to confirm isotopic ratios of plutonium and americium. Previous laboratory results were inconclusive concerning these isotopic ratios, especially at low activity levels. By collecting a sample that is known to have elevated activity, a more precise determination of these isotopic ratio can be determined.

3.0 Surface Radiation Measurements

Surface radiation measurements will be conducted by Reynolds Electrical & Engineering Co. (REECo) and EG&G, assisted by the IT project team. Procedures and requirement for these measurements are summarized in contractor specific procedures. ITs contribution to the field radiological measurements will consist of assisting in the selection of areas where measurements will be taken, collecting soil samples for possible laboratory analysis and assisting with the field interpretation of the data. IT will also be evaluating several soil removal techniques that will require additional surface radiation measurements to be performed by various instruments. These are discussed in greater detail in the following sections.

4.0 Soil Sampling

Several soil samples will be collected as part of this field effort. The sampling effort is focused primarily on field radiation measurements and method verification and not on site characterization. Because the focus of the sampling is not site characterization, some of the quality control and equipment decontamination criteria will not be as rigorous as is typically required. Variations to these procedures are discussed later in Sections 6 and 7.

The soil sampling effort can be divided into two tasks. The first task consists of an experiment to mine contaminated soils from selected areas. The second task consists of depth profile sampling that is being conducted to determine the depth plutonium and americium have been transported into the subsurface. It is anticipated that approximately 10 to 12 soil samples will be collected as part of this field effort.

4.1 Hot Spot Mining Samples

This phase of the field effort focuses on field instrument identified hot spots sampling. All soil samples retained as part of this effort will be contained in appropriate sample containers and sample collection and chain of custody forms properly filled out. The samples will be transported to Las Vegas where it will be determined during the following week which

samples will be forwarded to the laboratory for analysis and which will be archived. The delay is required to allow the project teams several days to review the field radiological measurements and other field notes and identify the appropriate samples to be submitted to the laboratory. It is anticipated that many of the samples will be archived.

During the soil mining experiment conducted in association with the Suburban and FIDLER instrument surveys, several samples (approximately five to ten) will be collected and retained. Approximately three to five samples will be passed through a Jones Splitter and three to five retained without splitting. A Jones Splitter is a device that will split the soil sample into two approximately equal volumes. After the sample has been split, it will be re-measured with the FIDLER. The activity should be approximately equal in each split sample. If this is not the case, the sample with the highest activity will be retained for possible laboratory analysis. Samples that are not split will not require re-measuring with the FIDLER.

4.2 Depth Profile Samples

Collection of depth profile samples will be associated with the tripod mounted collimated germanium detectors. Several methods of profile sampling will be conducted, with each requiring different sampling procedures. Approximately three to five samples will be collected during this phase of the field effort.

The general strategy of this field task is to collect field radiological measurements, remove or scrape a small layer of soil from the area of concern, and re-measure the radiological activity. This process will continue until approximately 80 to 90 percent of the activity has been removed. For soil sampling purposes, only the first layer of soil removed will be retained as a sample. It is anticipated the majority of the radiological contamination will be in this layer. If field instruments indicate that the radiological contamination is at a much greater depth, this sampling strategy will change and additional depth samples will be required.

The methods used to remove the layers of soil during this task include the following

- Using an adhesive and a small test plate (tile). The soil will be sprayed with an adhesive and allowed to dry. The plate with exposed adhesive will then be placed on the area of concern. The soil that adheres to the plate will be set aside and another field radiological measurement taken. This process may be repeated several times to determine if the radiological contaminants are effectively removed. Field experimentation may determine that it is more feasible to remove the deeper layers with one of the following scraper techniques.
- Another method to remove a small layer of soil will use a stainless steel scraper or trowel to physically scrape the layer of soil into a dust pan type device. After the layer of soil has been removed it will be set aside and another field radiological measurement taken. This process will be repeated several times to determine if the radiological contaminants are effectively removed.
- The final method that will be tested to remove the soil layer will be to use a dust broom, or "foxtail" to sweep the soil from the test area into dust pan type device. After the layer of soil has been removed it will be set aside and another field radiological measurement taken. This process will be repeated several times to determine if the radiological contaminants are effectively removed.

Several other types of scoops, shovels etc. will also be taken to the site and field tested if the first three options fail to obtain required results. This task is a "lets see what works best" type of exercise, so additional field notes should be taken to sufficiently document procedures, unanticipated problems, field instrument measurements and successes. Field notes will be prepared in accordance with SOP ITLV-0401.

5.0 Sample Management

After containerizing soil samples collected as part of this field effort, each must be field screened for worker health and safety requirements in accordance with SQP ITLV-0403. A REECo Radiological Control Technician (RCT) will perform the screening. Once the RCT has issued a Green Tag and Radiological Material Clearance Sticker, the sample can be removed from the site and transported for storage. Smear samples of the sample container exterior may be performed in accordance with the REECo approved procedures. Each shipment of samples will be accompanied by a Request Analysis Request and Chain of Custody (AR/COC) form according to SQP ITLV-0402. Following receipt of the Radiological Material Clearance Sticker, samples for shipment to the off-site laboratory shall be packaged in accordance with the procedures given in SQP ITLV-0403.

Samples submitted for laboratory analysis will be sent to the Quanterra Laboratory in St. Louis, Missouri, to the attention of Allen Field. Each shipment shall be accompanied by a AR/COC form completed according to SQP ITLV-0402.

6.0 Laboratory Analysis

Samples submitted to the laboratory will be analyzed for isotopic plutonium ($^{239/240}\text{Pu}$ and ^{238}Pu) and Americium (^{241}Am) and total uranium. Table 1 summarizes the analytical requirements.

7.0 Quality Control Samples

Because site characterization samples are not being collected as part of this field effort, some of the QA requirements typically followed will not be performed. In addition, only samples that are known to be contaminated will be collected so field blanks and rinsate blanks will not be required. Field duplicates will be collected at not less than 10 percent of the total number of samples collected. Soil is the only media that will be sampled during this field effort.

Special instructions will be given to the laboratory so that as a minimum, three selected

samples will be ball milled and split into two equal volumes at the laboratory prior to analysis of both fractions. A memorandum will be prepared that will instruct the laboratory on what is required. This memorandum will be modified as required based on field observations and experience and attached to the AR/COC. This information will also be verbally communicated to laboratory prior to shipment of the samples.

8.0 Equipment Decontamination

Because site characterization samples are not being collected as part of this field effort some equipment decontamination requirements typically followed during an investigation of this type will not be performed. Only samples that are known to be significantly radiologically contaminated (no organic compounds), will be collected, so solvent rinses will not be required. Disposable sampling equipment will not require decontamination. Reusable sampling equipment decontamination will consist of the following:

- Scrape or brush off residual soil
- Wash with a laboratory grade detergent and potable water
- Potable water rinse
- Final deionized water rinse
- Air dry.

After decontamination, sampling equipment will be stored in a manner to prevent recontamination, such as wrapping in plastic. Only equipment that has the potential of coming in direct contact with the soil sample will require decontamination between uses. For example, equipment used to mine hot spots that are not sampled do not have to be decontaminated between hot spot locations.

Table 1
Summary of Laboratory Analytical Requirements

Isotope/Analyte	CAS Number	Analytical Method	Detection Limit	Sample Container
Pu ^{239/240}	15117-48-3 14119-33-6	NAS-NS-3058	0.04 (pCi/g)	250 ml Glass
Pu ²³⁸	14111-32-5	NAS-NS-3058	0.04 (pCi/g)	250 ml Glass
Am ²⁴¹	14596-10-2	NAS-NS-3006	0.01 (pCi/g)	250 ml Glass
Total Uranium	N/A	ASTM 5174-91	0.05 (µg/g, ppm)	250 ml Glass

Scope of Work for Double Tracks Radiological Surveying

June 5 to 9, 1995

1.0 Introduction

This document is intended to describe the strategy and goals for the Double Tracks field effort that is to be conducted the week of June 5, 1995. The strategy of this field effort is to determine the extent of radiological contamination to a confidence level so corrective actions can be proposed. Based on previous field survey results, the types of radiological survey instruments, detectors, proposed have proven to perform to an acceptable level to accomplish the goal. Results from this field effort will be presented in the Implementation Plan and Corrective Action Plan. The field results will be used to select appropriate remedial technologies which will in turn prescribe remediation budgets and schedule. The data and results from this field investigation are not for the purposes of a baseline risk assessment.

2.0 General Scope of Work

The field efforts will focus on several radiological surveys that will utilize different types of detectors. The detectors that will be used include the following.

- FIDLER detectors, Sodium Iodine (NaI) mounted on an all terrain vehicle (ATV) bumper.
- A Suburban with a boom mounted Germanium (GE) detector.
- NaI detectors (from the EG&G helicopter) mounted on the bumper of a Suburban.
- A scintillation detector mounted on the bumper of a Jeep Cherokee.

All the above instruments are EG&G's, except the scintillation detector mounted on a Jeep Cherokee, which is an IT instrument.

Other field tasks to be conducted, in conjunction with the radiological surveys, include "hot spot" mining near ground zero (GZ), in the mound area, and land surveying. In addition, background will be surveyed with detectors used during this field effort. Because of the anticipated vehicle traffic inside the exclusion zone, one of the first tasks to be undertaken will be to pick up debris from inside the exclusion zone. This debris includes the many sample location stakes and markers, as well as the inner fence. All warning and safety markers will not be disturbed. The debris will be staged in a remote area of the exclusion zone until disposal requirements are determined. Unexploded ordinances (UXO) will be picked-up by DOD personnel, if possible. Otherwise, the UXO debris will be avoided.

2.1 Radiological Surveys

FIDLER detectors, mounted on an all terrain vehicle (ATV)

To quickly locate hot spots in the exclusion zone, three FIDLER detectors have been mounted on an ATV. This ATV will be driven systematically across the site on approximately two meters (seven-feet) center traverses. When a hot spot is detected, a marker will be placed in its general vicinity. Once the dust has settled in the vicinity of the marker, the area will be surveyed with hand held FIDLER detectors to locate and identify the hot spot material. If the hot spot represents a piece or chunk, the material will be taken to a central location, inside the exclusion zone until disposal requirements are determined. Based on the historical records and previous field efforts, many of the hot spots located within two to three hundred feet of GZ represented large pieces of unknown material. The unknown material may represent device encasement material, part of the steel plate or remnants of plutonium (Pu) and/or depleted uranium (DU).

To better understand and estimate the activity present in the collected pieces or chunks of material, several pieces will be weighted and counted in the field. The selected pieces will be weighted using a field balance, with the accuracy of approximately 0.01 grams, and counted with a NaI collimated detector. After taking these measurements, the piece will be labeled and containerized with the other pieces. These results will be used to estimate total activity so disposal options and requirements can be evaluated.

Suburban boom mounted Ge Detector

The Ge detector mounted on the Suburban has been proven to be an accurate detector of radiological contamination at the Double Tracks site and will supply the most reliable measurements. The detector when fully extended on the boom will see approximately a 13-meter diameter area. The only drawback of this detector is that it is slightly time consuming. It is anticipated that 25 to 30 measurements can be completed in the one week field effort. This represents approximately 5 percent of the entire exclusion zone's area, including GZ.

Previous ground survey results have ascertained that some of the anomalies in the helicopter flyover survey represent hot spots. By removing the hot spots before surveying the exclusion zone with the Suburban Ge detector, many of these anomalous areas should no longer exist. The Suburban data will be compared and contrasted with the older helicopter flyover survey results. Note that the Suburban survey will be on a much finer grid with the detector much closer to the ground.

Other Detector Surveys

Data from the scintillation detector mounted on a Jeep Cherokee (IT) and NaI detectors mounted on the Suburban (EG&G) will be used in conjunction with the Suburban Ge detector results to determine the nature and extent of contamination. During the initial scoping of this field effort, the intent was to have the NaI detectors, used in helicopter flyover surveys, mounted on a suburban bumper. The suburban would then systematically survey the exclusion zone at a much finer scale, and with the detectors much closer to the ground. Results from this survey will be compared with the Suburban Ge detector, previous helicopter survey results and FIDLER results. Combining these four survey results will accurately determine the extent of contamination.

The scintillation detector mounted on the Jeep Cherokee was decided upon as a cross check of the other radiological survey results. This scintillation detector was not in the original scope of work; however, it became available and was decided to be utilized as a cross-check. This scintillation was being used in southern California and will be mobilized to the Double Tracks site

at only minor costs. This detector system has a positioning system different from the other detectors so the locations of the hot spots and anomalous areas can be independently located. It is anticipated that the scintillation detector survey will only require two days to complete.

2.2 Ground Zero (Mound) Characterization

To characterize the extent of contamination in the vicinity of GZ, the ATV, with FIDLERS, will identify areas that are grossly contaminated from areas that are lightly contaminated. Historical records indicate that the contaminated soil in the immediate area around GZ was scraped into a mound at approximately GZ shortly after detonation. Other activities in the vicinity of GZ may also have reworked some of the material. These activities resulted in there being several relatively clean areas mixed in with more contaminated areas. The scintillation and FIDLER detectors will be used to determine the relative horizontal extent of radiological contamination in this localized area.

In the mound area, the vertical extent of contamination is not accurately known. To determine the vertical extent of contamination, several boreholes (five to ten) will be advanced.

Characteristic soil samples will be collected and field screened. The intent of this sampling is to determine the relative depth of contamination, not its magnitude. The rationale for only field screening the soil is that these samples will only be used to estimate the volume of contaminated material present, and generally characterize its physical property (e.g., mostly sand, silt, clay etc., or many large pieces, (i.e., chunks of concrete)).

The boreholes will be first attempted with hand bucket augers, and if this does not adequately penetrate the material, a power auger will be utilized. Also during the soil boring activities, the field crew will attempt to determine if the concrete pad, historically known to be located at GZ is still present or has been removed from the site. If the concrete pad is present, an attempt will be made to determine if it has been broken-up or is still in one piece. If the concrete pad is encountered, no attempt will be made to auger or core through the concrete to determine if contaminated soil is beneath it. In addition, it is known that oil was spread on the ground in the

vicinity of GZ, for dust suppression. An attempt will also be made to locate this horizon as marking the bottom of the contaminated zone. After completed, all the boreholes will be backfilled with the removed material.

In areas away from the mound, previous investigations have determined, with good certainty, that the contamination present is limited to the upper few centimeters (inches) of soil.

Double Tracks

Field Sampling Instructions

Prepared By

IT CORPORATION

4330 South Valley View Boulevard, Suite 114

Las Vegas, Nevada 89103

Work Performed Under Contract No.

DE-AC08-92NV10972

July 1995

Double Tracks
Field Sampling Instruction

Approved by:

J. Richard McKinley

Double Tracks Project Manager

Date:

7/24/95

Approved by:

Cheryl Prince

Quality Assurance Officer

Date:

7/24/95

1.0 Introduction

This Field Sampling Instruction document is intended to fulfill the Sampling Plan requirements for the Double Tracks field effort that will be conducted on July 25, 1995 as well as describe the activities that will be required by the field team. The overall strategy of this field effort is to go inside the exclusion zone at the Double Tracks site and collect contaminated soil at previously identified locations. The soil will then be sent to the IT Treatability Laboratory in Knoxville, Tennessee. Only one task will be conducted during this field effort and it is anticipated that the field crew can complete the required activities in one day. This sampling effort has been expedited because of limited access to the site.

A separate Health and Safety Plan associated with these field activities has been approved.

2.0 General Scope of Work

To more accurately determine the feasibility of conducting volume reduction, through particle separation, bench scale tests are scheduled to be conducted. These laboratory tests will require that contaminated soil from the Double Tracks site be collected. The intent of this sampling instruction is to describe the procedures that will be followed during the one-day field effort. The data and results from the field activities described in this document will be included in the site characterization report.

3.0 Soil Sampling

The general strategy of the soil sampling effort will be collect characteristic soil from areas known to be contaminated with radiological constituents. It is anticipated that 20 1-liter samples of soil will be collected from 10 sites, two samples per site, in order to adequately test the soil. The samples will be collected starting approximately 200 feet south of the Ground Zero mound, and then at 100 foot intervals at centers of the contaminant plume (See Attached Figure). Samples will be collected from south to north, least contaminated to most contaminated. Sample sites will be located using a surveying measuring wheel and measuring the distances from ground zero and the perimeter fence.

After the sampling site has been located, approximately four liters of soil will be excavated to a depth of approximately seven centimeters (three inches). Two liters of soil will then be collected and passed through a Jones Splitter. A Jones Splitter is a device that will split the soil sample into two approximately equal volumes. After this sample has been split, one half will be discarded and the other half placed in a clean 5-gallon plastic bucket. Another two liters will then be collected and also passed through the splitter. One split of this sample will be discarded and the other split combined with the soil in the 5-gallon bucket. The soil in the 5-gallon bucket will then be passed through the splitter a final time and each split placed in labeled sample bottles (See Attached Diagram). The sample bottles will be 1-liter, wide mouth plastic.

All samples will be accompanied by a properly completed chain of custody (COC). The intent of this sample splitting is to have one sample sent to the Knoxville Treatability Laboratory and the other given to the Desert Research Institute (DRI) from each sample location. To expedite the chain of custody procedures, as the samples are being collected, a separate COC will be filled out for the IT samples and another one for the DRI samples. This will avoid preparing another COC when the samples are released to the respective laboratory. The Sampling Collection Logs and Field Activity Daily Logs will cross-reference the respective samples with the COCs.

During sampling activities, the soil will be periodically field screened for radiological constituents, hot particles. If hot particles are detected in any split sample, the sampling crew will place the soil back in the excavation, move several feet from the initial sampling location and collect another sample. The intent is not to include hot particles in the sample volume.

4.0 Sample Management

After the soil sample has been collected, the exterior of the sample containers will be screened by the onsite Radiological Control Technician (RCT). Once the RCT has determined that there is no external contamination, they will be packaged into a cooler for transport back to Las

Vegas. The exterior of the cooler will also be screened before leaving the site. Each cooler will have an accompanying Chain of Custody (COC) form according to SQP ITLV-0402. In Las Vegas a sample from each location will be given to DRI for testing and the other sample repackaged in accordance with the procedures specified in SQP ITLV-0403 and shipped from the IT Las Vegas office to the Knoxville laboratory. Because only soil is being collected for treatability studies, the sample cooler will not require absorbent material or ice. All sample containers will be double bagged to insure no soil is accidentally released during transportation.

5.0 Quality Control Samples

Because site characterization samples are not being collected as part of this field effort, typical Quality Control/Quality Assurance (QA/QC) are not required. Soil is being collected for treatability studies so field QA/QC samples are not required.

6.0 Equipment Decontamination

Because site characterization samples are not being collected as part of this field effort, many equipment decontamination requirements typically followed during an investigation will not be performed. Only samples that are known to be radiologically contaminated (no organic compounds) will be collected, so solvent rinses will not be required. Disposable sampling equipment will not require decontamination. Reusable sampling equipment decontamination will consist scraping or brushing off residual soil and field screening the equipment for contamination. If contamination is not present, the equipment can be reused at the next sampling location. If gross contamination remains on the equipment the following procedure will be followed.

- Wash with a laboratory grade detergent and potable water
- Rinse with water

After decontamination, sampling equipment will be stored in a manner to prevent

recontamination, such as wrapping in plastic. Only equipment that has the potential of coming in direct contact with the soil sample will require decontamination between uses.

7.0 Laboratory Requirements

Treatability testing instructions and requirements will be given to the laboratory via a memorandum that will accompany the samples. This memorandum may be modified as required based on field observations or as directed by the laboratory as the treatability tests proceed. All changes to the treatability testing requirements will be properly documented in the project files.

Figure 1
Soils Media-Double Tracks
Proposed Sampling Locations
July 25, 1995

00 2000.00 2500.00 3000.00 3500.00
T INTERVALS

1250.00

750.00

250.00

Perimeter Fence ↘

-250.00

-750.00

Legend

- Proposed Sampling Locations
- x Approximate Location of Ground Zero

Z ARRAYS - ZGRID

A	50.00		-----	-----	-----
B	100.00	LT BLUE	-----	-----	-----
C	200.00		-----	-----	-----
D	400.00		-----	-----	-----
E	800.00	YELLOW	-----	-----	-----
F	1600.00		-----	-----	-----
G	3200.00		-----	-----	-----
H	6400.00		-----	-----	-----

.00

500.00

1000.00

1500.00

Appendix B

EG&G Remote-Sensing Mission Plans

REMOTE SENSING MISSION PLAN

IN SITU RADIATION SURVEY OF DOUBLE TRACKS TEST SITE

Nellis AF Bombing and Gunnery Range, Nevada

MISSION PLAN APPROVAL

FUNCTION

SIGNATURE

DATE

Mission Manager

Steven Riedhauser
Steven Riedhauser

8 March 95

Work Package Manager

Harvey W. Clark Jr.
Harvey Clark

8 March 95

Safety Officer

Victor Brandt
Victor Brandt

8 March 95

Director, Remote Sensing

Gene Sasso
for Gene Sasso

3/10/95

Purpose/Reason for this Mission

The Double Tracks Test Site was previously surveyed from an aerial platform in February 1977 and December 1993. The Department of Energy requested that IT Corporation conduct a series of tests to map the area which must be cleaned up prior to release of the site back to the Air Force. IT has asked REECO and us to help in a preliminary characterization by performing a series of experiments using our high-purity germanium (HPGe) detectors in concert with REECO's FIDLER system and IT's soil sampling. The survey is scheduled during the week of April 3-7, 1995 using the Suburban and two tripod HPGe detector systems of the Radiation Science Section.

Mission Objectives

The objectives of this mission are to gather *in situ* radiological data at a series of locations within the Double Tracks exclusion zone to compare with data collected by systems fielded by IT and REECO. A series of four experiments are planned as described briefly below and in more detail in the letter: "Data Collection Plans for Double Tracks" (RSS-95-033).

- (1) The first experiment is a mini-survey over a small region of the fenced-area at Double Tracks. This area will be approximately 90 meters by 90 meters in size and 200-300 meters south of GZ. The mini-survey will involve all of the different organizations and detection systems at one time or another and will probably last the entire week.

The collimated Suburban system will make measurements on a 15-meter grid to guarantee 100% coverage of the ground. For 1% statistical error, we need a counting time of 350 seconds. We should easily satisfy the statistical requirements using a 500-second (8.3-minute) live time counting period. The 90- by 90-meter grid, sampled every 15 meters (for a total of 49 measurements) with 20 minutes per measure-and-move cycle, will require 16.3 hours (about 2 days) to complete.

The collimated tripod HPGe detectors have a field-of-view of about 2 meters radius and will therefore need to make measurements every 2.5 meters over an area of roughly 15 meters by 15 meters. For 1% statistical error, we need a counting time of 210 seconds. We should easily satisfy the statistical requirements using a 300-second (5-minute) live time counting period. The 15- by 15-meter grid, sampled every 2.5 meters (for a total of 49 measurements) with 15 minutes per sample-and-move cycle, will require 12.25 hours to complete. This is a little more than one day of work for one tripod system to survey one Suburban footprint. The second tripod system should be used to survey another Suburban footprint.

Once these two systems have made their measurements on the grid, the FIDLER-based USRADS system will move through the grid, making their own measurements. Also, a set of electret ionization chambers will be arranged by personnel from ORNL. These

detectors are placed on the ground in a pattern of 9 locations to cover a single Suburban footprint. Three detectors would be fielded at each location for a total of 27 detectors. Finally, personnel from IT (and REEC?) will collect soil samples for analysis of the Pu/Am ratio and soil activity. It is expected that this procedure will greatly disturb the surrounding soil and therefore the digging would best be performed after all of the other measurements are completed.

- (2) This experiment will use a collimated tripod system placed as near to GZ as the crew deems reasonable. The purpose is to gather data with sufficient statistics to determine an accurate Pu/Am ratio. A 1-2 hour measurement does not seem unreasonable. Two independent measurements seem advisable (either the same tripod at two different locations, or both tripods in roughly the same location). To minimize exposure, the personnel will vacate the hot area after setting up the tripod system and not return until the measurement is completed.
- (3) This experiment will use a highly-collimated tripod-mounted HPGe detector to measure repeatedly an approximately 1-foot diameter patch of ground. After each measurement, a layer of soil will be removed from the field-of-view of the detector and another measurement made. The purpose of this experiment is to provide an alternative method of measuring the americium distribution versus depth in the soil. The thickness of the soil layers will depend on the type of material, but will probably vary between 1-2 cm.

Assuming counting periods of 600 seconds (10 minutes), another 10 minutes to dig the next layer of ground out of the detector's field-of-view, and taking data at a total of twelve layers requires 4 hours. Repeating this experiment at a second location brings the total time up to about 8 hours.

- (4) This experiment will use the Suburban to measure the count rate in two undisturbed locations inside the fence, one "lower" activity and one "higher" activity area. The purpose behind these measurements is to provide some data on the area's radiation uniformity. The measurements will be made at different heights above the ground (different size fields-of-view) centered above the same spot on the ground. This will duplicate to some extent the data from the first experiment, but will be looking at the different size areas using the same detector rather than different detectors.

Acquisition & Logistics Plan

The survey crew consists of five people with two alternates available for last-minute substitution. The crew will travel to the survey site on the morning of Monday, 3 April, set up the hot line and monitoring facilities in the afternoon, collect data for the various experiments all day Tuesday through Friday morning, and then pack up and travel back to Las Vegas Friday afternoon.

A general description of the day-to-day activities is presented in the table below. The table shows all of the activity by EG&G personnel. Activities by other organizations are not shown in this schedule.

Participant	Activity
13-29 March	Time window for Suburban and tripod detector calibration tests
30-31 March	Pack equipment into van
Monday, 3 April	Travel to Double Tracks in morning; Get Range access and set up operations in afternoon; Check operation of detectors
Tuesday, 4 April	
EG&G Suburban	Lay out grid if necessary; Begin measurements experiment #1
EG&G Tripod #1	Lay out grid if necessary; Begin measurements experiment #1
EG&G Tripod #2	Lay out grid if necessary; Begin measurements experiment #1
Wednesday, 5 April	
EG&G Suburban	Complete measurements experiment #1
EG&G Tripod #1	Complete measurements experiment #1
EG&G Tripod #2	Complete measurements experiment #1
Thursday, 6 April	
EG&G Suburban	Perform experiment #4
EG&G Tripod #1	Perform experiment #3
EG&G Tripod #2	Perform experiment #2
Friday, 7 April	
EG&G Suburban	In morning, finish any work from previous days
EG&G Tripod #1	In morning, finish any work from previous days
EG&G Tripod #2	In morning, finish any work from previous days
All	Return to Las Vegas in afternoon

Site Characteristics

The survey is not planned to cover the whole Double Tracks area. Instead, the intent is to perform a series of tests of our equipment versus REEC's and IT's equipment and techniques

to correlate the different data sets. The Double Tracks site is situated on an arid plain on the Nellis Air Force Bombing and Gunnery Range (NAFR). Access is through the Tonopah Test Range (TTR) and the crew will be staying in the dormitories on base.

The contacts identified so far are listed in the following table.

Contacts

Name	Organization	Telephone #
Craig Lyons	REECo Health Physics Dept.	(702)295-0781
Laura Tryboski	IT Corp.	(702)794-1712
J. R. McKinley	IT Corp.	(702)794-1703
Monica Sanchez	DOE/ER	(702)295-0160

Risk Documents

The ground-based operations associated with this survey have been addressed in several documents. The overall Health and Safety Plan (HASP) for work by the different organizations at Double Tracks is currently being created by REECo and IT Corporation. In addition, REECo and IT will prepare a Radiological Work Permit (RWP) for the work to be performed at Double Tracks. An assessment of the risks involved with the HPGe detector *in situ* measurements routinely conducted by EG&G is presented in the "Risk Assessment for Radiation Science Section" document (August 31, 1994).

All EG&G participants in the survey have attended the 40-hour OSHA 1910.120 training for Hazardous Waste Sites and have been fitted for respirators. The use of respirators is only expected if the survey area is very dry and the activity in the area raises appreciable amounts of dust into the air. All participants have attended the Radiological Worker II class. (One alternate technician only has Rad. Worker I, but the Health Physicist in charge has said there should be no problem if he needs to replace one of the scheduled technicians since the tech will be in a group under the direct supervision of other Rad. Worker II personnel.) Explosive Ordinance (EOD) Training will be conducted by Nellis AF personnel and will be held sometime during the last two weeks of March.

Cost Estimate

The table below summarizes the costs for this survey. The preparation costs only include those charges since 12 February. (The excluded costs are principally the costs of five people attending the OSHA 1910.120 training.)

Item	Preparation Costs	Field Costs	Analysis and Report Costs	Totals
Labor	\$20K	\$20K	\$11K	\$51K
Travel	\$0K	\$2K	\$0K	\$2K
Aircraft	\$0K	\$0K	\$0K	\$0K
M & S	\$0K	\$1K	\$0K	\$1K
Totals	\$20K	\$23K	\$11K	\$54K

The cost of each "down day" in the field (days when no useful survey work can be done due to inclement weather or other problems) is: \$4K

The job number for the survey is: S3F4A100

Deliverables/Reports and Deadlines

The Double Tracks *in situ* gamma measurements will collect data on the americium concentration at the site. EG&G will write a brief report outlining its procedures and presenting plots of its data in the gridded areas. Tables of the data from the other experiments conducted by EG&G will also be included. The presentation of the data from the various organizations will need to be done by project organizers, either IT Corp. or DOE.

The present schedule and plan specifies that preliminary results will be given to the project organizers when we leave Double Tracks at the end of the survey. A more-polished letter report (after completing our in-house scientific review and passing through our Reports Section) will be ready for customer review five months later. The final version of the report will be ready one to two months after the customer review is complete.

Attachment 1

Operations Safety Guidelines

1. The Mission Manager shall ensure that the mission is safely conducted and ensures that crew members are familiar with the procedures outlined in Manual 32: "Safety", pertinent to mission operations.
2. The Mission Manager shall appoint a Safety Coordinator from the survey crew if an RSL safety staff member is not available.

NOTE: Appointment of a Safety Coordinator from the RSL safety staff is an Operations Manager's decision.

3. The Mission Manager and Safety Coordinator will review the mission plan, pertinent policies and procedures, and establish general safety coordination for mission conduct in the following categories:
 - a. In-house preparation (in conjunction with the RSL safety officer).
 - (1) System characterization.
 - (2) Packing and loading.
 - (3) Deployment.
 - b. Field Operations in addition to the above items:
 - (1) Site-specific safety requirements and FBO requirements.
 - (2) Non-operational safety precautions.
4. The Safety Coordinator shall monitor safety practices from the inception of mission operations through mission completion and system restoration to operational status.

NOTE: The pilot(s) will be primarily responsible for implementing guidelines related to aircraft and flight safety; however, the safety coordinator shall monitor aircraft operations and assist with handling safety concerns whenever practical.

5. The Safety Coordinator shall conduct general safety briefings in conjunction with general briefings by the Mission Manager or other briefings where safety concerns are deemed necessary.

6. The pilots shall advise the Mission Manager and the Safety Coordinator on mission safety concerns relative to aircraft and flight operations.
7. During the mission, the mission safety coordinator shall:
 - a. Monitor mission tasks for safety hazards and unsafe acts.
 - b. Act as focal point for reporting and resolving safety problems.
 - c. Provide a daily safety status report to the Mission Manager for inclusion into the daily mission status report.
8. The pilot shall monitor all aspects of air crew, aircraft and associated support equipment safety.
 - a. Flight safety briefings will be conducted prior to any mission flights and as outlined in the appropriate flight safety regulation during flights.
 - b. The pilot and mechanic shall collectively monitor aircraft maintenance safety.
 - c. The command pilot for the mission shall submit a general flight safety report to the Mission Manager and Safety Coordinator to be included in the Mission Manager's general daily status report.
 - d. The pilot will continuously monitor the area weather conditions for foul weather indications so that the Mission Manager can adjust flight schedules accordingly.
9. Crew members shall:
 - a. Perform tasks safely with particular attention given to but not limited to: driving, lifting, hauling, carrying, climbing, and installing equipment. In particular, care will be exercised when performing any of these tasks in an unfamiliar environment.
 - b. Wear appropriate safety gear as required by the task or circumstance.
 - c. Monitor the work area(s) for any safety act or hazard that may affect co-workers.
 - d. Report any unsafe conditions or acts to the Safety Coordinator or Mission Manager.

Attachment 2

Survey Parameters

Mission Name: Double Tracks *In Situ* Survey

Location: Nellis Air Force Bombing and Gunnery Range, Nevada

Base of Operation: Nellis Air Force Bombing and Gunnery Range

Survey type: *In Situ* Gamma Radiation

Aircraft: none

Nominal elevation: 1450 to 1520 m (4800 to 5000 ft) MSL

Survey Dimensions: not applicable
Length (approx.):
Width (approx.):

Survey Altitude: not applicable

Line Spacing: not applicable

Line Direction: not applicable

Aircraft Speed: not applicable

Number of lines: not applicable

Total line length: not applicable

Flight time: not applicable

Total survey days: 5

Navigation System: not applicable

Detector Arrays: Suburban vehicle equipped with collimated HPGe detector on extendable mast
Two tripod systems with collimated HPGe detectors at 1-meter above ground level

REMOTE SENSING MISSION PLAN
SECOND *IN SITU* RADIATION SURVEY OF
DOUBLE TRACKS TEST SITE
Nellis AF Bombing and Gunnery Range, Nevada

MISSION PLAN APPROVAL

FUNCTION

SIGNATURE

DATE

Mission Manager

Steven Riedhauser
Steven Riedhauser

12 May 95

Work Package Manager

Harvey Clark (for HWD)
Harvey Clark

5-12-95

Safety Officer

Victor Brandt
Victor Brandt

5/12/95

Director, Remote Sensing

Gene Sasso
Gene Sasso

5/12/95

Purpose/Reason for this Mission

In early April, a team from EG&G made a trip to Double Tracks to conduct field tests of several characterization techniques. This survey is a continuation (and expansion of data collection) of that previous survey. It will constitute a preliminary characterization of the site according to the overall site decommissioning plan.

The survey is scheduled for June 5-9, 1995 using a ground vehicle equipped with several NaI pods and a REDAR IV system (a new platform being developed by Thane Hendricks), an all-terrain vehicle (ATV) with three FIDLER detectors (a new platform being developed by John Tipton), the Radiation Science Section's Suburban vehicle with an HPGe detector mounted on the end of a telescoping mast, and a tripod-mounted HPGe detector system.

Mission Objectives

The objectives of this mission are to gather *in situ* radiological data at a series of locations within the Double Tracks exclusion zone. A series of three major processes are planned as described briefly below.

- (1) This process uses the ATV with three FIDLER detectors. Each detector will be collimated to view a circular spot on the ground about 24" in diameter. With a little overlap between the fields-of-view, this will yield an approximately 5-foot wide path as the ATV travels. The ATV will travel back and forth within the fenced area and locate areas likely to contain chunks of radioactive material such as those we saw on the last trip. This particular activity will probably not last more than a day or two. After the areas are identified, personnel with handheld FIDLERs will locate the hot particles and collect them into containers. This "mining" activity will probably occupy IT and/or REECO personnel most of the rest of the week.
- (2) This process will use a specially-modified Suburban vehicle with three pods of NaI detectors mounted from the rear bumper. The signals from the detectors and from a John Chance differential GPS antenna are fed into a REDAR IV system. This system will operate in exactly the same way as our aerial systems; however, it will have increased spatial resolution and increased sensitivity. The array of six 2- x 4- x 16-inch NaI detectors at 2.5-foot altitude produces a footprint of about 3 meters (10 feet) versus a footprint of about 100 meters (300 feet) for the aerial system of eight 2- x 4- x 16-inch NaI detectors at 150-foot altitude. Calculations of the actual minimum detectable activity will be performed later. The John Chance differential GPS system will produce a positional uncertainty of only about 1 meter versus 3-5 meters for the differential system used on the aerial platforms and 100 meters for the autonomous GPS system.

The vehicle will first survey the wash areas south of the Double Tracks fenced area. The line spacing will be about 10 feet and the speed around 6 mph (9 feet/second).

The line length here is about 1 mile, so it will take about 10 minutes per line. The width of this area which must be surveyed will probably be determined by what is found during the first couple passes through the center of the plume seen in the aerial data. If we were to try to cover a 1000-foot wide, 1-mile long area with 10-foot spacing at 6 mph, we would need about 16 hours (at least two days). For this reason, if the pass through the hottest region doesn't discover anything unusual, the width of the survey will be greatly reduced.

The vehicle will then conduct its operations within the fenced area the remainder of the week. The survey inside the fence will begin in the bottom half of the area and gradually work its way north. Some of the area will include regions searched by the ATV and mined of the hot chunks. This will provide further confirmation on the efficacy of the mining technique (as demonstrated in one location during the first trip) and may verify that large regions of the fenced area are below the radiation limits being proposed for the cleanup operation.

- (3) This process will use the Suburban vehicle with the mast and collimated HPGe detector. The vehicle will make measurements at various locations in and around the Double Tracks area. On the first work day, the vehicle will make a series of measurements outside the fenced area. These measurements will serve as a measurement of the "background" radiation field for reference after the site cleanup operations. On the remaining days, the Suburban will make measurements at selected locations within the fenced area.

Acquisition & Logistics Plan

The survey crew consists of four people from EG&G with several workers borrowed from IT Corp. and/or REEC Co. (There are a very limited number of people with the required OSHA training available during this time period.) The crew will travel to the survey site on the morning of Monday, 5 June, get rooms and check out the equipment in the afternoon. The REEC Co people will set up the hot line and monitoring facilities Monday afternoon so that the site is ready for work to begin Tuesday morning. The crew will collect data all day Tuesday through Friday morning, and then pack up and travel back to Las Vegas Friday afternoon.

A general description of the day-to-day activities is presented in the table below. The table shows all of the activity by EG&G personnel. Activities by other organizations are not shown in this schedule.

Date/Participant	Activity
15-31 May	Time window for Suburban and ATV detector calibration tests
1-2 June	Pack equipment into van; Last minute instructions on new equipment
Monday, 5 June	Travel to Double Tracks in morning; Get rooms and check operation of detectors in afternoon; REECo establishes hotline at site
Tuesday, 6 June	
NaI Suburban	Conduct measurements south of fenced area
HPGe Suburban	Conduct spot measurements in "Bkgnd" areas outside fence
ATV	Conduct search for hot particles inside fence
Wednesday, 7 June	
NaI Suburban	Conduct measurements inside fenced area
HPGe Suburban	Conduct spot measurements inside Double Tracks fenced area
ATV	Additional search for hot particles (?)
Thursday, 8 June	
NaI Suburban	Conduct measurements inside fenced area
HPGe Suburban	Conduct spot measurements inside Double Tracks fenced area
ATV	Probably no activity
Friday, 9 June	
All	In morning, finish any work from previous days
All	Return to Las Vegas in afternoon

Site Characteristics

The survey is not planned to cover the whole Double Tracks area. Instead, the intent is to perform a preliminary characterization of the area, concentrating the measurements in areas of higher activity. The Double Tracks site is situated on an arid plain on the Nellis Air Force Bombing and Gunnery Range (NAFR). Access is through the Tonopah Test Range (TTR) and the crew will be staying in the dormitories on base.

The contacts identified so far are listed in the following table.

Contacts

Name	Organization	Telephone #
Craig Lyons	REECo Health Physics Dept.	(702)295-0781
Wayne Bliss	REECo	(702)295-0540
J. R. McKinley	IT Corp.	(702)794-1703
Monica Sanchez	DOE/ER	(702)295-0160

Risk Documents

The ground-based operations associated with this survey have been addressed in several documents. The overall Health and Safety Plan (HASP) for work by the different organizations at Double Tracks is currently being created by REECo and IT Corporation. In addition, REECo and IT will prepare a Radiological Work Permit (RWP) for the work to be performed at Double Tracks. An assessment of the risks involved with the HPGe detector *in situ* measurements routinely conducted by EG&G is presented in the "Risk Assessment for Radiation Science Section" document (August 31, 1994).

All EG&G participants in the survey have attended the 40-hour OSHA 1910.120 training for Hazardous Waste Sites and have been fitted for respirators. The use of respirators is only expected if the survey area is very dry and the activity in the area raises appreciable amounts of dust into the air. All participants have attended the Radiological Worker II class. Explosive Ordinance (EOD) Training was conducted by Nellis AF personnel before the first trip to TTR and will be repeated for the new crew members on 18 May.

Cost Estimate

The table below summarizes the costs for this survey under the "Double Tracks" job number of S3FEA100. The preparation costs shown are only those needed to coordinate the survey for the field. The preparation work to get the NaI Suburban and the ATV systems ready for field use are being conducted under the job numbers assigned to the development of those systems. There are no "Analysis and Report Costs" listed with this mission since a combined report of the April and June trips will be made and these costs have already been assembled under the cost estimate for that first trip.

Item	Preparation Costs	Field Costs	Analysis and Report Costs	Totals
Labor	\$10K	\$16K	\$0K	\$26K
Travel	\$0K	\$2K	\$0K	\$2K
Aircraft	\$0K	\$0K	\$0K	\$0K
M & S	\$0K	\$1K	\$0K	\$1K
Totals	\$10K	\$19K	\$0K	\$29K

The cost of each "down day" in the field (days when no useful survey work can be done due to inclement weather or other problems) is: \$4K

Deliverables/Reports and Deadlines

The Double Tracks *in situ* gamma measurements will collect data on the americium concentration at the site. EG&G will write a single report summarizing the results of the April and June trips.

The present schedule and plan specifies that preliminary results will be given to the project organizers when we leave Double Tracks at the end of the survey. A more-polished letter report (after completing our in-house scientific review and passing through our Reports Section) will be ready for customer review five months later. The final version of the report will be ready one to two months after the customer review is complete.

Attachment 1

Operations Safety Guidelines

1. The Mission Manager shall ensure that the mission is safely conducted and ensures that crew members are familiar with the procedures outlined in Manual 32: "Safety", pertinent to mission operations.
2. The Mission Manager shall appoint a Safety Coordinator from the survey crew if an RSL safety staff member is not available.

NOTE: Appointment of a Safety Coordinator from the RSL safety staff is an Operations Manager's decision.

3. The Mission Manager and Safety Coordinator will review the mission plan, pertinent policies and procedures, and establish general safety coordination for mission conduct in the following categories:
 - a. In-house preparation (in conjunction with the RSL safety officer).
 - (1) System characterization.
 - (2) Packing and loading.
 - (3) Deployment.
 - b. Field Operations in addition to the above items:
 - (1) Site-specific safety requirements and FBO requirements.
 - (2) Non-operational safety precautions.
4. The Safety Coordinator shall monitor safety practices from the inception of mission operations through mission completion and system restoration to operational status.

NOTE: The pilot(s) will be primarily responsible for implementing guidelines related to aircraft and flight safety; however, the safety coordinator shall monitor aircraft operations and assist with handling safety concerns whenever practical.

5. The Safety Coordinator shall conduct general safety briefings in conjunction with general briefings by the Mission Manager or other briefings where safety concerns are deemed necessary.
6. The pilots shall advise the Mission Manager and the Safety Coordinator on mission safety concerns relative to aircraft and flight operations.

7. During the mission, the mission safety coordinator shall:
 - a. Monitor mission tasks for safety hazards and unsafe acts.
 - b. Act as focal point for reporting and resolving safety problems.
 - c. Provide a daily safety status report to the Mission Manager for inclusion into the daily mission status report.
8. The pilot shall monitor all aspects of air crew, aircraft and associated support equipment safety.
 - a. Flight safety briefings will be conducted prior to any mission flights and as outlined in the appropriate flight safety regulation during flights.
 - b. The pilot and mechanic shall collectively monitor aircraft maintenance safety.
 - c. The command pilot for the mission shall submit a general flight safety report to the Mission Manager and Safety Coordinator to be included in the Mission Manager's general daily status report.
 - d. The pilot will continuously monitor the area weather conditions for foul weather indications so that the Mission Manager can adjust flight schedules accordingly.
9. Crew members shall:
 - a. Perform tasks safely with particular attention given to but not limited to: driving, lifting, hauling, carrying, climbing, and installing equipment. In particular, care will be exercised when performing any of these tasks in an unfamiliar environment.
 - b. Wear appropriate safety gear as required by the task or circumstance.
 - c. Monitor the work area(s) for any safety act or hazard that may affect co-workers.
 - d. Report any unsafe conditions or acts to the Safety Coordinator or Mission Manager.

Attachment 2

Survey Parameters

Mission Name: Double Tracks *In Situ* Survey

Location: Nellis Air Force Bombing and Gunnery Range, Nevada

Base of Operation: Tonopah Test Range Base

Survey type: Gamma Radiation

Aircraft: none

Nominal elevation: 1450 to 1520 m (4800 to 5000 ft) MSL

Survey Dimensions: (1) < 1000- x 5000-feet and (2) 700- x 1500-feet

Survey Altitude: 2.5 feet

Line Spacing: 10 feet

Line Direction: (1) nearly N-S and (2) E-W

Vehicle Speed: 6 mph

Number of lines: < 250

Total line length: < 120 miles

Total time: < 25 hours

Total survey days: 5

Navigation System: John Chance differential GPS

Detector Arrays: Suburban vehicle equipped with NaI pods and REDAR IV
also:
ATV equipped with three FIDLER detectors
Tripod-mounted HPGe detector
Suburban vehicle equipped with collimated HPGe detector on extendable mast

Appendix C

Soil Sample Analytical Data

Table C-1
Summary of Laboratory Analyses for Characterization Event 1
Soil Samples at the Double Tracks Test Site
(Page 1 of 2)

Sample Number	Sample Location	Interval Depth (inches)	Analytical Parameter ^a					
			Isotopic Plutonium	Am-241	Isotopic Uranium	Gamma Spec.	TAL Metals	TCLP RCRA Metals
DT00002	1	0 to 2	X	X	X	X	X	
DT00003	1	2 to 4	X	X	X			
DT00004	1	4 to 6	X	X	X			
DT00006	2	0 to 2	X	X	X	X	X	
DT00007	2	2 to 4	X	X	X			
DT00008	2	4 to 6	X	X	X			
DT00010	3	0 to 2	X	X	X	X	X	
DT00011	3	2 to 4	X	X	X			
DT00012	3	4 to 6	X	X	X			
DT00014	4	0 to 2	X	X	X	X	X	
DT00015	4	2 to 4	X	X	X			
DT00016	4	4 to 6	X	X	X			
DT00018	FB ^b	NA ^c	X	X	X	X	X	
DT00019	5	0 to 2	X	X	X	X	X	
DT00020	5	2 to 4	X	X	X			
DT00021	5	4 to 6	X	X	X			
DT00022	5	4 to 6	X	X	X			
DT00024	6	0 to 2	X	X	X	X	X	
DT00025	6	2 to 4	X	X	X			
DT00026	6	4 to 6	X	X	X			
DT00028	7	0 to 2	X	X	X	X	X	
DT00029	7	2 to 4	X	X	X			
DT00030	7	4 to 6	X	X	X			

Refer to footnotes at end of table.

Table C-1
Summary of Laboratory Analyses for Characterization Event 1
Soil Samples at the Double Tracks Test Site
(Page 2 of 2)

Sample Number	Sample Location	Interval Depth (inches)	Analytical Parameter ^a					
			Isotopic Plutonium	Am-241	Isotopic Uranium	Gamma Spec.	TAL Metals	TCLP RCRA Metals
DT00032	8	0 to 2	X	X	X	X	X	
DT00033	8	2 to 4	X	X	X			
DT00034	8	4 to 6	X	X	X			
DT00036	9	0 to 2	X	X	X	X		X
DT00037	9	2 to 4	X	X	X			
DT00038	9	4 to 6	X	X	X			
DT00040	10	0 to 2	X	X	X	X		X
DT00041	10	2 to 4	X	X	X			
DT00042	10	4 to 6	X	X	X			
DT00043	10	4 to 6	X	X	X			
DT00045	11	0 to 2	X	X	X	X		X
DT00046	11	2 to 4	X	X	X			
DT00047	11	4 to 6	X	X	X			
DT00049	12	0 to 2	X	X	X	X	X	
DT00050	12	2 to 4	X	X	X			
DT00051	12	4 to 6	X	X	X			

^a Analytical Parameter:

Isotopic Plutonium; Plutonium-238,-239/240 (Method NAS-NS-3058)

Am-241; Americium-241 (Method NAS-NS-3006)

Isotopic Uranium; Uranium-234,-235/236,-238 (Method NAS-NS-3050)

Gamma Spec.; Gamma Spectroscopy (Method HASL 300)

TAL Metals; Target Analyte List Metals (Method [CLP] Contract Laboratory Procedure)

TCLP/RCRA Metals; Toxicity Characteristic Leaching Procedure/Resource Conservation and Recovery Act Metals (Methods EPA 6010/7470).

^b Field Blank.

^c Not Applicable.

Table C-2
Summary of Laboratory Analyses for Characterization Event 2
Soil Samples at the Double Tracks Test Site

Sample Number	Sample Location	Analytical Parameter ^a			
		Isotopic Plutonium	Am-241	Total Uranium	TCLP RCRA Metals
DT00100	Hot Spot #1	X	X	X	X
DT00101	Hot Spot #2	X	X	X	
DT00102	Hot Spot #3	X	X	X	X
DT00103	Hot Spot #4	X	X	X	X
DT00104	Hot Spot #5	X	X	X	X
DT00105	Hot Spot #6	X	X	X	

^a Analytical Parameter:

Isotopic Plutonium; Plutonium-238,-239/240 (Method NAS-NS-3058)

Am-241; Americium-241 (Method NAS-NS-3006)

Total Uranium; (Method ASTM 5174-91)

TCLP/RCRA Metals; Toxicity Characteristic Leaching Procedure/Resource Conservation and Recovery Act Metals (Methods EPA 6010/7470).

Appendix C
NAEG Soil Laboratory Results and In Situ Radioactivity Measurements

Location	Easting	Northing	Strata	Stake	Plutonium pCi/g	FIDLER counts/sec
DT	1074833	407000	1	1	471	2300
DT	1074485	407112	1	2	14.5	1300
DT	1074588	407175	1	3	0	1300
DT	1074067	406934	1	4	51.2	1300
DT	1075363	407092	1	5	291	4300
DT	1075866	407296	1	6	0	1300
DT	1075564	407196	1	7	0	1300
DT	1076626	407037	1	8	0	1300
DT	1074942	407192	1	9	3.3	1300
DT	1073864	407057	1	10	0	1300
DT	1076999	407407	1	11	1.18	1300
DT	1075218	407275	1	12	2.07	1300
DT	1076445	407394	1	13	0	1300
DT	1076973	407228	1	14	5.25	1300
DT	1074334	407166	1	15	0	1300
DT	1076902	407139	1	16	1.55	1300
DT	1075443	406917	1	17	0	1300
DT	1074741	407148	1	18	0.86	1300
DT	1074151	407035	1	19	378	2300
DT	1076672	406918	1	20	0.52	1300
DT	1076670	407273	1	21	5.57	1300
DT	1074423	407180	1	22	30	1300
DT	1074328	407124	1	23	0	1300
DT	1074937	407339	1	24	18.3	1300
DT	1075054	407365	1	25	1.04	1300
DT	1074339	406902	1	26	0	1300
DT	1076524	407186	1	27	8.2	1300
DT	1075575	407443	1	28	5.68	1300
DT	1073914	406837	1	29	33.7	1300
DT	1074620	407195	1	30	0	1300
DT	1074789	407028	1	31	1290	2800
DT	1076953	407399	1	32	0	1300
DT	1074797	407145	1	33	0	1300
DT	1073860	407021	1	34	0	1300
DT	1076436	407109	1	35	0	1300
DT	1076015	407042	1	36	60.8	1300
DT	1075639	407004	1	37	10.6	1300
DT	1074159	406973	1	38	0	1300
DT	1073941	406791	1	39	3.69	1300
DT	1076233	407167	2	1	219	1800
DT	1076263	407238	2	2	410	1800
DT	1076135	407175	2	3	0	2300
DT	1076282	407250	2	4	386	1800
DT	1076264	407273	2	5	608	3300
DT	1076034	407233	2	6	0	4800
DT	1076221	407162	2	7	28.7	1800
DT	1076284	407201	2	8	10.1	1800

Appendix C
NAEG Soil Laboratory Results and In Situ Radioactivity Measurements

Location	Easting	Northing	Strata	Stake	Plutonium pCi/g	FIDLER counts/sec
DT	1076077	407249	2	9	629	3300
DT	1076206	407197	2	10	0	27000
DT	1076202	407182	2	11	39500	17300
DT	1076075	407193	2	12	0	6000
DT	1076255	407242	2	13	13500	22000
DT	1076602	407218	2	14	1690	4000
DT	1076107	407263	2	15	0	4300
DT	1076284	407193	2	16	0	1300
DT	1076627	407306	2	17	15.3	1300
DT	1076239	407249	3	1	4290	7000
DT	1076231	407193	3	2	0	2000
DT	1076219	407238	3	3	5930	17000
DT	1076198	407203	3	4	5360	36400
DT	1076117	407186	3	5	3410	1800
DT	1076119	407200	3	6	1180	9300
DT	1076017	407185	3	7	2570	7000
DT	1076128	407185	3	8	184	4200
DT	1076240	407189	3	9	1610	5000
DT	1076139	407239	3	10	5140	17000
DT	1076219	407252	3	11	9760	17000
DT	1076173	407293	3	12	12100	39000
DT	1076272	407235	3	13	951	1800
DT	1076078	407107	3	14	8.43	1800
DT	1076056	407189	3	15	136	5300
DT	1076157	407207	3	16	14800	17000
DT	1076168	407300	3	17	792	7300
DT	1076174	407226	4	1	12400	17300
DT	1076229	407284	4	2	36100	41700
DT	1076175	407257	4	3	0	46700
DT	1076198	407270	4	4	68300	174900
DT	1076182	407260	4	5	39600	96400
DT	1076235	407243	4	6	5450	22000
DT	1076184	407287	4	7	27900	89700
DT	1076141	407229	4	8	2350	17000
DT	1076209	407291	4	9	118000	224000
DT	1076245	407255	4	10	1520	2300
DT	1076205	407267	4	11	18900	47000
DT	1076196	407253	4	12	77500	115200
DT	1076215	407280	4	13	1540	4000
DT	1076155	407264	4	14	0	12300
DT	1076227	407287	4	15	111000	135800
DT	1076153	407223	4	16	10900	37000
DT	1076173	407437	4	17	29500	86700

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00002	Aluminum	6390	mg/kg		Soil
DT00002	Antimony	9.3	mg/kg	U	Soil
DT00002	Arsenic	2.7	mg/kg		Soil
DT00002	Barium	140	mg/kg		Soil
DT00002	Beryllium	0.64	mg/kg	B	Soil
DT00002	Cadmium	0.75	mg/kg	U	Soil
DT00002	Calcium	11700	mg/kg		Soil
DT00002	Chromium	3.3	mg/kg		Soil
DT00002	Cobalt	4.1	mg/kg	B	Soil
DT00002	Copper	6.9	mg/kg		Soil
DT00002	Iron	8220	mg/kg		Soil
DT00002	Lead	9.5	mg/kg		Soil
DT00002	Magnesium	3090	mg/kg		Soil
DT00002	Manganese	385	mg/kg		Soil
DT00002	Mercury	0.051	mg/kg	U	Soil
DT00002	Nickel	4.8	mg/kg	B	Soil
DT00002	Potassium	3800	mg/kg		Soil
DT00002	Selenium	0.34	mg/kg	U	Soil
DT00002	Silver	0.77	mg/kg	U	Soil
DT00002	Sodium	386	mg/kg	B	Soil
DT00002	Vanadium	12.4	mg/kg		Soil
DT00002	Zinc	25.5	mg/kg		Soil
DT00002 Dup	Aluminum	8830	mg/kg		Soil
DT00002 Dup	Antimony	9.3	mg/kg	U	Soil
DT00002 Dup	Arsenic	2.2	mg/kg		Soil
DT00002 Dup	Barium	172	mg/kg		Soil
DT00002 Dup	Beryllium	0.73	mg/kg	B	Soil
DT00002 Dup	Cadmium	0.75	mg/kg	U	Soil
DT00002 Dup	Calcium	11600	mg/kg		Soil
DT00002 Dup	Chromium	4.1	mg/kg		Soil
DT00002 Dup	Cobalt	4.5	mg/kg	B	Soil
DT00002 Dup	Copper	7.7	mg/kg		Soil
DT00002 Dup	Iron	9970	mg/kg		Soil
DT00002 Dup	Lead	8.9	mg/kg		Soil
DT00002 Dup	Magnesium	3550	mg/kg		Soil
DT00002 Dup	Manganese	409	mg/kg		Soil
DT00002 Dup	Mercury	0.065	mg/kg	B	Soil
DT00002 Dup	Nickel	5.7	mg/kg	B	Soil
DT00002 Dup	Potassium	5360	mg/kg		Soil
DT00002 Dup	Selenium	0.34	mg/kg	U	Soil
DT00002 Dup	Silver	0.77	mg/kg	U	Soil
DT00002 Dup	Sodium	523	mg/kg	B	Soil
DT00002 Dup	Thallium	0.3	mg/kg	U	Soil
DT00002 Dup	Thallium	0.3	mg/kg	U	Soil
DT00002 Dup	Vanadium	16.6	mg/kg		Soil
DT00002 Dup	Zinc	30.4	mg/kg		Soil
DT00006	Aluminum	9050	mg/kg		Soil
DT00006	Antimony	9.3	mg/kg	U	Soil

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00006	Arsenic	2.1	mg/kg		Soil
DT00006	Barium	182	mg/kg		Soil
DT00006	Beryllium	0.73	mg/kg	B	Soil
DT00006	Cadmium	0.75	mg/kg	U	Soil
DT00006	Calcium	12300	mg/kg		Soil
DT00006	Chromium	4.2	mg/kg		Soil
DT00006	Cobalt	4.3	mg/kg	B	Soil
DT00006	Copper	6.2	mg/kg		Soil
DT00006	Iron	11000	mg/kg		Soil
DT00006	Lead	11.8	mg/kg		Soil
DT00006	Magnesium	3520	mg/kg		Soil
DT00006	Manganese	447	mg/kg		Soil
DT00006	Mercury	0.051	mg/kg	U	Soil
DT00006	Nickel	5.6	mg/kg	B	Soil
DT00006	Potassium	3600	mg/kg		Soil
DT00006	Selenium	0.35	mg/kg	U	Soil
DT00006	Silver	0.77	mg/kg	U	Soil
DT00006	Sodium	385	mg/kg	B	Soil
DT00006	Thallium	0.3	mg/kg	U	Soil
DT00006	Vanadium	19.2	mg/kg		Soil
DT00006	Zinc	33.5	mg/kg		Soil
DT00010	Aluminum	9460	mg/kg		Soil
DT00010	Antimony	9.3	mg/kg	U	Soil
DT00010	Arsenic	3.1	mg/kg		Soil
DT00010	Barium	151	mg/kg		Soil
DT00010	Beryllium	0.73	mg/kg	B	Soil
DT00010	Cadmium	0.75	mg/kg	U	Soil
DT00010	Calcium	11100	mg/kg		Soil
DT00010	Chromium	5.1	mg/kg		Soil
DT00010	Cobalt	4.9	mg/kg	B	Soil
DT00010	Copper	7.3	mg/kg		Soil
DT00010	Iron	12200	mg/kg		Soil
DT00010	Lead	10.7	mg/kg		Soil
DT00010	Magnesium	3880	mg/kg		Soil
DT00010	Manganese	416	mg/kg		Soil
DT00010	Mercury	0.05	mg/kg	U	Soil
DT00010	Nickel	5.5	mg/kg	B	Soil
DT00010	Potassium	4090	mg/kg		Soil
DT00010	Selenium	0.34	mg/kg	U	Soil
DT00010	Silver	0.77	mg/kg	U	Soil
DT00010	Sodium	446	mg/kg	B	Soil
DT00010	Thallium	0.3	mg/kg	U	Soil
DT00010	Vanadium	19.2	mg/kg		Soil
DT00010	Zinc	35.4	mg/kg		Soil
DT00014	Aluminum	8660	mg/kg		Soil
DT00014	Antimony	9.3	mg/kg	U	Soil
DT00014	Arsenic	2.2	mg/kg		Soil
DT00014	Barium	128	mg/kg		Soil

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00014	Beryllium	0.76	mg/kg	B	Soil
DT00014	Cadmium	0.75	mg/kg	U	Soil
DT00014	Calcium	19800	mg/kg		Soil
DT00014	Chromium	5	mg/kg		Soil
DT00014	Cobalt	5.3	mg/kg	B	Soil
DT00014	Copper	7.4	mg/kg		Soil
DT00014	Iron	13000	mg/kg		Soil
DT00014	Lead	11	mg/kg		Soil
DT00014	Magnesium	4200	mg/kg		Soil
DT00014	Manganese	394	mg/kg		Soil
DT00014	Mercury	0.051	mg/kg	U	Soil
DT00014	Nickel	7.3	mg/kg	B	Soil
DT00014	Potassium	3960	mg/kg		Soil
DT00014	Selenium	0.34	mg/kg	U	Soil
DT00014	Silver	0.77	mg/kg	U	Soil
DT00014	Sodium	476	mg/kg	B	Soil
DT00014	Thallium	0.3	mg/kg	U	Soil
DT00014	Vanadium	23.1	mg/kg		Soil
DT00014	Zinc	38	mg/kg		Soil
DT00018	Aluminum	21.2	mg/kg	B	Soil
DT00018	Antimony	9.2	mg/kg	U	Soil
DT00018	Arsenic	0.36	mg/kg	U	Soil
DT00018	Barium	0.56	mg/kg	B	Soil
DT00018	Beryllium	0.06	mg/kg	U	Soil
DT00018	Cadmium	0.74	mg/kg	U	Soil
DT00018	Calcium	242	mg/kg	B	Soil
DT00018	Chromium	1.1	mg/kg	U	Soil
DT00018	Cobalt	0.68	mg/kg	U	Soil
DT00018	Copper	1.5	mg/kg	U	Soil
DT00018	Iron	36.6	mg/kg		Soil
DT00018	Lead	0.72	mg/kg		Soil
DT00018	Magnesium	39.2	mg/kg	B	Soil
DT00018	Manganese	2.3	mg/kg	B	Soil
DT00018	Mercury	0.05	mg/kg	U	Soil
DT00018	Nickel	3.1	mg/kg	U	Soil
DT00018	Potassium	389	mg/kg	U	Soil
DT00018	Selenium	0.34	mg/kg	U	Soil
DT00018	Silver	0.76	mg/kg	U	Soil
DT00018	Sodium	70.5	mg/kg	B	Soil
DT00018	Thallium	0.3	mg/kg	U	Soil
DT00018	Vanadium	1.9	mg/kg	U	Soil
DT00018	Zinc	3.3	mg/kg	B	Soil
DT00019	Aluminum	7090	mg/kg		Soil
DT00019	Antimony	9.3	mg/kg	U	Soil
DT00019	Arsenic	1.7	mg/kg	B	Soil
DT00019	Barium	123	mg/kg		Soil
DT00019	Beryllium	0.62	mg/kg	B	Soil
DT00019	Cadmium	0.75	mg/kg	U	Soil

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00019	Calcium	12000	mg/kg		Soil
DT00019	Chromium	4.4	mg/kg		Soil
DT00019	Cobalt	4.2	mg/kg	B	Soil
DT00019	Copper	7.1	mg/kg		Soil
DT00019	Iron	10300	mg/kg		Soil
DT00019	Lead	9.9	mg/kg		Soil
DT00019	Magnesium	3650	mg/kg		Soil
DT00019	Manganese	358	mg/kg		Soil
DT00019	Mercury	0.05	mg/kg	U	Soil
DT00019	Nickel	6.3	mg/kg	B	Soil
DT00019	Potassium	3290	mg/kg		Soil
DT00019	Selenium	0.34	mg/kg	U	Soil
DT00019	Silver	0.77	mg/kg	U	Soil
DT00019	Sodium	524	mg/kg	B	Soil
DT00019	Thallium	0.3	mg/kg	U	Soil
DT00019	Vanadium	15.3	mg/kg		Soil
DT00019	Zinc	33.4	mg/kg		Soil
DT00024	Aluminum	8330	mg/kg		Soil
DT00024	Antimony	9.3	mg/kg	U	Soil
DT00024	Arsenic	3.2	mg/kg		Soil
DT00024	Barium	143	mg/kg		Soil
DT00024	Beryllium	0.73	mg/kg	B	Soil
DT00024	Cadmium	0.75	mg/kg	U	Soil
DT00024	Calcium	16900	mg/kg		Soil
DT00024	Chromium	5.2	mg/kg		Soil
DT00024	Cobalt	5.4	mg/kg	B	Soil
DT00024	Copper	9.8	mg/kg		Soil
DT00024	Iron	11200	mg/kg		Soil
DT00024	Lead	8.2	mg/kg		Soil
DT00024	Magnesium	4830	mg/kg		Soil
DT00024	Manganese	431	mg/kg		Soil
DT00024	Mercury	0.051	mg/kg	U	Soil
DT00024	Nickel	7.9	mg/kg	B	Soil
DT00024	Potassium	4790	mg/kg		Soil
DT00024	Selenium	0.34	mg/kg	U	Soil
DT00024	Silver	0.77	mg/kg	U	Soil
DT00024	Sodium	1110	mg/kg		Soil
DT00024	Thallium	0.3	mg/kg	U	Soil
DT00024	Vanadium	17.7	mg/kg		Soil
DT00024	Zinc	41.3	mg/kg		Soil
DT00028	Aluminum	9360	mg/kg		Soil
DT00028	Antimony	9.3	mg/kg	U	Soil
DT00028	Arsenic	3.2	mg/kg		Soil
DT00028	Barium	159	mg/kg		Soil
DT00028	Beryllium	0.76	mg/kg	B	Soil
DT00028	Cadmium	0.75	mg/kg	U	Soil
DT00028	Calcium	14200	mg/kg		Soil
DT00028	Chromium	5.6	mg/kg		Soil

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00028	Cobalt	5	mg/kg	B	Soil
DT00028	Copper	8.4	mg/kg		Soil
DT00028	Iron	12100	mg/kg		Soil
DT00028	Lead	10.3	mg/kg		Soil
DT00028	Magnesium	4720	mg/kg		Soil
DT00028	Manganese	453	mg/kg		Soil
DT00028	Mercury	0.051	mg/kg	U	Soil
DT00028	Nickel	8	mg/kg	B	Soil
DT00028	Potassium	4430	mg/kg		Soil
DT00028	Selenium	0.34	mg/kg	U	Soil
DT00028	Silver	0.77	mg/kg	U	Soil
DT00028	Sodium	598	mg/kg	B	Soil
DT00028	Thallium	0.3	mg/kg	U	Soil
DT00028	Vanadium	18.7	mg/kg		Soil
DT00028	Zinc	35.9	mg/kg		Soil
DT00032	Aluminum	8710	mg/kg		Soil
DT00032	Antimony	9.3	mg/kg	U	Soil
DT00032	Arsenic	2.8	mg/kg		Soil
DT00032	Barium	144	mg/kg		Soil
DT00032	Beryllium	0.66	mg/kg	B	Soil
DT00032	Cadmium	0.75	mg/kg	U	Soil
DT00032	Calcium	15600	mg/kg		Soil
DT00032	Chromium	4.7	mg/kg		Soil
DT00032	Cobalt	3.7	mg/kg	B	Soil
DT00032	Copper	9.6	mg/kg		Soil
DT00032	Iron	10100	mg/kg		Soil
DT00032	Lead	13.8	mg/kg		Soil
DT00032	Magnesium	3940	mg/kg		Soil
DT00032	Manganese	374	mg/kg		Soil
DT00032	Mercury	0.051	mg/kg	U	Soil
DT00032	Nickel	7	mg/kg	B	Soil
DT00032	Potassium	4040	mg/kg		Soil
DT00032	Selenium	0.34	mg/kg	U	Soil
DT00032	Silver	0.77	mg/kg	U	Soil
DT00032	Sodium	479	mg/kg	B	Soil
DT00032	Thallium	0.3	mg/kg	U	Soil
DT00032	Vanadium	14.7	mg/kg		Soil
DT00032	Zinc	34.1	mg/kg		Soil
DT00049	Aluminum	10300	mg/kg		Soil
DT00049	Antimony	9.3	mg/kg	U	Soil
DT00049	Arsenic	3	mg/kg		Soil
DT00049	Barium	167	mg/kg		Soil
DT00049	Beryllium	0.76	mg/kg	B	Soil
DT00049	Cadmium	0.75	mg/kg	U	Soil
DT00049	Calcium	13300	mg/kg		Soil
DT00049	Chromium	6.3	mg/kg		Soil
DT00049	Cobalt	5.2	mg/kg	B	Soil
DT00049	Copper	9	mg/kg		Soil

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00049	Iron	13500	mg/kg		Soil
DT00049	Lead	10.1	mg/kg		Soil
DT00049	Magnesium	4760	mg/kg		Soil
DT00049	Manganese	487	mg/kg		Soil
DT00049	Mercury	0.051	mg/kg	U	Soil
DT00049	Nickel	7.5	mg/kg	B	Soil
DT00049	Potassium	4130	mg/kg		Soil
DT00049	Selenium	0.34	mg/kg	U	Soil
DT00049	Silver	0.77	mg/kg	U	Soil
DT00049	Sodium	523	mg/kg	B	Soil
DT00049	Thallium	0.3	mg/kg	U	Soil
DT00049	Vanadium	20.8	mg/kg		Soil
DT00049	Zinc	38.6	mg/kg		Soil
DT00036	Arsenic	0.011	mg/l		TCLP
DT00036	Barium	0.45	mg/l		TCLP
DT00036	Cadmium	0.005	mg/l	U	TCLP
DT00036	Chromium	0.02	mg/l	U	TCLP
DT00036	Lead	0.008	mg/l		TCLP
DT00036	Mercury	0.002	mg/l	U	TCLP
DT00036	Selenium	0.007	mg/l		TCLP
DT00036	Silver	0.01	mg/l	U	TCLP
DT00040	Arsenic	0.004	mg/l		TCLP
DT00040	Barium	0.2	mg/l	U	TCLP
DT00040	Cadmium	0.005	mg/l	U	TCLP
DT00040	Chromium	0.02	mg/l	U	TCLP
DT00040	Lead	0.003	mg/l	U	TCLP
DT00040	Mercury	0.002	mg/l	U	TCLP
DT00040	Selenium	0.004	mg/l		TCLP
DT00040	Silver	0.01	mg/l	U	TCLP
DT00045	Arsenic	0.014	mg/l		TCLP
DT00045	Barium	0.42	mg/l		TCLP
DT00045	Cadmium	0.005	mg/l	U	TCLP
DT00045	Chromium	0.02	mg/l	U	TCLP
DT00045	Lead	0.003	mg/l	U	TCLP
DT00045	Mercury	0.002	mg/l	U	TCLP
DT00045	Selenium	0.006	mg/l		TCLP
DT00045	Silver	0.01	mg/l	U	TCLP
DT00001	Aluminum	29.8	ug/l	B	Field Rinsate
DT00001	Antimony	46.2	ug/l	U	Field Rinsate
DT00001	Arsenic	1.8	ug/l	U	Field Rinsate
DT00001	Barium	1.7	ug/l	B	Field Rinsate
DT00001	Beryllium	0.53	ug/l	B	Field Rinsate
DT00001	Cadmium	3.7	ug/l	U	Field Rinsate
DT00001	Calcium	267	ug/l	B	Field Rinsate
DT00001	Chromium	5.3	ug/l	U	Field Rinsate
DT00001	Cobalt	3.4	ug/l	U	Field Rinsate
DT00001	Copper	10.5	ug/l	B	Field Rinsate
DT00001	Iron	302	ug/l		Field Rinsate

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00001	Lead	1	ug/l	U	Field Rinsate
DT00001	Magnesium	179	ug/l	B	Field Rinsate
DT00001	Manganese	2.4	ug/l	B	Field Rinsate
DT00001	Mercury	0.1	ug/l	U	Field Rinsate
DT00001	Nickel	15.5	ug/l	U	Field Rinsate
DT00001	Potassium	1940	ug/l	U	Field Rinsate
DT00001	Selenium	1.7	ug/l	U	Field Rinsate
DT00001	Silver	3.8	ug/l	U	Field Rinsate
DT00001	Sodium	142	ug/l	B	Field Rinsate
DT00001	Thallium	1.7	ug/l	B	Field Rinsate
DT00001	Vanadium	9.6	ug/l	U	Field Rinsate
DT00001	Zinc	10.2	ug/l	B	Field Rinsate
DT00053	Aluminum	29	ug/l	U	Field Rinsate
DT00053	Antimony	46.2	ug/l	U	Field Rinsate
DT00053	Arsenic	1.8	ug/l	U	Field Rinsate
DT00053	Barium	1	ug/l	U	Field Rinsate
DT00053	Beryllium	0.68	ug/l	B	Field Rinsate
DT00053	Cadmium	3.7	ug/l	U	Field Rinsate
DT00053	Calcium	179	ug/l	B	Field Rinsate
DT00053	Chromium	5.3	ug/l	U	Field Rinsate
DT00053	Cobalt	3.4	ug/l	U	Field Rinsate
DT00053	Copper	12	ug/l	B	Field Rinsate
DT00053	Iron	51	ug/l	B	Field Rinsate
DT00053	Lead	1	ug/l	U	Field Rinsate
DT00053	Magnesium	168	ug/l	B	Field Rinsate
DT00053	Manganese	1.9	ug/l	B	Field Rinsate
DT00053	Mercury	0.1	ug/l	U	Field Rinsate
DT00053	Nickel	15.5	ug/l	U	Field Rinsate
DT00053	Potassium	1940	ug/l	U	Field Rinsate
DT00053	Selenium	1.7	ug/l	U	Field Rinsate
DT00053	Silver	3.8	ug/l	U	Field Rinsate
DT00053	Sodium	151	ug/l	B	Field Rinsate
DT00053	Thallium	1.7	ug/l	B	Field Rinsate
DT00053	Vanadium	9.6	ug/l	U	Field Rinsate
DT00053	Zinc	19.8	ug/l	B	Field Rinsate
DT00054	Aluminum	39.6	ug/l	B	Field Rinsate
DT00054	Antimony	46.2	ug/l	U	Field Rinsate
DT00054	Arsenic	1.8	ug/l	U	Field Rinsate
DT00054	Barium	1	ug/l	U	Field Rinsate
DT00054	Beryllium	0.67	ug/l	B	Field Rinsate
DT00054	Cadmium	3.7	ug/l	U	Field Rinsate
DT00054	Calcium	164	ug/l	B	Field Rinsate
DT00054	Chromium	5.3	ug/l	U	Field Rinsate
DT00054	Cobalt	3.4	ug/l	U	Field Rinsate
DT00054	Copper	12.7	ug/l	B	Field Rinsate
DT00054	Iron	46.6	ug/l	B	Field Rinsate
DT00054	Lead	1	ug/l	U	Field Rinsate
DT00054	Magnesium	197	ug/l	B	Field Rinsate

Appendix C
Laboratory Results for Target Analyte List Constituents in Soil
(plus field and laboratory QA/QC)
First Characterization Event

Sample Number	Analyte	Result	Units	Qualifier	Matrix
DT00054	Manganese	1.9	ug/l	B	Field Rinsate
DT00054	Mercury	0.1	ug/l	U	Field Rinsate
DT00054	Nickel	15.5	ug/l	U	Field Rinsate
DT00054	Potassium	1940	ug/l	U	Field Rinsate
DT00054	Selenium	1.7	ug/l	U	Field Rinsate
DT00054	Silver	4.4	ug/l	B	Field Rinsate
DT00054	Sodium	46.6	ug/l	B	Field Rinsate
DT00054	Thallium	1.5	ug/l	U	Field Rinsate
DT00054	Vanadium	9.6	ug/l	U	Field Rinsate
DT00054	Zinc	107	ug/l		Field Rinsate
DT00002 MS	Antimony	69	% Recovery		Lab Matrix Spike
DT00002 MS	Arsenic	90	% Recovery		Lab Matrix Spike
DT00002 MS	Barium	106	% Recovery		Lab Matrix Spike
DT00002 MS	Beryllium	109	% Recovery		Lab Matrix Spike
DT00002 MS	Cadmium	112	% Recovery		Lab Matrix Spike
DT00002 MS	Chromium	107	% Recovery		Lab Matrix Spike
DT00002 MS	Cobalt	106	% Recovery		Lab Matrix Spike
DT00002 MS	Copper	110	% Recovery		Lab Matrix Spike
DT00002 MS	Lead	36	% Recovery		Lab Matrix Spike
DT00002 MS	Manganese	60	% Recovery		Lab Matrix Spike
DT00002 MS	Mercury	117	% Recovery		Lab Matrix Spike
DT00002 MS	Nickel	109	% Recovery		Lab Matrix Spike
DT00002 MS	Selenium	88	% Recovery		Lab Matrix Spike
DT00002 MS	Silver	100	% Recovery		Lab Matrix Spike
DT00002 MS	Thallium	26	% Recovery		Lab Matrix Spike
DT00002 MS	Vanadium	109	% Recovery		Lab Matrix Spike
DT00002 MS	Zinc	113	% Recovery		Lab Matrix Spike
DT00036 MS	Arsenic	100	% Recovery		Lab Matrix Spike
DT00036 MS	Barium	89	% Recovery		Lab Matrix Spike
DT00036 MS	Cadmium	93	% Recovery		Lab Matrix Spike
DT00036 MS	Chromium	94	% Recovery		Lab Matrix Spike
DT00036 MS	Lead	88	% Recovery		Lab Matrix Spike
DT00036 MS	Mercury	48	% Recovery		Lab Matrix Spike
DT00036 MS	Selenium	97	% Recovery		Lab Matrix Spike
DT00036 MS	Silver	70	% Recovery		Lab Matrix Spike

Qualifiers

U - Analyte was analyzed for but not detected

B - Reported value was obtained from a reading that was less than the required detection limit but greater than the instrument detection limit.

Dup - Duplicate sample

milligram/kilogram (mg/kg) or parts per million (ppm)

microgram/kilogram (ug/kg) or parts per billion (ppb)

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00002	Actinium 227	ND	pCi/g		Gamma Spec
DT00002	Americium 241	0.056	pCi/g	0.021	NAS-NS-3006
DT00002	Americium 241	ND	pCi/g		Gamma Spec
DT00002	Antimony 125	ND	pCi/g		Gamma Spec
DT00002	Barium-133	ND	pCi/g		Gamma Spec
DT00002	Bismuth 214	1.4	pCi/g	0.14	Gamma Spec
DT00002	Cesium 137	0.54	pCi/g	0.08	Gamma Spec
DT00002	Cobalt 60	ND	pCi/g		Gamma Spec
DT00002	Europium 152	ND	pCi/g		Gamma Spec
DT00002	Europium 154	ND	pCi/g		Gamma Spec
DT00002	Europium 155	0.12	pCi/g	0.07	Gamma Spec
DT00002	Lead 210	1.6	pCi/g	0.55	Gamma Spec
DT00002	Lead 212	1.97	pCi/g	0.23	Gamma Spec
DT00002	Plutonium 238	0.008	pCi/g	0.011	NAS-NA-3058
DT00002	Plutonium 239/240	0.12	pCi/g	0.04	NAS-NA-3058
DT00002	Potassium 40	33.6	pCi/g	3.6	Gamma Spec
DT00002	Protactinium-231	ND	pCi/g		Gamma Spec
DT00002	Protactinium-234	ND	pCi/g		Gamma Spec
DT00002	Radium-223	ND	pCi/g		Gamma Spec
DT00002	Radium-226	1.32	pCi/g	0.09	Gamma Spec
DT00002	Thallium 208	0.59	pCi/g	0.07	Gamma Spec
DT00002	Thorium-232	1.93	pCi/g	0.2	Gamma Spec
DT00002	Uranium 234	0.92	pCi/g	0.2	NAS-NA-3050
DT00002	Uranium 235/236	0.073	pCi/g	0.046	NAS-NA-3050
DT00002	Uranium 238	0.8	pCi/g	0.18	NAS-NA-3050
DT00002	Uranium-234	0.96	pCi/g	0.54	Gamma Spec
DT00002	Uranium-235	ND	pCi/g		Gamma Spec
DT00002	Uranium-238	0.96	pCi/g	0.54	Gamma Spec
DT00002 DUP	Actinium 227	1.41	pCi/g	0.34	Gamma Spec
DT00002 DUP	Americium 241	0.02	pCi/g	0.012	NAS-NS-3006
DT00002 DUP	Americium 241	ND	pCi/g		Gamma Spec
DT00002 DUP	Antimony 125	ND	pCi/g		Gamma Spec
DT00002 DUP	Barium-133	ND	pCi/g		Gamma Spec
DT00002 DUP	Bismuth 214	1.28	pCi/g	0.14	Gamma Spec
DT00002 DUP	Cesium 137	0.53	pCi/g	0.08	Gamma Spec
DT00002 DUP	Cobalt 60	ND	pCi/g		Gamma Spec
DT00002 DUP	Europium 152	ND	pCi/g		Gamma Spec
DT00002 DUP	Europium 154	ND	pCi/g		Gamma Spec
DT00002 DUP	Europium 155	ND	pCi/g		Gamma Spec
DT00002 DUP	Lead 210	ND	pCi/g		Gamma Spec
DT00002 DUP	Lead 212	2.03	pCi/g	0.22	Gamma Spec
DT00002 DUP	Plutonium 238	-0.004	pCi/g	0.01	NAS-NA-3058
DT00002 DUP	Plutonium 239/240	0.063	pCi/g	0.035	NAS-NA-3058
DT00002 DUP	Potassium 40	35.2	pCi/g	3.8	Gamma Spec
DT00002 DUP	Protactinium-231	ND	pCi/g		Gamma Spec
DT00002 DUP	Protactinium-234	ND	pCi/g		Gamma Spec
DT00002 DUP	Radium-223	ND	pCi/g		Gamma Spec
DT00002 DUP	Radium-226	1.27	pCi/g	0.1	Gamma Spec
DT00002 DUP	Thallium 208	0.64	pCi/g	0.08	Gamma Spec
DT00002 DUP	Thorium-232	1.8	pCi/g	0.23	Gamma Spec

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00002 DUP	Uranium 234	0.82	pCi/g	0.18	NAS-NA-3050
DT00002 DUP	Uranium 235/236	0.043	pCi/g	0.034	NAS-NA-3050
DT00002 DUP	Uranium 238	0.51	pCi/g	0.13	NAS-NA-3050
DT00002 DUP	Uranium-234	1.96	pCi/g	0.88	Gamma Spec
DT00002 DUP	Uranium-235	ND	pCi/g		Gamma Spec
DT00002 DUP	Uranium-238	1.96	pCi/g	0.88	Gamma Spec
DT00003	Americium 241	0.024	pCi/g	0.014	NAS-NS-3006
DT00003	Plutonium 238	0.003	pCi/g	0.007	NAS-NA-3058
DT00003	Plutonium 239/240	0.066	pCi/g	0.032	NAS-NA-3058
DT00003	Uranium 234	1.03	pCi/g	0.21	NAS-NA-3050
DT00003	Uranium 235/236	0.077	pCi/g	0.045	NAS-NA-3050
DT00003	Uranium 238	1.06	pCi/g	0.22	NAS-NA-3050
DT00004	Americium 241	0.011	pCi/g	0.008	NAS-NS-3006
DT00004	Plutonium 238	-0.008	pCi/g	0.005	NAS-NA-3058
DT00004	Plutonium 239/240	0.1	pCi/g	0.43	NAS-NA-3058
DT00004	Uranium 234	1.18	pCi/g	0.24	NAS-NA-3050
DT00004	Uranium 235/236	0.07	pCi/g	0.046	NAS-NA-3050
DT00004	Uranium 238	1.05	pCi/g	0.22	NAS-NA-3050
DT00006	Actinium 227	ND	pCi/g		Gamma Spec
DT00006	Americium 241	0.28	pCi/g	0.15	NAS-NS-3006
DT00006	Americium 241	1.82	pCi/g	0.21	Gamma Spec
DT00006	Antimony 125	ND	pCi/g		Gamma Spec
DT00006	Barium-133	ND	pCi/g		Gamma Spec
DT00006	Bismuth 214	1.16	pCi/g	0.13	Gamma Spec
DT00006	Cesium 137	1.06	pCi/g	0.13	Gamma Spec
DT00006	Cobalt 60	ND	pCi/g		Gamma Spec
DT00006	Europium 152	ND	pCi/g		Gamma Spec
DT00006	Europium 154	ND	pCi/g		Gamma Spec
DT00006	Europium 155	0.13	pCi/g	0.07	Gamma Spec
DT00006	Lead 210	1.77	pCi/g	0.58	Gamma Spec
DT00006	Lead 212	1.77	pCi/g	0.15	Gamma Spec
DT00006	Plutonium 238	0.15	pCi/g	0.06	NAS-NA-3058
DT00006	Plutonium 239/240	6.92	pCi/g	1.16	NAS-NA-3058
DT00006	Potassium 40	29.6	pCi/g	3.1	Gamma Spec
DT00006	Protactinium-231	ND	pCi/g		Gamma Spec
DT00006	Protactinium-234	ND	pCi/g		Gamma Spec
DT00006	Radium-223	ND	pCi/g		Gamma Spec
DT00006	Radium-226	1.24	pCi/g	0.09	Gamma Spec
DT00006	Thallium 208	0.58	pCi/g	0.07	Gamma Spec
DT00006	Thorium-232	1.68	pCi/g	0.2	Gamma Spec
DT00006	Uranium 234	1.11	pCi/g	0.26	NAS-NA-3050
DT00006	Uranium 235/236	0.049	pCi/g	0.044	NAS-NA-3050
DT00006	Uranium 238	0.92	pCi/g	0.23	NAS-NA-3050
DT00006	Uranium-234	1.1	pCi/g	0.5	Gamma Spec
DT00006	Uranium-235	ND	pCi/g		Gamma Spec
DT00006	Uranium-238	1.1	pCi/g	0.5	Gamma Spec
DT00006 RE	Americium 241	0.3	pCi/g	0.08	NAS-NS-3006
DT00006 RE	Plutonium 238	0.065	pCi/g	0.022	NAS-NS-3058
DT00006 RE	Plutonium 239/240	7.08	pCi/g	1.16	NAS-NS-3058
DT00007	Americium 241	0.21	pCi/g	0.05	NAS-NS-3006

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00007	Plutonium 238	0.012	pCi/g	0.015	NAS-NA-3058
DT00007	Plutonium 239/240	1.15	pCi/g	0.21	NAS-NA-3058
DT00007	Uranium 234	0.97	pCi/g	0.2	NAS-NA-3050
DT00007	Uranium 235/236	0.13	pCi/g	0.06	NAS-NA-3050
DT00007	Uranium 238	0.85	pCi/g	0.18	NAS-NA-3050
DT00008	Americium 241	0.001	pCi/g	0.003	NAS-NS-3006
DT00008	Plutonium 238	0.001	pCi/g	0.007	NAS-NA-3058
DT00008	Plutonium 239/240	0.02	pCi/g	0.018	NAS-NA-3058
DT00008	Uranium 234	1.16	pCi/g	0.25	NAS-NA-3050
DT00008	Uranium 235/236	0.079	pCi/g	0.05	NAS-NA-3050
DT00008	Uranium 238	0.95	pCi/g	0.21	NAS-NA-3050
DT00010	Actinium 227	2.31	pCi/g	0.44	Gamma Spec
DT00010	Americium 241	0.089	pCi/g	0.036	NAS-NS-3006
DT00010	Americium 241	ND	pCi/g		Gamma Spec
DT00010	Antimony 125	ND	pCi/g		Gamma Spec
DT00010	Barium-133	ND	pCi/g		Gamma Spec
DT00010	Bismuth 214	1.22	pCi/g	0.16	Gamma Spec
DT00010	Cesium 137	1.09	pCi/g	0.16	Gamma Spec
DT00010	Cobalt 60	ND	pCi/g		Gamma Spec
DT00010	Europium 152	ND	pCi/g		Gamma Spec
DT00010	Europium 154	ND	pCi/g		Gamma Spec
DT00010	Europium 155	ND	pCi/g		Gamma Spec
DT00010	Lead 210	ND	pCi/g		Gamma Spec
DT00010	Lead 212	1.86	pCi/g	0.2	Gamma Spec
DT00010	Plutonium 238	0.012	pCi/g	0.01	NAS-NA-3058
DT00010	Plutonium 239/240	0.68	pCi/g	0.13	NAS-NA-3058
DT00010	Potassium 40	29.3	pCi/g	3.4	Gamma Spec
DT00010	Protactinium-231	ND	pCi/g		Gamma Spec
DT00010	Protactinium-234	ND	pCi/g		Gamma Spec
DT00010	Radium-223	ND	pCi/g		Gamma Spec
DT00010	Radium-226	1.23	pCi/g	0.11	Gamma Spec
DT00010	Thallium 208	0.68	pCi/g	0.09	Gamma Spec
DT00010	Thorium-232	1.48	pCi/g	0.22	Gamma Spec
DT00010	Uranium 234	1.2	pCi/g	0.27	NAS-NA-3050
DT00010	Uranium 235/236	0.089	pCi/g	0.059	NAS-NA-3050
DT00010	Uranium 238	1.16	pCi/g	0.26	NAS-NA-3050
DT00010	Uranium-234	1.44	pCi/g	1.11	Gamma Spec
DT00010	Uranium-235	ND	pCi/g		Gamma Spec
DT00010	Uranium-238	1.44	pCi/g	1.11	Gamma Spec
DT00011	Americium 241	0.035	pCi/g	0.018	NAS-NS-3006
DT00011	Plutonium 238	0.017	pCi/g	0.021	NAS-NA-3058
DT00011	Plutonium 239/240	0.1	pCi/g	0.05	NAS-NA-3058
DT00011	Uranium 234	1.2	pCi/g	0.25	NAS-NA-3050
DT00011	Uranium 235/236	0.072	pCi/g	0.043	NAS-NA-3050
DT00011	Uranium 238	0.96	pCi/g	0.21	NAS-NA-3050
DT00012	Americium 241	0.015	pCi/g	0.012	NAS-NS-3006
DT00012	Plutonium 238	0.008	pCi/g	0.035	NAS-NA-3058
DT00012	Plutonium 239/240	0.8	pCi/g	0.22	NAS-NA-3058
DT00012	Uranium 234	0.98	pCi/g	0.23	NAS-NA-3050
DT00012	Uranium 235/236	0.08	pCi/g	0.055	NAS-NA-3050

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00012	Uranium 238	1.07	pCi/g	0.25	NAS-NA-3050
DT00014	Actinium 227	ND	pCi/g		Gamma Spec
DT00014	Americium 241	0.009	pCi/g	0.011	NAS-NS-3006
DT00014	Americium 241	0.58	pCi/g	0.08	Gamma Spec
DT00014	Antimony 125	ND	pCi/g		Gamma Spec
DT00014	Barium-133	ND	pCi/g		Gamma Spec
DT00014	Bismuth 214	1.24	pCi/g	0.12	Gamma Spec
DT00014	Cesium 137	1.34	pCi/g	0.15	Gamma Spec
DT00014	Cobalt 60	0.061	pCi/g	0.031	Gamma Spec
DT00014	Europium 152	ND	pCi/g		Gamma Spec
DT00014	Europium 154	ND	pCi/g		Gamma Spec
DT00014	Europium 155	ND	pCi/g		Gamma Spec
DT00014	Lead 210	1.66	pCi/g	0.48	Gamma Spec
DT00014	Lead 212	1.77	pCi/g	0.2	Gamma Spec
DT00014	Plutonium 238	-0.004	pCi/g	0.004	NAS-NA-3058
DT00014	Plutonium 239/240	0.066	pCi/g	0.19	NAS-NA-3058
DT00014	Potassium 40	31.9	pCi/g	3.3	Gamma Spec
DT00014	Protactinium-231	ND	pCi/g		Gamma Spec
DT00014	Protactinium-234	ND	pCi/g		Gamma Spec
DT00014	Radium-223	ND	pCi/g		Gamma Spec
DT00014	Radium-226	1.19	pCi/g	0.08	Gamma Spec
DT00014	Thallium 208	0.6	pCi/g	0.06	Gamma Spec
DT00014	Thorium-232	1.63	pCi/g	0.17	Gamma Spec
DT00014	Uranium 234	0.94	pCi/g	0.29	NAS-NA-3050
DT00014	Uranium 235/236	0.11	pCi/g	0.09	NAS-NA-3050
DT00014	Uranium 238	1.28	pCi/g	0.36	NAS-NA-3050
DT00014	Uranium-234	0.89	pCi/g	0.44	Gamma Spec
DT00014	Uranium-235	ND	pCi/g		Gamma Spec
DT00014	Uranium-238	0.89	pCi/g	0.44	Gamma Spec
DT00015	Americium 241	0.085	pCi/g	0.067	NAS-NS-3006
DT00015	Plutonium 238	-0.007	pCi/g	0.005	NAS-NA-3058
DT00015	Plutonium 239/240	0.017	pCi/g	0.029	NAS-NA-3058
DT00015	Uranium 234	1.45	pCi/g	0.4	NAS-NA-3050
DT00015	Uranium 235/236	0.25	pCi/g	0.15	NAS-NA-3050
DT00015	Uranium 238	1.05	pCi/g	0.32	NAS-NA-3050
DT00016	Americium 241	0.087	pCi/g	0.04	NAS-NS-3006
DT00016	Plutonium 238	0.003	pCi/g	0.014	NAS-NA-3058
DT00016	Plutonium 239/240	0.024	pCi/g	0.027	NAS-NA-3058
DT00016	Uranium 234	2.23	pCi/g	0.54	NAS-NA-3050
DT00016	Uranium 235/236	0.3	pCi/g	0.16	NAS-NA-3050
DT00016	Uranium 238	2.51	pCi/g	0.59	NAS-NA-3050
DT00018	Actinium 227	ND	pCi/g		Gamma Spec
DT00018	Americium 241	0.009	pCi/g	0.018	NAS-NS-3006
DT00018	Americium 241	ND	pCi/g		Gamma Spec
DT00018	Antimony 125	ND	pCi/g		Gamma Spec
DT00018	Barium-133	ND	pCi/g		Gamma Spec
DT00018	Bismuth 214	0.06	pCi/g	0.027	Gamma Spec
DT00018	Cesium 137	ND	pCi/g		Gamma Spec
DT00018	Cobalt 60	ND	pCi/g		Gamma Spec
DT00018	Europium 152	ND	pCi/g		Gamma Spec

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00018	Europium 154	ND	pCi/g		Gamma Spec
DT00018	Europium 155	ND	pCi/g		Gamma Spec
DT00018	Lead 210	ND	pCi/g		Gamma Spec
DT00018	Lead 212	ND	pCi/g		Gamma Spec
DT00018	Plutonium 238	-0.001	pCi/g	0.001	NAS-NA-3058
DT00018	Plutonium 239/240	0.012	pCi/g	0.019	NAS-NA-3058
DT00018	Potassium 40	ND	pCi/g		Gamma Spec
DT00018	Protactinium-231	ND	pCi/g		Gamma Spec
DT00018	Protactinium-234	ND	pCi/g		Gamma Spec
DT00018	Radium-223	ND	pCi/g		Gamma Spec
DT00018	Radium-226	0.06	pCi/g	0.027	Gamma Spec
DT00018	Thallium 208	ND	pCi/g		Gamma Spec
DT00018	Thorium-232	ND	pCi/g		Gamma Spec
DT00018	Uranium 234	0.28	pCi/g	0.19	NAS-NA-3050
DT00018	Uranium 235/236	0.07	pCi/g	0.1	NAS-NA-3050
DT00018	Uranium 238	0.23	pCi/g	0.17	NAS-NA-3050
DT00018	Uranium-234	0.36	pCi/g	0.12	Gamma Spec
DT00018	Uranium-235	ND	pCi/g		Gamma Spec
DT00018	Uranium-238	0.36	pCi/g	0.12	Gamma Spec
DT00019	Actinium 227	ND	pCi/g		Gamma Spec
DT00019	Americium 241	0.21	pCi/g	0.07	NAS-NS-3006
DT00019	Americium 241	0.27	pCi/g	0.06	Gamma Spec
DT00019	Antimony 125	ND	pCi/g		Gamma Spec
DT00019	Barium-133	ND	pCi/g		Gamma Spec
DT00019	Bismuth 214	1.31	pCi/g	0.14	Gamma Spec
DT00019	Cesium 137	0.38	pCi/g	0.06	Gamma Spec
DT00019	Cobalt 60	ND	pCi/g		Gamma Spec
DT00019	Europium 152	ND	pCi/g		Gamma Spec
DT00019	Europium 154	ND	pCi/g		Gamma Spec
DT00019	Europium 155	0.14	pCi/g	0.07	Gamma Spec
DT00019	Lead 210	1.43	pCi/g	0.51	Gamma Spec
DT00019	Lead 212	1.92	pCi/g	0.15	Gamma Spec
DT00019	Plutonium 238	0.021	pCi/g	0.032	NAS-NA-3058
DT00019	Plutonium 239/240	1.42	pCi/g	0.33	NAS-NA-3058
DT00019	Potassium 40	31.3	pCi/g	3.3	Gamma Spec
DT00019	Protactinium-231	ND	pCi/g		Gamma Spec
DT00019	Protactinium-234	ND	pCi/g		Gamma Spec
DT00019	Radium-223	ND	pCi/g		Gamma Spec
DT00019	Radium-226	1.29	pCi/g	0.09	Gamma Spec
DT00019	Thallium 208	0.59	pCi/g	0.07	Gamma Spec
DT00019	Thorium-232	1.72	pCi/g	0.2	Gamma Spec
DT00019	Uranium 234	1.12	pCi/g	0.33	NAS-NA-3050
DT00019	Uranium 235/236	0.074	pCi/g	0.077	NAS-NA-3050
DT00019	Uranium 238	0.92	pCi/g	0.29	NAS-NA-3050
DT00019	Uranium-234	1.39	pCi/g	0.51	Gamma Spec
DT00019	Uranium-235	ND	pCi/g		Gamma Spec
DT00019	Uranium-238	1.39	pCi/g	0.51	Gamma Spec
DT00020	Americium 241	0	pCi/g	0.019	NAS-NS-3006
DT00020	Plutonium 238	0.001	pCi/g	0.029	NAS-NA-3058
DT00020	Plutonium 239/240	0.18	pCi/g	0.09	NAS-NA-3058

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00020	Uranium 234	1.05	pCi/g	0.3	NAS-NA-3050
DT00020	Uranium 235/236	0.015	pCi/g	0.034	NAS-NA-3050
DT00020	Uranium 238	0.76	pCi/g	0.25	NAS-NA-3050
DT00021	Americium 241	0.11	pCi/g	0.06	NAS-NS-3006
DT00021	Plutonium 238	0	pCi/g	0	NAS-NA-3058
DT00021	Plutonium 239/240	0.2	pCi/g	0.1	NAS-NA-3058
DT00021	Uranium 234	1.09	pCi/g	0.32	NAS-NA-3050
DT00021	Uranium 235/236	0.053	pCi/g	0.064	NAS-NA-3050
DT00021	Uranium 238	0.56	pCi/g	0.21	NAS-NA-3050
DT00022	Americium 241	0.29	pCi/g	0.08	NAS-NS-3006
DT00022	Plutonium 238	-0.008	pCi/g	0.006	NAS-NA-3058
DT00022	Plutonium 239/240	0.017	pCi/g	0.026	NAS-NA-3058
DT00022	Uranium 234	1.55	pCi/g	0.4	NAS-NA-3050
DT00022	Uranium 235/236	0.068	pCi/g	0.069	NAS-NA-3050
DT00022	Uranium 238	1.3	pCi/g	0.35	NAS-NA-3050
DT00024	Actinium 227	1.35	pCi/g	0.29	Gamma Spec
DT00024	Americium 241	8.96	pCi/g	1.56	NAS-NS-3006
DT00024	Americium 241	12.2	pCi/g	2	Gamma Spec
DT00024	Antimony 125	ND	pCi/g		Gamma Spec
DT00024	Barium-133	ND	pCi/g		Gamma Spec
DT00024	Bismuth 214	1.26	pCi/g	0.13	Gamma Spec
DT00024	Cesium 137	0.26	pCi/g	0.05	Gamma Spec
DT00024	Cobalt 60	ND	pCi/g		Gamma Spec
DT00024	Europium 152	ND	pCi/g		Gamma Spec
DT00024	Europium 154	ND	pCi/g		Gamma Spec
DT00024	Europium 155	ND	pCi/g		Gamma Spec
DT00024	Lead 210	ND	pCi/g		Gamma Spec
DT00024	Lead 212	1.86	pCi/g	0.19	Gamma Spec
DT00024	Plutonium 238	0.47	pCi/g	0.61	NAS-NA-3058
DT00024	Plutonium 239/240	80	pCi/g	15.3	NAS-NA-3058
DT00024	Potassium 40	32.5	pCi/g	3.5	Gamma Spec
DT00024	Protactinium-231	ND	pCi/g		Gamma Spec
DT00024	Protactinium-234	0.2	pCi/g	0.11	Gamma Spec
DT00024	Radium-223	ND	pCi/g		Gamma Spec
DT00024	Radium-226	1.28	pCi/g	0.09	Gamma Spec
DT00024	Thallium 208	0.59	pCi/g	0.07	Gamma Spec
DT00024	Thorium-232	1.69	pCi/g	0.2	Gamma Spec
DT00024	Total Uranium	1.98	ug/g	0.21	ASTM 5174-91
DT00024	Uranium 234	0.9	pCi/g	0.28	NAS-NA-3050
DT00024	Uranium 235/236	0.1	pCi/g	0.09	NAS-NA-3050
DT00024	Uranium 238	0.84	pCi/g	0.26	NAS-NA-3050
DT00024	Uranium-234	1.86	pCi/g	0.77	Gamma Spec
DT00024	Uranium-235	ND	pCi/g		Gamma Spec
DT00024	Uranium-238	1.86	pCi/g	0.77	Gamma Spec
DT00025	Americium 241	0.089	pCi/g	0.053	NAS-NS-3006
DT00025	Plutonium 238	0.025	pCi/g	0.032	NAS-NA-3058
DT00025	Plutonium 239/240	2.41	pCi/g	0.5	NAS-NA-3058
DT00025	Uranium 234	1.08	pCi/g	0.31	NAS-NA-3050
DT00025	Uranium 235/236	0.051	pCi/g	0.06	NAS-NA-3050
DT00025	Uranium 238	1.21	pCi/g	0.34	NAS-NA-3050

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00026	Americium 241	0.009	pCi/g	0.013	NAS-NS-3006
DT00026	Plutonium 238	-0.004	pCi/g	0.004	NAS-NA-3058
DT00026	Plutonium 239/240	1.31	pCi/g	0.31	NAS-NA-3058
DT00026	Uranium 234	0.42	pCi/g	0.15	NAS-NA-3050
DT00026	Uranium 235/236	0.12	pCi/g	0.08	NAS-NA-3050
DT00026	Uranium 238	0.3	pCi/g	0.12	NAS-NA-3050
DT00028	Actinium 227	2.34	pCi/g	0.45	Gamma Spec
DT00028	Americium 241	0.007	pCi/g	0.017	NAS-NS-3006
DT00028	Americium 241	ND	pCi/g		Gamma Spec
DT00028	Antimony 125	ND	pCi/g		Gamma Spec
DT00028	Barium-133	ND	pCi/g		Gamma Spec
DT00028	Bismuth 214	1.34	pCi/g	0.17	Gamma Spec
DT00028	Cesium 137	0.31	pCi/g	0.07	Gamma Spec
DT00028	Cobalt 60	ND	pCi/g		Gamma Spec
DT00028	Europium 152	ND	pCi/g		Gamma Spec
DT00028	Europium 154	ND	pCi/g		Gamma Spec
DT00028	Europium 155	ND	pCi/g		Gamma Spec
DT00028	Lead 210	ND	pCi/g		Gamma Spec
DT00028	Lead 212	1.9	pCi/g	0.21	Gamma Spec
DT00028	Plutonium 238	0.004	pCi/g	0.018	NAS-NA-3058
DT00028	Plutonium 239/240	0.077	pCi/g	0.053	NAS-NA-3058
DT00028	Potassium 40	31.9	pCi/g	3.6	Gamma Spec
DT00028	Protactinium-231	ND	pCi/g		Gamma Spec
DT00028	Protactinium-234	ND	pCi/g		Gamma Spec
DT00028	Radium-223	ND	pCi/g		Gamma Spec
DT00028	Radium-226	1.38	pCi/g	0.11	Gamma Spec
DT00028	Thallium 208	0.64	pCi/g	0.09	Gamma Spec
DT00028	Thorium-232	1.73	pCi/g	0.23	Gamma Spec
DT00028	Uranium 234	0.72	pCi/g	0.24	NAS-NA-3050
DT00028	Uranium 235/236	0	pCi/g	0	NAS-NA-3050
DT00028	Uranium 238	0.68	pCi/g	0.23	NAS-NA-3050
DT00028	Uranium-234	ND	pCi/g		Gamma Spec
DT00028	Uranium-235	ND	pCi/g		Gamma Spec
DT00028	Uranium-238	ND	pCi/g		Gamma Spec
DT00029	Americium 241	0.03	pCi/g	0.03	NAS-NS-3006
DT00029	Plutonium 238	-0.007	pCi/g	0.005	NAS-NA-3058
DT00029	Plutonium 239/240	0.035	pCi/g	0.038	NAS-NA-3058
DT00029	Uranium 234	1.01	pCi/g	0.31	NAS-NA-3050
DT00029	Uranium 235/236	0.16	pCi/g	0.11	NAS-NA-3050
DT00029	Uranium 238	1	pCi/g	0.31	NAS-NA-3050
DT00030	Americium 241	-0.011	pCi/g	0.007	NAS-NS-3006
DT00030	Plutonium 238	-0.003	pCi/g	0.003	NAS-NA-3058
DT00030	Plutonium 239/240	-0.002	pCi/g	0.003	NAS-NA-3058
DT00030	Uranium 234	1.07	pCi/g	0.3	NAS-NA-3050
DT00030	Uranium 235/236	0.082	pCi/g	0.075	NAS-NA-3050
DT00030	Uranium 238	1.07	pCi/g	0.31	NAS-NA-3050
DT00032	Actinium 227	4.46	pCi/g	0.68	Gamma Spec
DT00032	Americium 241	0.076	pCi/g	0.059	NAS-NS-3006
DT00032	Americium 241	3.17	pCi/g	0.49	Gamma Spec
DT00032	Antimony 125	ND	pCi/g		Gamma Spec

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00032	Barium-133	ND	pCi/g		Gamma Spec
DT00032	Bismuth 214	1.09	pCi/g	0.16	Gamma Spec
DT00032	Cesium 137	0.29	pCi/g	0.05	Gamma Spec
DT00032	Cobalt 60	ND	pCi/g		Gamma Spec
DT00032	Europium 152	ND	pCi/g		Gamma Spec
DT00032	Europium 154	ND	pCi/g		Gamma Spec
DT00032	Europium 155	ND	pCi/g		Gamma Spec
DT00032	Lead 210	ND	pCi/g		Gamma Spec
DT00032	Lead 212	1.88	pCi/g	0.19	Gamma Spec
DT00032	Plutonium 238	-0.012	pCi/g	0.007	NAS-NA-3058
DT00032	Plutonium 239/240	0.66	pCi/g	0.19	NAS-NA-3058
DT00032	Potassium 40	30.8	pCi/g	3.5	Gamma Spec
DT00032	Protactinium-231	ND	pCi/g		Gamma Spec
DT00032	Protactinium-234	ND	pCi/g		Gamma Spec
DT00032	Radium-223	ND	pCi/g		Gamma Spec
DT00032	Radium-226	1.12	pCi/g	0.1	Gamma Spec
DT00032	Thallium 208	0.61	pCi/g	0.07	Gamma Spec
DT00032	Thorium-232	1.72	pCi/g	0.28	Gamma Spec
DT00032	Uranium 234	1.13	pCi/g	0.31	NAS-NA-3050
DT00032	Uranium 235/236	0.077	pCi/g	0.07	NAS-NA-3050
DT00032	Uranium 238	1.07	pCi/g	0.3	NAS-NA-3050
DT00032	Uranium-234	1.81	pCi/g	0.59	Gamma Spec
DT00032	Uranium-235	ND	pCi/g		Gamma Spec
DT00032	Uranium-238	1.81	pCi/g	0.59	Gamma Spec
DT00033	Americium 241	0.012	pCi/g	0.017	NAS-NS-3006
DT00033	Plutonium 238	-0.003	pCi/g	0.003	NAS-NA-3058
DT00033	Plutonium 239/240	0.31	pCi/g	0.12	NAS-NA-3058
DT00033	Uranium 234	1.03	pCi/g	0.29	NAS-NA-3050
DT00033	Uranium 235/236	0.063	pCi/g	0.064	NAS-NA-3050
DT00033	Uranium 238	0.94	pCi/g	0.27	NAS-NA-3050
DT00034	Americium 241	0.048	pCi/g	0.034	NAS-NS-3006
DT00034	Plutonium 238	0.004	pCi/g	0.018	NAS-NA-3058
DT00034	Plutonium 239/240	0.039	pCi/g	0.04	NAS-NA-3058
DT00034	Uranium 234	0.9	pCi/g	0.27	NAS-NA-3050
DT00034	Uranium 235/236	0.046	pCi/g	0.06	NAS-NA-3050
DT00034	Uranium 238	1.01	pCi/g	0.3	NAS-NA-3050
DT00036	Actinium 227	1.52	pCi/g	0.31	Gamma Spec
DT00036	Americium 241	2.27	pCi/g	0.45	NAS-NS-3006
DT00036	Americium 241	4.16	pCi/g	1.05	Gamma Spec
DT00036	Antimony 125	ND	pCi/g		Gamma Spec
DT00036	Barium-133	ND	pCi/g		Gamma Spec
DT00036	Bismuth 214	1.29	pCi/g	0.13	Gamma Spec
DT00036	Cesium 137	0.41	pCi/g	0.06	Gamma Spec
DT00036	Cobalt 60	ND	pCi/g		Gamma Spec
DT00036	Europium 152	ND	pCi/g		Gamma Spec
DT00036	Europium 154	ND	pCi/g		Gamma Spec
DT00036	Europium 155	ND	pCi/g		Gamma Spec
DT00036	Lead 210	ND	pCi/g		Gamma Spec
DT00036	Lead 212	1.88	pCi/g	0.19	Gamma Spec
DT00036	Plutonium 238	0.18	pCi/g	0.06	NAS-NA-3058

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00036	Plutonium 239/240	29.3	pCi/g	4.6	NAS-NA-3058
DT00036	Potassium 40	32.6	pCi/g	3.5	Gamma Spec
DT00036	Protactinium-231	ND	pCi/g		Gamma Spec
DT00036	Protactinium-234	ND	pCi/g		Gamma Spec
DT00036	Radium-223	ND	pCi/g		Gamma Spec
DT00036	Radium-226	1.36	pCi/g	0.09	Gamma Spec
DT00036	Thallium 208	0.62	pCi/g	0.07	Gamma Spec
DT00036	Thorium-232	1.74	pCi/g	0.21	Gamma Spec
DT00036	Uranium 234	0.81	pCi/g	0.19	NAS-NA-3050
DT00036	Uranium 235/236	0.046	pCi/g	0.039	NAS-NA-3050
DT00036	Uranium 238	0.82	pCi/g	0.19	NAS-NA-3050
DT00036	Uranium-234	ND	pCi/g		Gamma Spec
DT00036	Uranium-235	ND	pCi/g		Gamma Spec
DT00036	Uranium-238	ND	pCi/g		Gamma Spec
DT00037	Americium 241	0.03	pCi/g	0.015	NAS-NS-3006
DT00037	Plutonium 238	0.015	pCi/g	0.011	NAS-NA-3058
DT00037	Plutonium 239/240	1.17	pCi/g	0.21	NAS-NA-3058
DT00037	Uranium 234	0.98	pCi/g	0.21	NAS-NA-3050
DT00037	Uranium 235/236	0.064	pCi/g	0.039	NAS-NA-3050
DT00037	Uranium 238	0.87	pCi/g	0.19	NAS-NA-3050
DT00038	Americium 241	0.016	pCi/g	0.011	NAS-NS-3006
DT00038	Plutonium 238	0.001	pCi/g	0.013	NAS-NA-3058
DT00038	Plutonium 239/240	0.02	pCi/g	0.02	NAS-NA-3058
DT00038	Uranium 234	1.3	pCi/g	0.3	NAS-NA-3050
DT00038	Uranium 235/236	0.035	pCi/g	0.042	NAS-NA-3050
DT00038	Uranium 238	1.18	pCi/g	0.28	NAS-NA-3050
DT00040	Actinium 227	4.34	pCi/g	0.67	Gamma Spec
DT00040	Americium 241	17.1	pCi/g	3.1	NAS-NS-3006
DT00040	Americium 241	21.3	pCi/g	3.8	Gamma Spec
DT00040	Americium 241	64.3	pCi/g	9.4	Gamma Spec
DT00040	Antimony 125	ND	pCi/g		Gamma Spec
DT00040	Barium-133	ND	pCi/g		Gamma Spec
DT00040	Bismuth 214	1.15	pCi/g	0.17	Gamma Spec
DT00040	Cesium 137	0.33	pCi/g	0.06	Gamma Spec
DT00040	Cobalt 60	ND	pCi/g		Gamma Spec
DT00040	Europium 152	ND	pCi/g		Gamma Spec
DT00040	Europium 154	ND	pCi/g		Gamma Spec
DT00040	Europium 155	ND	pCi/g		Gamma Spec
DT00040	Lead 210	17.4	pCi/g	6.1	Gamma Spec
DT00040	Lead 212	1.98	pCi/g	0.2	Gamma Spec
DT00040	Plutonium 238	2.4	pCi/g	1.38	NAS-NA-3058
DT00040	Plutonium 239/240	341	pCi/g	58	NAS-NA-3058
DT00040	Potassium 40	32.1	pCi/g	3.7	Gamma Spec
DT00040	Protactinium-231	ND	pCi/g		Gamma Spec
DT00040	Protactinium-234	0.33	pCi/g	0.13	Gamma Spec
DT00040	Radium-223	ND	pCi/g		Gamma Spec
DT00040	Radium-226	1.18	pCi/g	0.11	Gamma Spec
DT00040	Thallium 208	0.69	pCi/g	0.08	Gamma Spec
DT00040	Thorium-232	1.95	pCi/g	0.31	Gamma Spec
DT00040	Total Uranium	2.56	ug/g	0.27	ASTM 5174-91

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00040	Uranium 234	1.11	pCi/g	0.25	NAS-NA-3050
DT00040	Uranium 235/236	0.08	pCi/g	0.05	NAS-NA-3050
DT00040	Uranium 238	0.86	pCi/g	0.2	NAS-NA-3050
DT00040	Uranium-234	1.9	pCi/g	0.62	Gamma Spec
DT00040	Uranium-235	ND	pCi/g		Gamma Spec
DT00040	Uranium-238	1.9	pCi/g	0.62	Gamma Spec
DT00040 RE	Americium 241	8.63	pCi/g	3.37	NAS-NS-3006
DT00040 RE	Plutonium 238	2.44	pCi/g	1.46	NAS-NS-3058
DT00040 RE	Plutonium 239/240	292	pCi/g	51	NAS-NS-3058
DT00041	Americium 241	0.18	pCi/g	0.05	NAS-NS-3006
DT00041	Plutonium 238	0.26	pCi/g	0.47	NAS-NA-3058
DT00041	Plutonium 239/240	0.82	pCi/g	0.75	NAS-NA-3058
DT00041	Uranium 234	0.78	pCi/g	0.19	NAS-NA-3050
DT00041	Uranium 235/236	0.046	pCi/g	0.036	NAS-NA-3050
DT00041	Uranium 238	0.66	pCi/g	0.17	NAS-NA-3050
DT00042	Americium 241	0.14	pCi/g	0.04	NAS-NS-3006
DT00042	Plutonium 238	0.003	pCi/g	0.013	NAS-NA-3058
DT00042	Plutonium 239/240	0.27	pCi/g	0.08	NAS-NA-3058
DT00042	Uranium 234	0.79	pCi/g	0.2	NAS-NA-3050
DT00042	Uranium 235/236	0.043	pCi/g	0.039	NAS-NA-3050
DT00042	Uranium 238	0.92	pCi/g	0.22	NAS-NA-3050
DT00043	Americium 241	1.42	pCi/g	0.42	NAS-NS-3006
DT00043	Plutonium 238	0.21	pCi/g	0.04	NAS-NA-3058
DT00043	Plutonium 239/240	30.8	pCi/g	4.8	NAS-NA-3058
DT00043	Uranium 234	1.24	pCi/g	0.27	NAS-NA-3050
DT00043	Uranium 235/236	0.032	pCi/g	0.034	NAS-NA-3050
DT00043	Uranium 238	1.06	pCi/g	0.24	NAS-NA-3050
DT00045	Actinium 227	ND	pCi/g		Gamma Spec
DT00045	Americium 241	0.081	pCi/g	0.052	NAS-NS-3006
DT00045	Americium 241	1.3	pCi/g	0.16	Gamma Spec
DT00045	Antimony 125	ND	pCi/g		Gamma Spec
DT00045	Barium-133	ND	pCi/g		Gamma Spec
DT00045	Bismuth 214	1.24	pCi/g	0.16	Gamma Spec
DT00045	Cesium 137	0.29	pCi/g	0.05	Gamma Spec
DT00045	Cobalt 60	ND	pCi/g		Gamma Spec
DT00045	Europium 152	ND	pCi/g		Gamma Spec
DT00045	Europium 154	ND	pCi/g		Gamma Spec
DT00045	Europium 155	ND	pCi/g		Gamma Spec
DT00045	Lead 210	1.66	pCi/g	0.55	Gamma Spec
DT00045	Lead 212	1.69	pCi/g	0.17	Gamma Spec
DT00045	Plutonium 238	0.007	pCi/g	0.016	NAS-NA-3058
DT00045	Plutonium 239/240	2.33	pCi/g	0.47	NAS-NA-3058
DT00045	Potassium 40	32	pCi/g	3.3	Gamma Spec
DT00045	Protactinium-231	ND	pCi/g		Gamma Spec
DT00045	Protactinium-234	ND	pCi/g		Gamma Spec
DT00045	Radium-223	ND	pCi/g		Gamma Spec
DT00045	Radium-226	1.28	pCi/g	0.09	Gamma Spec
DT00045	Thallium 208	0.67	pCi/g	0.08	Gamma Spec
DT00045	Thorium-232	1.84	pCi/g	0.2	Gamma Spec
DT00045	Uranium 234	1.15	pCi/g	0.39	NAS-NA-3050

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00045	Uranium 235/236	0.57	pCi/g	0.28	NAS-NA-3050
DT00045	Uranium 238	1.11	pCi/g	0.38	NAS-NA-3050
DT00045	Uranium-234	1.07	pCi/g	0.49	Gamma Spec
DT00045	Uranium-235	ND	pCi/g		Gamma Spec
DT00045	Uranium-238	1.07	pCi/g	0.49	Gamma Spec
DT00046	Americium 241	0.19	pCi/g	0.07	NAS-NS-3006
DT00046	Plutonium 238	0.006	pCi/g	0.014	NAS-NA-3058
DT00046	Plutonium 239/240	0.68	pCi/g	0.18	NAS-NA-3058
DT00046	Uranium 234	3.43	pCi/g	0.79	NAS-NA-3050
DT00046	Uranium 235/236	2.18	pCi/g	0.56	NAS-NA-3050
DT00046	Uranium 238	3.12	pCi/g	0.73	NAS-NA-3050
DT00047	Americium 241	0.17	pCi/g	0.07	NAS-NS-3006
DT00047	Plutonium 238	-0.008	pCi/g	0.005	NAS-NA-3058
DT00047	Plutonium 239/240	0.11	pCi/g	0.06	NAS-NA-3058
DT00047	Uranium 234	1.29	pCi/g	0.35	NAS-NA-3050
DT00047	Uranium 235/236	0.082	pCi/g	0.075	NAS-NA-3050
DT00047	Uranium 238	1	pCi/g	0.29	NAS-NA-3050
DT00049	Actinium 227	ND	pCi/g		Gamma Spec
DT00049	Americium 241	0.053	pCi/g	0.026	NAS-NS-3006
DT00049	Americium 241	0.64	pCi/g	0.09	Gamma Spec
DT00049	Antimony 125	ND	pCi/g		Gamma Spec
DT00049	Barium-133	ND	pCi/g		Gamma Spec
DT00049	Bismuth 214	1.38	pCi/g	0.14	Gamma Spec
DT00049	Cesium 137	0.46	pCi/g	0.07	Gamma Spec
DT00049	Cobalt 60	ND	pCi/g		Gamma Spec
DT00049	Europium 152	ND	pCi/g		Gamma Spec
DT00049	Europium 154	ND	pCi/g		Gamma Spec
DT00049	Europium 155	ND	pCi/g		Gamma Spec
DT00049	Lead 210	1.39	pCi/g	0.49	Gamma Spec
DT00049	Lead 212	1.94	pCi/g	0.15	Gamma Spec
DT00049	Plutonium 238	0.034	pCi/g	0.026	NAS-NA-3058
DT00049	Plutonium 239/240	2.23	pCi/g	0.39	NAS-NA-3058
DT00049	Potassium 40	33.5	pCi/g	3.3	Gamma Spec
DT00049	Protactinium-231	ND	pCi/g		Gamma Spec
DT00049	Protactinium-234	0.17	pCi/g	0.09	Gamma Spec
DT00049	Radium-223	ND	pCi/g		Gamma Spec
DT00049	Radium-226	1.34	pCi/g	0.09	Gamma Spec
DT00049	Thallium 208	0.61	pCi/g	0.07	Gamma Spec
DT00049	Thorium-232	1.75	pCi/g	0.19	Gamma Spec
DT00049	Uranium 234	1.11	pCi/g	0.24	NAS-NA-3050
DT00049	Uranium 235/236	0.11	pCi/g	0.06	NAS-NA-3050
DT00049	Uranium 238	0.94	pCi/g	0.21	NAS-NA-3050
DT00049	Uranium-234	1.24	pCi/g	0.53	Gamma Spec
DT00049	Uranium-235	ND	pCi/g		Gamma Spec
DT00049	Uranium-238	1.24	pCi/g	0.53	Gamma Spec
DT00049 RE	Americium 241	0.035	pCi/g	0.019	NAS-NS-3006
DT00049 RE	Plutonium 238	0.009	pCi/g	0.008	NAS-NS-3058
DT00049 RE	Plutonium 239/240	0.63	pCi/g	0.12	NAS-NS-3058
DT00050	Americium 241	0.056	pCi/g	0.023	NAS-NS-3006
DT00050	Plutonium 238	0.007	pCi/g	0.014	NAS-NA-3058

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00050	Plutonium 239/240	0.11	pCi/g	0.05	NAS-NA-3058
DT00050	Uranium 234	0.99	pCi/g	0.23	NAS-NA-3050
DT00050	Uranium 235/236	0.085	pCi/g	0.056	NAS-NA-3050
DT00050	Uranium 238	0.97	pCi/g	0.23	NAS-NA-3050
DT00051	Americium 241	0.086	pCi/g	0.028	NAS-NS-3006
DT00051	Plutonium 238	0.025	pCi/g	0.025	NAS-NA-3058
DT00051	Plutonium 239/240	0.036	pCi/g	0.028	NAS-NA-3058
DT00051	Uranium 234	1.15	pCi/g	0.25	NAS-NA-3050
DT00051	Uranium 235/236	0.17	pCi/g	0.08	NAS-NA-3050
DT00051	Uranium 238	0.93	pCi/g	0.22	NAS-NA-3050
DT00001	Actinium 227	ND	pCi/l		Gamma Spec
DT00001	Americium 241	0.012	pCi/l	0.062	NAS-NS-3006
DT00001	Americium 241	ND	pCi/l		Gamma Spec
DT00001	Antimony 125	ND	pCi/l		Gamma Spec
DT00001	Barium-133	ND	pCi/l		Gamma Spec
DT00001	Bismuth 214	14.4	pCi/l	8.2	Gamma Spec
DT00001	Cesium 137	ND	pCi/l		Gamma Spec
DT00001	Cobalt 60	ND	pCi/l		Gamma Spec
DT00001	Europium 152	ND	pCi/l		Gamma Spec
DT00001	Europium 154	ND	pCi/l		Gamma Spec
DT00001	Europium 155	ND	pCi/l		Gamma Spec
DT00001	Lead 210	208	pCi/l	54	Gamma Spec
DT00001	Lead 212	10.5	pCi/l	6	Gamma Spec
DT00001	Plutonium 238	0.13	pCi/l	0.1	NAS-NS-3058
DT00001	Plutonium 239/240	0.15	pCi/l	0.09	NAS-NS-3058
DT00001	Potassium 40	ND	pCi/l		Gamma Spec
DT00001	Protactinium-231	ND	pCi/l		Gamma Spec
DT00001	Protactinium-234	ND	pCi/l		Gamma Spec
DT00001	Radium-223	ND	pCi/l		Gamma Spec
DT00001	Radium-226	14.4	pCi/l	8.2	Gamma Spec
DT00001	Thallium 208	ND	pCi/l		Gamma Spec
DT00001	Thorium-232	ND	pCi/l		Gamma Spec
DT00001	Uranium 234	-0.06	pCi/l	0.08	NAS-NA-3050
DT00001	Uranium 235/236	1.03	pCi/l	2.16	NAS-NA-3050
DT00001	Uranium 238	-0.08	pCi/l	0.09	NAS-NA-3050
DT00001	Uranium-234	397	pCi/l	74	Gamma Spec
DT00001	Uranium-235	ND	pCi/l		Gamma Spec
DT00001	Uranium-238	397	pCi/l	74	Gamma Spec
DT00001 RE	Uranium 234	0.14	pCi/l	0.21	NAS-NA-3050
DT00001 RE	Uranium 235/236	0.089	pCi/l	0.18	NAS-NA-3050
DT00001 RE	Uranium 238	0	pCi/l	0	NAS-NA-3050
DT00053	Actinium 227	ND	pCi/l		Gamma Spec
DT00053	Americium 241	0.095	pCi/l	0.1	NAS-NS-3006
DT00053	Americium 241	ND	pCi/l		Gamma Spec
DT00053	Antimony 125	ND	pCi/l		Gamma Spec
DT00053	Barium-133	ND	pCi/l		Gamma Spec
DT00053	Bismuth 214	ND	pCi/l		Gamma Spec
DT00053	Cesium 137	ND	pCi/l		Gamma Spec
DT00053	Cobalt 60	ND	pCi/l		Gamma Spec
DT00053	Europium 152	ND	pCi/l		Gamma Spec

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
DT00053	Europium 154	ND	pCi/l		Gamma Spec
DT00053	Europium 155	ND	pCi/l		Gamma Spec
DT00053	Lead 210	ND	pCi/l		Gamma Spec
DT00053	Lead 212	ND	pCi/l		Gamma Spec
DT00053	Plutonium 238	0.005	pCi/l	0.014	NAS-NS-3058
DT00053	Plutonium 239/240	-0.002	pCi/l	0.011	NAS-NS-3058
DT00053	Potassium 40	ND	pCi/l		Gamma Spec
DT00053	Protactinium-231	ND	pCi/l		Gamma Spec
DT00053	Protactinium-234	ND	pCi/l		Gamma Spec
DT00053	Radium-223	ND	pCi/l		Gamma Spec
DT00053	Radium-226	ND	pCi/l		Gamma Spec
DT00053	Thallium 208	ND	pCi/l		Gamma Spec
DT00053	Thorium-232	ND	pCi/l		Gamma Spec
DT00053	Uranium 234	0.23	pCi/l	0.34	NAS-NA-3050
DT00053	Uranium 235/236	0	pCi/l	0.01	NAS-NA-3050
DT00053	Uranium 238	0.12	pCi/l	0.24	NAS-NA-3050
DT00053	Uranium-234	434	pCi/l	70	Gamma Spec
DT00053	Uranium-235	23.5	pCi/l	13.2	Gamma Spec
DT00053	Uranium-238	434	pCi/l	70	Gamma Spec
DT00054	Actinium 227	ND	pCi/l		Gamma Spec
DT00054	Americium 241	-0.035	pCi/l	0.036	NAS-NS-3006
DT00054	Americium 241	ND	pCi/l		Gamma Spec
DT00054	Antimony 125	ND	pCi/l		Gamma Spec
DT00054	Barium-133	ND	pCi/l		Gamma Spec
DT00054	Bismuth 214	14.8	pCi/l	6.8	Gamma Spec
DT00054	Cesium 137	ND	pCi/l		Gamma Spec
DT00054	Cobalt 60	ND	pCi/l		Gamma Spec
DT00054	Europium 152	ND	pCi/l		Gamma Spec
DT00054	Europium 154	ND	pCi/l		Gamma Spec
DT00054	Europium 155	ND	pCi/l		Gamma Spec
DT00054	Lead 210	ND	pCi/l		Gamma Spec
DT00054	Lead 212	ND	pCi/l		Gamma Spec
DT00054	Plutonium 238	0.006	pCi/l	0.018	NAS-NS-3058
DT00054	Plutonium 239/240	0.02	pCi/l	0.021	NAS-NS-3058
DT00054	Potassium 40	ND	pCi/l		Gamma Spec
DT00054	Protactinium-231	ND	pCi/l		Gamma Spec
DT00054	Protactinium-234	ND	pCi/l		Gamma Spec
DT00054	Radium-223	ND	pCi/l		Gamma Spec
DT00054	Radium-226	14.8	pCi/l	6.8	Gamma Spec
DT00054	Thallium 208	ND	pCi/l		Gamma Spec
DT00054	Thorium-232	ND	pCi/l		Gamma Spec
DT00054	Uranium 234	0.37	pCi/l	0.31	NAS-NA-3050
DT00054	Uranium 235/236	0	pCi/l	0	NAS-NA-3050
DT00054	Uranium 238	0.06	pCi/l	0.12	NAS-NA-3050
DT00054	Uranium-234	412	pCi/l	73	Gamma Spec
DT00054	Uranium-235	ND	pCi/l		Gamma Spec
DT00054	Uranium-238	412	pCi/l	73	Gamma Spec
QCBLK	Americium 241	0.002	pCi/g	0.006	NAS-NS-3006
QCBLK	Americium 241	0.026	pCi/g	0.032	NAS-NS-3006
QCBLK	Americium 241	0.03	pCi/g	0.042	NAS-NS-3006

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
QCBLK	Americium 241	0.094	pCi/g	0.137	NAS-NS-3006
QCBLK	Americium 241	0.001	pCi/g	0.004	NAS-NS-3006
QCBLK	Plutonium 238	0	pCi/g	0	NAS-NS-3058
QCBLK	Plutonium 238	-0.005	pCi/g	0.019	NAS-NS-3058
QCBLK	Plutonium 238	0.001	pCi/g	0.019	NAS-NS-3058
QCBLK	Plutonium 238	0.009	pCi/g	0.016	NAS-NS-3058
QCBLK	Plutonium 238	-0.26	pCi/g	0.18	NAS-NS-3058
QCBLK	Plutonium 238	0.001	pCi/g	0.004	NAS-NS-3058
QCBLK	Plutonium 239/240	0.001	pCi/g	0.003	NAS-NS-3058
QCBLK	Plutonium 239/240	-0.002	pCi/g	0.017	NAS-NS-3058
QCBLK	Plutonium 239/240	0.02	pCi/g	0.031	NAS-NS-3058
QCBLK	Plutonium 239/240	-0.001	pCi/g	0.002	NAS-NS-3058
QCBLK	Plutonium 239/240	-0.21	pCi/g	0.16	NAS-NS-3058
QCBLK	Plutonium 239/240	0.001	pCi/g	0.004	NAS-NS-3058
QCBLK	Total Uranium	ND	ug/g	NA	ASTM 5174-91
QCBLK	Uranium-234	1.23	pCi/g	0.39	NAS-NA-3050
QCBLK	Uranium-234	0.034	pCi/g	0.037	NAS-NA-3050
QCBLK	Uranium-234	0.006	pCi/g	0.012	NAS-NA-3050
QCBLK	Uranium-234	0.11	pCi/g	0.21	NAS-NA-3050
QCBLK	Uranium-234	0.05	pCi/g	0.11	NAS-NA-3050
QCBLK	Uranium-235/236	0.073	pCi/g	0.086	NAS-NA-3050
QCBLK	Uranium-235/236	0.022	pCi/g	0.03	NAS-NA-3050
QCBLK	Uranium-235/236	0.003	pCi/g	0.01	NAS-NA-3050
QCBLK	Uranium-235/236	-0.027	pCi/g	0.031	NAS-NA-3050
QCBLK	Uranium-235/236	0.06	pCi/g	0.14	NAS-NA-3050
QCBLK	Uranium-238	0.99	pCi/g	0.34	NAS-NA-3050
QCBLK	Uranium-238	0	pCi/g	0	NAS-NA-3050
QCBLK	Uranium-238	0	pCi/g	0.001	NAS-NA-3050
QCBLK	Uranium-238	0.29	pCi/g	0.29	NAS-NA-3050
QCBLK	Uranium-238	0	pCi/g	0	NAS-NA-3050
QCLCS	Americium 241	91	% Recovery	NA	NAS-NS-3006
QCLCS	Americium 241	81	% Recovery	NA	NAS-NS-3006
QCLCS	Americium 241	95	% Recovery	NA	NAS-NS-3006
QCLCS	Americium 241	85	% Recovery	NA	NAS-NS-3006
QCLCS	Americium 241	99	% Recovery	NA	NAS-NS-3006
QCLCS	Americium 241	93	% Recovery	NA	Gamma Spec
QCLCS	Americium 241	90	% Recovery	NA	Gamma Spec
QCLCS	Cesium 137	105	% Recovery	NA	Gamma Spec
QCLCS	Cesium 137	104	% Recovery	NA	Gamma Spec
QCLCS	Cobalt 60	99	% Recovery	NA	Gamma Spec
QCLCS	Cobalt 60	103	% Recovery	NA	Gamma Spec
QCLCS	Plutonium 238	98	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 238	96	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 238	96	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 238	97	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 238	101	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 238	95	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 239/240	112	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 239/240	101	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 239/240	104	% Recovery	NA	NAS-NS-3058

Appendix C
Isotopic Laboratory Analytical Results in Soil
First Characterization Event

Sample Number	Isotope	Result	Units	2 Sigma	Analytical Method
QCLCS	Plutonium 239/240	99	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 239/240	106	% Recovery	NA	NAS-NS-3058
QCLCS	Plutonium 239/240	96	% Recovery	NA	NAS-NS-3058
QCLCS	Total Uranium	83	% Recovery	NA	ASTM 5174-91
QCLCS	Uranium-234	103	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-234	137	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-234	126	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-234	148	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-234	124	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-238	156	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-238	125	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-238	134	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-238	132	% Recovery	NA	NAS-NA-3050
QCLCS	Uranium-238	131	% Recovery	NA	NAS-NA-3050

Dup - Duplicate sample

RE - Sample reanalyzed (counted)

ND - Not Detected

NA - Not Applicable

milligram/kilogram (mg/kg) or parts per million (ppm)

Appendix C
Laboratory Results of Toxic Characteristic Leaching Procedures
(Hot Spot Samples)
Second Characterization Event

Sample Number	Analyte	Units	Result	Qualifiers	Detection Limit
DT00100	Arsenic	mg/l	0.0078		0.005
DT00100	Barium	mg/l	0.4		0.01
DT00100	Cadmium	mg/l	0.0024	U	0.005
DT00100	Chromium	mg/l	0.0047	U	0.01
DT00100	Lead	mg/l	0.0077		0.003
DT00100	Selenium	mg/l	0.0096		0.005
DT00100	Silver	mg/l	0.0041	U	0.01
DT00100	Mercury	mg/l	0.0001	U	0.0002
DT00102	Arsenic	mg/l	0.0074		0.005
DT00102	Barium	mg/l	0.43		0.01
DT00102	Cadmium	mg/l	0.0024	U	0.005
DT00102	Chromium	mg/l	0.0047	U	0.01
DT00102	Lead	mg/l	0.005		0.003
DT00102	Selenium	mg/l	0.0096		0.005
DT00102	Silver	mg/l	0.0041	U	0.01
DT00102	Mercury	mg/l	0.00029		0.0002
DT00103	Arsenic	mg/l	0.0092		0.005
DT00103	Barium	mg/l	0.39		0.01
DT00103	Cadmium	mg/l	0.0024	U	0.005
DT00103	Chromium	mg/l	0.0047	U	0.01
DT00103	Lead	mg/l	0.002	B	0.003
DT00103	Selenium	mg/l	0.0091		0.005
DT00103	Silver	mg/l	0.0041	U	0.01
DT00103	Mercury	mg/l	0.00012	B	0.0002
DT00104	Arsenic	mg/l	0.0061		0.005
DT00104	Barium	mg/l	0.044		0.01
DT00104	Cadmium	mg/l	0.0024	U	0.005
DT00104	Chromium	mg/l	0.0047	U	0.01
DT00104	Lead	mg/l	0.0022	B	0.003
DT00104	Selenium	mg/l	0.0096		0.005
DT00104	Silver	mg/l	0.0041	U	0.01
DT00104	Mercury	mg/l	0.00016	B	0.0002
Extraction Blank	Arsenic	mg/l	0.003	B	0.005
Extraction Blank	Barium	mg/l	0.0034	B	0.01
Extraction Blank	Cadmium	mg/l	0.0024	U	0.005
Extraction Blank	Chromium	mg/l	0.0047	U	0.01
Extraction Blank	Lead	mg/l	0.0015	B	0.003
Extraction Blank	Selenium	mg/l	0.0035	U	0.005
Extraction Blank	Silver	mg/l	0.0041	U	0.01
Extraction Blank	Mercury	mg/l	0.0001	U	0.0002

Appendix C
Laboratory Results of Toxic Characteristic Leaching Procedures
(Hot Spot Samples)
Second Characterization Event

Sample Number	Analyte	Units	Result	Qualifiers	Detection Limit
QC Blank	Arsenic	mg/l	0.0018	U	0.005
QC Blank	Barium	mg/l	0.0013	U	0.01
QC Blank	Cadmium	mg/l	0.0024	U	0.005
QC Blank	Chromium	mg/l	0.0047	U	0.01
QC Blank	Lead	mg/l	0.0011	U	0.003
QC Blank	Selenium	mg/l	0.0025	U	0.005
QC Blank	Silver	mg/l	0.0041	U	0.01
QC Blank	Mercury	mg/l	0.0001	U	0.0002
QC Blank	Arsenic	mg/l	0.0018	U	0.005
QC Blank	Barium	mg/l	0.0013	B	0.01
QC Blank	Cadmium	mg/l	0.0024	U	0.005
QC Blank	Chromium	mg/l	0.0047	U	0.01
QC Blank	Lead	mg/l	0.0011	U	0.003
QC Blank	Selenium	mg/l	0.0025	U	0.005
QC Blank	Silver	mg/l	0.0041	U	0.01
QC Blank	Mercury	mg/l	0.0001	U	0.0002
QCLCS	Arsenic	percent	108		
QCLCS	Barium	percent	98		
QCLCS	Cadmium	percent	105		
QCLCS	Chromium	percent	104		
QCLCS	Lead	percent	102		
QCLCS	Selenium	percent	108		
QCLCS	Silver	percent	85		
QCLCS	Mercury	percent	111		
QCLCS	Arsenic	percent	110		
QCLCS	Barium	percent	101		
QCLCS	Cadmium	percent	107		
QCLCS	Chromium	percent	106		
QCLCS	Lead	percent	105		
QCLCS	Selenium	percent	105		
QCLCS	Silver	percent	86		
QCLCS	Mercury	percent	113		

Qualifiers

U - Analyte was analyzed for but not detected

B - Reported value was obtained from a reading that was less than the required detection limit but greater than the instrument detection limit.

milligram/kilogram (mg/kg) or parts per million (ppm)
microgram/kilogram (ug/kg) or parts per billion (ppb)

Appendix C
Isotopic Laboratory Analytical Results in Soil
(Hot Spot Samples)
Second Characterization Event

Sample Number	Analyte	Units	Result	2-sigma	MDA
DT00100	Plutonium 239/240	pCi/g	12000	2030	2
DT00100	Plutonium 238	pCi/g	90	22.5	3
DT00100	Americium 241	pCi/g	734	163	5
DT00100	Total Uranium	ppm	3.5	0.37	0.005
DT00100 Dup	Plutonium 239/240	pCi/g	10600	1870	4
DT00100 Dup	Plutonium 238	pCi/g	101	27	5
DT00100 Dup	Americium 241	pCi/g	656	154	7
DT00100 Dup	Total Uranium	ppm	3.59	0.38	0.005
DT00101	Plutonium 239/240	pCi/g	10800	2010	6
DT00101	Plutonium 238	pCi/g	95	28.5	7
DT00101	Americium 241	pCi/g	567	133	4
DT00101	Total Uranium	ppm	2.63	0.27	0.005
DT00102	Plutonium 239/240	pCi/g	998	200	7
DT00102	Plutonium 238	pCi/g	9.45	7.51	6.22
DT00102	Americium 241	pCi/g	64.6	25	7
DT00102	Total Uranium	ppm	3.92	0.41	0.005
DT00103	Plutonium 239/240	pCi/g	11900	2060	5
DT00103	Plutonium 238	pCi/g	91	23.8	5.1
DT00103	Americium 241	pCi/g	783	172	6
DT00103	Total Uranium	ppm	3.41	0.36	0.005
DT00104	Plutonium 239/240	pCi/g	775	158	8
DT00104	Plutonium 238	pCi/g	10.9	8.2	7.2
DT00104	Americium 241	pCi/g	29.6	12.1	5.1
DT00104	Total Uranium	ppm	2.55	0.27	0.005
DT00105	Plutonium 239/240	pCi/g	183	48	9
DT00105	Plutonium 238	pCi/g	6.1	6.7	10.4
DT00105	Americium 241	pCi/g	10.1	7.3	6.1
DT00105	Total Uranium	ppm	2.12	0.22	0.005
QC Blank	Plutonium 239/240	pCi/g	1.27	0.72	0.35
QC Blank	Plutonium 238	pCi/g	0.058	0.183	0.5
QC Blank	Americium 241	pCi/g	0.1	0.19	0.39
QC Blank	Total Uranium	ppm	ND	NA	0.005
QCLCS	Plutonium 239/240	% recovery	92		
QCLCS	Plutonium 238	% recovery	99		
QCLCS	Americium 241	% recovery	98		
QCLCS	Total Uranium	% recovery	99		

Manimum Detection Activity (MDA)

Dup - Duplicate sample

milligram/kilogram (mg/kg) or parts per million (ppm)

Appendix D

Bechtel Nevada, Remote Sensing Laboratory Report on the Second and Third Characterization Events

IN SITU RADIOLOGICAL SURVEYING AT THE DOUBLE TRACKS SITE

NELLIS AIR FORCE RANGE
TONOPAH, NEVADA

DATES OF SURVEYS: APRIL 10-13, 1995, AND JUNE 5-9, 1995

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, Tennessee 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal, Springfield, Virginia 22161.

IN SITU RADIOLOGICAL SURVEYING AT THE DOUBLE TRACKS SITE

**NELLIS AIR FORCE RANGE
TONOPAH, NEVADA**

DATE OF SURVEY: APRIL 10-13, 1995, AND JUNE 5-9, 1995

**S. R. Riedhauser
W. J. Tipton
Project Scientists**

REVIEWED BY

**H. W. Clark, Jr., Manager
Radiation Science Section**

This Document is UNCLASSIFIED

**T. M. Hayes
Authorized Derivative Classifier**

ABSTRACT

A team from the Remote Sensing Laboratory conducted a series of *in situ* radiological measurements at the Double Tracks site on the Nellis Air Force Range just east of Goldfield, Nevada, during the periods of April 10-13 and June 5-9, 1995. The survey team measured the terrestrial gamma radiation at the site to determine the levels of natural and man-made radiation. This site includes the areas covered by previous surveys conducted from 1962 through 1993.

The main purpose of the first expedition was to assess several new techniques for characterizing sites with dispersed plutonium. The two purposes of the second expedition were to characterize the distribution of transuranic contamination (primarily plutonium) at the site by measuring the gamma rays from americium-241 and to assess the performance of the two new detector platforms. Both of the new platforms performed well, and the characterization of the americium-241 activity at the site was completed.

Several plots compare these ground-based system measurements and the 1993 aerial data. The agreement is good considering the systems are characterized and calibrated through independent means.

During the April expedition, several methods for measuring the depth distribution of americium-241 in the field were conducted as a way of quickly and reliably obtaining depth profiles without the need to wait for laboratory analysis. Two of the methods were not very effective, but the results of the third method appear very promising.

CONTENTS

Abstract	ii
----------------	----

Sections

1.0 Introduction	1
2.0 Survey Site Description	1
3.0 Natural Background Radiation	2
4.0 Survey Equipment and Procedures	2
4.1 Experiment #1 (April)—HPGe <i>In Situ</i> Measurements	4
4.1.1 Suburban Versus Tripod Measurements	4
4.1.2 Measurements South of the Exclusion Fence	4
4.2 Experiment #2 (April)—Pu:Am Ratio Measurements	5
4.3 Experiment #3 (April)—Depth Profiling Measurements	5
4.3.1 Side Wall Measurements with Thermoluminescent Dosimetry Material	6
4.3.2 Comparison Between the Pu X-Rays and the ²⁴¹ Am Gamma Ray	6
4.3.3 Direct HPGe Measurements	7
4.4 Experiment #4 (June)—ATV Hot-Piece Search	7
4.5 Experiment #5 (June)—Kiwi Survey Measurements	8
4.6 Experiment #6 (June)—HPGe <i>In Situ</i> Measurements	9
4.7 Experiment #7 (June)—Hot-Piece Activity Measurements	9
5.0 Data Reduction Procedures	10
5.1 Gross Count Rate Algorithm	10
5.2 Isotope Extraction Algorithms	10
5.2.1 Two-Window Algorithm	11
5.2.2 Three-Window Algorithm	11
5.3 Gridding of Data	12
5.4 Count Rate Conversion to Soil Activity Concentration	12
5.4.1 Distribution of the Isotope in the Soil	12
5.4.2 Derivation of the Conversion Factors	13
5.4.3 Conversion Factors for Selected Isotopes in the Soil	14
5.4.4 Average and Total Activity	14
6.0 Discussion of Results	15

6.1	Experiment #1 (April)—HPGe <i>In Situ</i> Measurements	15
6.1.1	Suburban Versus Tripod Measurements	15
6.1.2	Measurements South of the Exclusion Fence	18
6.1.3	Highest Concentration of TRU Activity	19
6.2	Experiment #2 (April)—Pu:Am Ratio Measurements	20
6.3	Experiment #3 (April)—Depth Profiling Measurements	22
6.3.1	Side Wall Measurements with TLD Material	22
6.3.2	Comparison Between the Pu X-Rays and the ²⁴¹ Am Gamma Ray	23
6.3.3	Direct HPGe Measurements	25
6.4	Experiment #4 (June)—ATV Hot-Piece Search	25
6.5	Experiment #5 (June)—Kiwi Survey Measurements	25
6.6	Experiment #6 (June)—HPGe <i>In Situ</i> Measurements	30
6.7	Experiment #7 (June)—Hot-Piece Activity Measurements	32
7.0	Summary	32

Figures

1	Suburban Vehicle with HPGe Detector on Mast	4
2	ATV with FIDLER Detectors	8
3	Kiwi Vehicle	9
4	Geometry for Radiation Measurements	14
5	Measurement Locations of the Suburban System (April)	17
6	Suburban Versus Tripod Measurements—First Location	19
7	Suburban Versus Tripod Measurements—Second Location	19
8	Suburban Versus Tripod Measurements—Third Location	20
9	Tripod Measurements Made South of the Double Tracks Fence (April)	21
10	Kiwi Point-by-Point Gross Count and TRU Activity Levels	26
11	Kiwi 30-ft Gridded and 30-ft Averaged Gross Count Data	27
12	Kiwi 30-ft Gridded and 30-ft Averaged TRU Activities	28
13	Kiwi 30-ft Gridded and 270-ft Averaged TRU Activities	29
14	Measurement Locations of the Suburban System (June)	33
B-1	Soil Surface Alpha Map with CaSO ₄ Tm (Grain Size 10 to 40 microns)	40

B-2	Plot of Subsurface Alpha Activity	41
B-3	This Plot is Derived from Figure B-2 and Represents the Average Net Signal per Minute Integrated over the TLD Sheet Portion that was Subsurface	42

Tables

1	Suburban Measurements in April	16
2	"Mining" Location Measurements	18
3	Pu:Am Ratio Measurements for the First Method	22
4	Pu:Am Ratio Measurements for the Second Method	23
5	Pu:Am Ratio Calculations from Initial Composition	24
6	Suburban Measurements in June	31
7	Control Point Suburban Measurements in June	34
8	"Pieces" Activity Measurements from June	35
9	Soil Sample Activity Measurements from June	36

Appendix

A	Survey Parameters and Results	37
B	<i>In Situ</i> Measurement of Environmental Alpha Activity at Very High Spatial Resolution and Sensitivity	38
	References	43

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) maintains the Remote Sensing Laboratory (RSL), which provides several systems for measuring terrestrial radiation. In addition to the aerial radiological surveillance systems mounted in either BO-105 helicopters or B-200 airplanes, RSL has several systems for ground-based measurements. During these expeditions, RSL was operated by EG&G Energy Measurements, Inc., (EG&G/EM) under contract to DOE, with bases of operation at Nellis Air Force Base in Las Vegas, Nevada, and at Andrews Air Force Base near Washington, D.C.

The Double Tracks site was previously surveyed by the RSL from helicopter platforms in 1977 and 1993. The DOE requested that International Technology Corporation (IT) characterize the nature and extent of contamination, so that corrective action options could be evaluated. If necessary, the site would be cleaned up prior to its release back to the U.S. Air Force. Teams from the RSL participated in two ground-based expeditions to the Double Tracks site in the first half of 1995.

The first RSL expedition was performed from April 10-13, 1995, using the RSL's Chevrolet Suburban vehicle with a high-purity germanium (HPGe) detector mounted on its 7.5-m (25-ft) mast and two tripod HPGe detector systems. The objectives of this survey were to gather *in situ* radiological data with a set of different instruments at a series of locations within the Double Tracks exclusion zone (fenced area) and to compare this data with similar data collected by previous aerial surveys and by systems fielded by IT and Reynolds Electrical and Engineering Co, Inc. (REECo).

Based on the information acquired during the first trip, a second expedition took place during the week of June 5-9, 1995, when two new detector platforms were field tested. One platform used a set of three Field Instrument for Detection of Low-Energy Radiation (FIDLER) detectors mounted on the front of an all-terrain vehicle (ATV) about one-half meter above the ground. This system was used to search in a systematic manner for pieces of metal which had plutonium (Pu) adhering to their surfaces. The second detector platform fielded during this trip was the standard RSL aerial detection and recording system adapted to a ground-based vehicle and nicknamed the Kiwi. Specifically, a set of sodium iodide (NaI) detectors were mounted on the rear of a Chevrolet Suburban vehicle. As the vehicle moved, individual

gamma-ray spectra were recorded each second to provide complete coverage of the Double Tracks area. The field-of-view of the detector system was approximately 3 m (10 ft) in diameter.

For consistency between this report and the *Double Tracks Test Site Characterization Report* being prepared by IT, the phrase "hot fragment" will refer to any piece of radioactive material larger than 5 μm (0.0002 in). Pieces smaller than this size will be called "hot particles." The term "piece" will refer to either a fragment or a particle. Any piece which is visible to the unaided eye is a fragment.

2.0 SURVEY SITE DESCRIPTION

The Double Tracks site is situated on Stonewall Flat (an arid plain) on the Nellis Air Force Range (NAFR) and is about 25 km (16 mi) east of Goldfield and 35 km (22 mi) southeast of Tonopah, Nevada.¹ Access is through the Tonopah Test Range (TTR). The Double Tracks site has an elevation of approximately 1,500 m (4,900 ft). The area is mostly sandy soil with a thin layer of small gravel on the surface and is covered with small shrubs and some grass. The Double Tracks test involved the detonation of a high explosive near an assembly of Pu and depleted uranium (U) to study the means of dispersal of transuranic (TRU) elements and their uptake in animals. The quantity of depleted U was 4-5 times the quantity of Pu. The test was conducted at 2:55 a.m. on May 15, 1963.

The five-sided fence currently surrounding the Double Tracks site forms the radiation exclusion zone of approximately 18 hectares (2 million ft²). This fence was established several years after the test and the boundary was based on the gamma radiation levels measured by a set of FIDLER detectors. After the test, soil from an area near the blast was pushed on top of the original concrete platform to produce a mound about 1.3 m (4 ft) high. An older, almost circular fence still existed (until the June expedition) around the mound of soil at ground zero (GZ) and extended 30-40 m (100-130 ft) from GZ.

Previous semiannual ground-based surveys of the Double Tracks site were conducted by REECo for several years after the tests.² These surveys consisted of air samples, surface swipes, and water examination, as well as gas proportional counter measurements made in the four compass directions at 30-m (100-ft) intervals from the (what is now inner) fence. As described in the REECo report, these measurements were strongly influenced by high-activity debris near the measurement locations.

RSL performed aerial surveys of the Double Tracks site using helicopters in February 1977 and December 1993. The 1977 survey was conducted at a 30-m (100-ft) altitude using a line spacing of 61 m (200 ft).³ The 1993 survey was also conducted at a height of 30 m but used a line spacing of 46 m (150 ft).⁴ A separate report presents additional processing of the 1993 data to improve the minimum detectable activity for americium-241 (²⁴¹Am).⁵ However, this additional processing had the deleterious side effect of enlarging the footprint of the measurement system and decreasing the spatial resolution of the data thus distorting the size of the area which needed remediation.

3.0 NATURAL BACKGROUND RADIATION

Many factors—both radiation from sources of interest to the current investigation, radiation from sources not of current interest, and electrical noise—contribute to forming the total measured gamma-ray energy spectrum. These components can be summarized as the five terms in the following equation:

$$\left(\begin{array}{l} \text{Measured} \\ \text{Radiation} \\ \text{Spectrum} \end{array} \right) = \begin{array}{l} \text{Natural Terrestrial Radionuclides} \\ + \text{Man-Made Radionuclides} \\ + \text{Airborne Radon} \\ + \text{Cosmic Rays} \\ + \text{Equipment Contributions} \end{array} \quad (1)$$

The term "natural background radiation" is generally considered to comprise three of the terms in the above equation; namely, natural terrestrial radionuclides, airborne radon (Rn) gas and its daughter products, and cosmic rays. The man-made radionuclides, such as cobalt-60 (⁶⁰Co) and cesium-137 (¹³⁷Cs), produced through actions by man are generally the components of the radiation field of most interest. The final term in this equation represents all sources of "noise" in the final spectrum, ranging from electrical noise in the electronics processing the detector signals to radiation sources inherent in the detectors and other measurement equipment.

Long-lived radionuclides present in the earth's crust are usually the largest source of background radiation. Naturally occurring isotopes found in the soil and bedrock consist mainly of radionuclides from the U and thorium (Th) decay chains and radioactive potassium (K). The most prominent natural isotopes usually seen in spectra are potassium-40 (⁴⁰K)

(0.012% of natural K), thallium-208 (²⁰⁸Tl) and actinium-228 (²²⁸Ac) (daughters in the ²³²Th chain), and bismuth-214 (²¹⁴Bi) (a daughter in the ²³⁸U chain). Although it is considered a man-made radionuclide, a measurable amount of ¹³⁷Cs is found throughout the world (initially as a surface deposition and then, over time, migrating several inches into the soil) as a result of the atmospheric testing of nuclear weapons. These naturally occurring isotopes typically contribute 1-15 μ R/h to the background radiation field.⁶

Rn (a noble gas) is a member of both the U and Th decay chains. After being created in the soil from its parent isotope, Rn can diffuse through the soil and become airborne. While the isotopes of Rn have relatively short half-lives, their daughters may become attached to dust particles in the atmosphere and contribute to the airborne radiation field until the dust eventually settles to the ground. The contribution of Rn and its daughters to the background radiation field depends on several factors, including the concentration of U and Th isotopes in the soil, the permeability of the soil, and the meteorological conditions at the time of measurement. Typically, airborne radiation from Rn and its daughters contributes 1-10% of the natural background radiation level.

Cosmic rays entering the earth's atmosphere are a third source of background radiation. High-energy cosmic rays (principally protons, alpha particles, and some heavier nuclei) interact predominantly with atoms in the upper atmosphere to produce showers of secondary radiation. The contribution of cosmic rays to the background radiation field varies with elevation above mean sea level and with geomagnetic latitude. The earth's magnetic field traps some of the cosmic rays, so a larger fraction of them reaches the poles than the equator. In the continental U.S., values range from 3.3 μ R/h at sea level to 12 μ R/h at an elevation of 3,000 m (10,000 ft).⁷ For surveys in the continental U.S., the dependence on geomagnetic latitude is very small and the elevation of the survey is the predominant determinant of the cosmic ray flux.

4.0 SURVEY EQUIPMENT AND PROCEDURES

Each radioactive isotope emits one or more types of radiation when it decays—alpha particles, beta particles, gamma rays, or X-rays. More importantly, these decay products have a specific energy which helps to indicate what parent isotope emitted it. The mix of Pu isotopes present at Double Tracks decay either by the emission of an alpha particle (which is

impossible to detect more than a few centimeters away) or by the emission of a very low-energy beta particle (which is also very difficult to detect). In addition to these particles, Pu emits some low-energy X-rays and, at a very low rate, some gamma rays. Nearly all systems used to search for Pu rely on detecting the 60-keV gamma ray emitted by ^{241}Am , the decay product of plutonium-241 (^{241}Pu). These gamma rays are relatively easy to detect, even from aerial detection systems 30-50 m (100-150 ft) above the ground, and are much more abundant than the gamma rays emitted directly from the Pu decays.

The NaI detectors (used in the Kiwi system and by previous aerial surveys) can be made with large areas and volumes which allow them to efficiently collect most of the gamma rays incident on their crystal face. However, their energy resolution is relatively poor, so the ability to identify specific gamma-ray energies and, therefore, specific isotopes is limited to areas containing only a few isotopes. The HPGe detectors (used on the Suburban system and on the tripods) are much smaller in size than the NaI detectors. Consequently, they collect gamma rays at a much lower rate. Their advantage is their high-energy resolution, which makes the isotopic identification relatively easy even in areas containing many isotopes.

The above discussion regarding the identification of isotopes from the measured gamma-ray energies assumes that all of the initial gamma-ray energy is collected by the detector. This is not often the case. Many of the gamma rays emitted by an isotope will be scattered (by soil or air or inside the detector) and lose some of their energy, breaking the correlation between a specific energy and a specific isotope. This is a process known as Compton scattering, and it creates a smoothly varying background within the energy spectrum. Statistical fluctuations at a given energy due to this Compton background increase the uncertainty in how many gamma rays of this initial energy were detected. Thus the uncertainty in the amount of an isotope present during a measurement increases with the increase in the Compton background.

Unlike alpha and beta particles, gamma rays can travel large distances through the atmosphere. With a detector suspended 1 m (3 ft) above a perfectly flat ground, 50% of the detected 60-keV ^{241}Am gamma rays will originate from more than 6 m (20 ft) away. Typical ground-roughness effects will decrease the number of gamma rays from large distances, but a 6-m radius circle is still not a very localized area. When a measurement must be made of a well-defined

spot on the ground, a collimator must be used to shield the detector from gamma rays emitted from areas outside this one spot. Generally, limiting the field-of-view requires the use of a large quantity of very dense material. However, for 60-keV gamma rays, this can be accomplished by using approximately 3mm (1/8 in) of lead (Pb).

The following paragraphs present a sketch of the data collection procedures used for this survey. Each of the experiments used a specific means of obtaining positioning information. The Kiwi used a differential global positioning system (GPS), licensed from John Chance Corporation, which has a positioning uncertainty of less than 1 m (3 ft). The HPGe Suburban has a slightly less accurate differential GPS system, which yields an uncertainty of 3-5 m (10-16 ft). Some of the locations measured by the Suburban in June were centered over locations marked by stakes in a circular grid which dates back to the 1960s. The 0° reference of this circular grid appeared to be aligned with magnetic north, rather than the polar north implicit in the latitude, longitude coordinates of the GPS. The difference between polar north and magnetic north is about 15° in the Double Tracks area. Most of the measurements made with the tripod detector systems and some of the Suburban measurements are referenced to this circular grid.

The coordinates listed in the literature for GZ are 37°42'22.52" N and 116°59'14.23" W in the NAD27 coordinate system.³ The GPSs used when collecting the data in this report are referenced to the WGS84 coordinate system. For the Double Tracks area, the U.S. Geological Survey (USGS) guidelines instruct one to move the NAD27 grid by 10 m (33 ft) (0°0'0.32") N and 79 m (259 ft) (0°0'3.23") E to convert the position into the WGS84 system. Applying this to the GZ position quoted above yields a position of 37°42'22.20" N and 116°59'17.46" W in the WGS84 system.

While no GPS measurements were made at GZ, Suburban-system measurements were made at the 30-m (100-ft) positions on the circular grid at 0°, 90°, 180°, and 270°. These four measurements yield an average GZ position of 37°42'21.95" N and 116°59'17.80" W (in the WGS84 coordinate system). This average position is only 7.7 m (25.3 ft) (0°0'0.25") S and 8.4 m (27.6 ft) (0°0'0.34") W of the published location.

The April survey made a number of isolated measurements and did not cover the whole Double Tracks area. In June, the Kiwi covered all of the area inside the fence as well as a few test spots south of the

fence. The ATV covered most of the area inside the fence less than 152 m (500 ft) from GZ.

4.1 Experiment #1 (April)—HPGe *In Situ* Measurements

This experiment was designed to provide a correlation between the various methods of ground-based data taken during the April survey and, if possible, a comparison with the aerial data taken in December 1993. To this end, a series of measurements with the different instruments was taken in the same area. First, a four-wheel drive vehicle (Chevrolet Suburban, see Figure 1) with a collimated HPGe detector suspended on a mast 7.5 m (25 ft) above ground level (AGL) made a set of measurements across an area identified by the aerial data as having a relatively constant ^{241}Am concentration. The collimated detector views a circular area with a diameter of approximately 13 m (43 ft). In comparison, the aerial system made measurements with a 100-m (330-ft) diameter spatial resolution.

At several of these locations, the mast was lowered and an additional measurement was made with the detector only 3 m (10 ft) AGL. At this height, the field-of-view for the ^{241}Am 60-keV gamma rays is approximately 5.2 m (17 ft). In addition to these comparison measurements, a number of isolated Suburban and

tripod measurements were made throughout the fenced area.

4.1.1 Suburban Versus Tripod Measurements

Following the measurements taken by the Suburban system, a different HPGe detector, mounted on a tripod and placed 1 m (3 ft) AGL, made a set of measurements covering the area measured by the Suburban detector at a 3-m (10-ft) height. The tripod systems were collimated with a Pb shield to produce a field-of-view for the low-energy ^{241}Am 60-keV gamma rays of approximately 2 m (6.6 ft). To minimize the number of measurements needed, the measurements were made using a triangular grid pattern. Thus the Suburban footprint could be almost covered by seven tripod measurements.

Following the tripod measurements, systems fielded by REECo and the Oak Ridge National Laboratory (ORNL) made their measurements in this same area.

4.1.2 Measurements South of the Exclusion Fence

A series of nine measurements was made south of the fenced area using a tripod-mounted HPGe detector. Measurements were made to corroborate the results obtained from the December 1993 aerial survey,

FIGURE 1. SUBURBAN VEHICLE WITH HPGe DETECTOR ON MAST. The detector on the end of the mast can be extended up to 7.5 m above the ground.

which indicated a very low-level plume extending from the southern fence. Since there were no means to determine an exact position with this system, an attempt was made to pace off distances along the concentration center line of the plume using a compass for reference. The actual measurement line, however, deviated somewhat from the planned line.

4.2 Experiment #2 (April)—Pu:Am Ratio Measurements

The experiments performed at Double Tracks in April were intended to determine the nature and extent of TRU contamination by detecting gamma rays. All of the measurements rely on detecting the 60-keV gamma rays emitted by ^{241}Am , a daughter of ^{241}Pu , and inferring the amount of Pu and TRUs through a combination of field measurements and theoretical considerations.

The activity levels in the eastern part of the central mound were high enough to allow direct measurement of the very weak gamma rays from ^{239}Pu at 129 keV, 375 keV, and 414 keV. The 129-keV gamma ray is approximately 6,000 times less intense per disintegration than the 60-keV gamma ray from Am. The other two Pu gamma rays are approximately 23,000 times less intense. The Pu:Am ratio is usually obtained in the laboratory using small soil samples that are chemically dissolved and then analyzed using alpha spectrometry. However, the physical characteristics of Pu make this laboratory analysis very difficult. Because the activities at the Double Tracks site are large enough, *in situ* measurements are capable of accurately measuring the gamma rays from Pu. Thus the TRU:Am ratio calculated from the *in situ* data will have a better accuracy than the ratio from the laboratory analysis.

Two independent methods of measuring of the Pu:Am ratio were performed. The actual location on the mound was approximately 12 m (40 ft) from GZ and about 105° E of magnetic north (referenced to the circular grid). The first method used an HPGe detector mounted on a tripod 1 m (3 ft) AGL. The first set of measurements using this system left the detector uncollimated and the gamma-ray spectrum was written to tape at the end of 10-, 20-, and 30-minute periods. The second set of measurements used a Pb collimator to reduce the field-of-view to about a 2-m (6-ft) radius. The plan in using the collimator was to collect the 60-keV gamma rays from ^{241}Am and the 39-keV and 51-keV X-rays from ^{239}Pu from the same area.

The use of the collimator was not as successful as originally anticipated. The large Compton background generated by the ^{241}Am gamma rays made the extraction of the small quantity of 39- and 51-keV gamma rays very difficult.

The second method to measure the Pu:Am ratio used a highly collimated, tripod-mounted HPGe detector. Measurements were made for 300 and 600 seconds. The measured gamma-ray count rates were then converted into the appropriate radioactivity values. To make this conversion for an *in situ* measurement, it is necessary to know or make assumptions on the depth distribution of the contaminant. Results are presented for assumed exponential distributions with relaxation lengths of 3, 20, and 100 cm (1, 8, and 40 in). The mound was formed by scraping the contaminated surface around the detonation site after the explosion, and this most likely led to contamination being mixed throughout the mound. In this case, a deeper depth distribution would be more representative of the contamination than the shallow distribution usually encountered due to weathering of surface Pu into the soil.

4.3 Experiment #3 (April)—Depth Profiling Measurements

The purpose of these measurements was to develop an inexpensive, fast (hopefully field-calculable) method of measuring the ^{241}Am depth distribution over large areas of contamination. The depth distribution is required to convert HPGe *in situ* count-rate data into soil activity concentration results. It is also critical for obtaining a reasonable estimate of the amount of contaminated material that might have to be removed. Currently, the established method is to take soil samples from selected depths and analyze the samples in the laboratory. This method involves transportation of contaminated soil, time to prepare the samples, and the counting time in the laboratory. The final results are also sensitive to the depth interval used for each sample. Usually, samples are taken in 2.5-cm (1-in) layers. This rather coarse sampling does not provide representative data for the shallow distributions typically encountered with Pu contamination. In typical Pu contamination situations, samples taken in 1- or 2-cm layers are usually required. Hot pieces, routinely found around the safety shot tests, also introduce a serious problem in obtaining useful data.

Three techniques were evaluated during the April field survey for obtaining depth profile data. These include the following:

- Side wall measurements with TLD material
- Comparison between the X-rays from ^{239}Pu and the gamma ray from ^{241}Am
- Direct measurement with highly collimated HPGe detector as thin layers of soil were removed

4.3.1 Side Wall Measurements with Thermoluminescent Dosimetry Material

Thermoluminescent material, when used for thermoluminescent dosimetry (TLD), can be used to measure surface alpha contamination. The TLD material used for these measurements ($\text{CaSO}_4:\text{Tm}$) is gamma insensitive, with a beta sensitivity approximately 100 times less than the alpha sensitivity. The alpha sensitivity is quite high with about one Read-Out Count (ROC) per disintegration per minute (dpm) and a large dynamic range in which the sensitivity is linear. This allows their use in mapping areas containing low to very high levels of radioactivity. Measurements made previously with this material in Area 11 of the Nevada Test Site (see Appendix B) accurately portrayed the erratic surface distribution of the TRU isotopes around those safety shot sites. It was found that a good deal of the contamination is in discrete "hot spots" that can cause rapid variations in activity levels over distances of only a few centimeters. This is why typical soil sample counting can produce widely varying results even for samples taken adjacent to each other. Because the material proved so successful for the surface measurements, an attempt was made to try to obtain similar results for depth profiles.

The TLD material was affixed to sheets 30 cm (12 in) on each side. Readout can be controlled to 1-mm (0.04-in) intervals in both the x and y directions, providing excellent spatial resolution for the measurements. Thirty-minute measurements are sufficient to obtain background alpha activity levels. The material was then sent to a laboratory for analysis. If these measurements are performed routinely, a film reading station could be purchased for field use. The film is reusable after it has been analyzed and read.

Six TLD sheets were used, in pairs, at three measurement locations. One sheet was placed on the surface. The other sheet was inserted into the ground by digging a small trench, placing the sheet against the wall, and then backfilling the trench to hold the sheet in place for the required exposure time. This created a "surface" approximately 25-30 cm (10-12 in) deep and 30 cm (12 in) across. The TLD sheet was held against

the side wall for approximately 30 minutes. All three measurements were made near the inner fence south of GZ.

4.3.2 Comparison Between the Pu X-Rays and the ^{241}Am Gamma Ray

A second technique evaluated during the April expedition tried to measure the difference in the number of 60-keV ^{241}Am gamma rays compared to the number of 17- to 23-keV X-rays emitted during the decay of ^{241}Am and the various Pu isotopes.

Pu contamination is usually measured using the 60-keV gamma ray from ^{241}Am . It can also be detected using the L X-rays from the Pu and Am decay in the 17- to 23-keV range. For contamination near the surface, the X-ray region is useful. Due to the rapid attenuation of these low-energy X-rays in soil, however, the 60-keV gamma ray is more useful for activity that has migrated into the soil. The mass attenuation coefficient for soil at 20 keV is approximately ten times greater than at 60 keV. The X-rays will be attenuated much faster with depth in soil than the 60-keV gamma ray. This difference in attenuation may be able to provide an indicator of the contamination distribution with depth. To make the measurements, it is necessary to ensure that all radiation reaching the detector travels through the same depth of soil. This can be done using a long collimator that only allows radiation from directly below the detector to be counted. The ratio of the 60-keV gamma ray to one or more of the X-rays would then provide an indicator of the depth of the contamination.

With an HPGe detector mounted on a low tripod, a collimator was built that extended from the detector to the ground to ensure only radiation from directly below the detector would be counted. The collimator was made of tin (Sn) with an inner liner of copper (Cu). Since the collimator (as well as the detector) will be bathed by the gamma rays from the natural radionuclides, a fraction of the atoms will be excited by the gamma rays and will emit their own particular-energy X-rays. Thus, since the collimator material is going to emit X-rays which will be detected, the goal is to find a collimator material which adds the fewest counts to the particular-energy range of interest. Sn is somewhat better than Pb for these applications. Pb has K X-rays in the 70-90 keV range which increases the background in the 60-keV window. Pb also has L X-rays which extend into the Pu and Am X-ray window. Sn has K X-rays just above the Pu-Am window and L X-rays below this window. The Cu liner stops the K X-rays

and puts all possible interference from the collimator below the Pu-Am X-ray window.

Six measurements were made just inside and outside the inner fence. Measurements were made at the three locations where the TLD material measurements were conducted and at three additional areas where spot FIDLER measurements showed elevated activity.

4.3.3 Direct HPGe Measurements

The third technique that was evaluated directly measured the ^{241}Am activity level as thin layers of soil were removed. A detector was collimated to limit the field-of-view to an area approximately 40 cm (16 in) in diameter. Soil was then removed in layers approximately 1-3 cm (0.4-1.2 in) thick, with measurements made after each layer was removed. Spraying the soil lightly and uniformly with a little water allowed a person with a metal dustpan to scoop up a thin layer of soil and minimize the creation of blowing dust. A little practice was required to avoid getting the ground too wet too deep and to scoop up only a thin layer of soil. The soil was removed over an area larger than the field-of-view of the collimated detector to ensure that only the newly exposed surface was measured.

This method is similar to obtaining profile samples in the field and returning them to a laboratory for analysis. The primary differences are the much larger sample size counted (approximately 1,600 cm² [248 in²] versus 100 cm² [16 in²] for a typical soil sample) and the convenience of not having to transport soil from the site.

4.4 Experiment #4 (June)—ATV Hot-Piece Search

FIDLER detectors have been used extensively in the past for locating regions contaminated with ^{241}Am (and Pu by inference). Although the system only reports the total count rate observed in the detector, medium- or high-energy gamma rays are very unlikely to have any interaction with the very thin detector crystal. This makes the detectors insensitive to much of the variation in the natural terrestrial radioactive isotopes or to fallout isotopes such as ^{137}Cs .

During the April expedition, a hand-held FIDLER found many locations where the radioactivity level was elevated and very localized. In most of these cases, small pieces of metal with Pu and Am adhering

to the surface were found in the area. Two locations were "mined" by IT personnel. "Before" and "after" measurements of these locations produced encouraging results (see Section 6.1). During the week of the April expedition, it became very clear that there were many localized regions near GZ with elevated activities.

The ATV experiment was included in the June expedition to test our ability to systematically locate and remove the fragmented pieces. A set of three collimated FIDLER detectors mounted on the ATV is shown in Figure 2. This system traveled east and west inside the fenced area within several hundred feet of GZ to look for hot pieces. The collimators on the detectors limited the fields-of-view to about a 0.6-m (2-ft) diameter on the ground. There was sufficient overlap between the fields-of-view to ensure that complete coverage was obtained over an area about 1.5 m (5 ft) wide.

Because this was still an experimental vehicle, the driver had to steer the ATV by keeping the tire tracks from the previous pass a constant distance to the side. While the ATV occasionally had to be maneuvered around some of the larger bushes, the amount of ground possibly missed by the detectors was very small. If the detected activity exceeded a set level, an alarm sounded. A larger than expected amount of time was spent at Double Tracks determining the optimum trip levels for the alarms on the detectors. It was finally determined that 50% above background was a reasonable level which resulted in finding many hot pieces and produced very few false alarms. (False alarms were often produced if the ATV bounced excessively while going over a bush or the edge of a small wash.)

When the alarm on one or more detectors sounded, the driver would stop and back over the area to verify that it was not a false alarm and then place a colored flag in the ground. A group of "miners" would go to each of the flagged locations with a hand-held FIDLER and shovels to find the hot piece and remove it from the area. Fragments were usually located immediately using the hand-held FIDLER, but after a while, the miners sometimes could recognize fragments visually before using the FIDLER. After removing the fragment, the FIDLER would be used to survey the immediate area for any flakes which may be left behind from the original fragment. In a few instances, the radiation was spread over a small area and a few shovels of soil and hot particles were excavated. The hot fragments and soil containing hot particles were

FIGURE 2. ATV WITH FIDLER DETECTORS. *The three detectors see slightly overlapping areas on the ground as the ATV travels at several feet per second. A sharp rise in the count rate by one of the detectors signifies a hot piece underneath that detector.*

placed in secured containers for later disposal during the clean-up operations.

4.5 Experiment #5 (June)—Kiwi Survey Measurements

The Kiwi system is the result of mounting the detectors and data collecting system from RSL's standard aerial system onto a Chevrolet Suburban vehicle (see Figure 3). Six 5- x 10- x 40-cm (2- x 4- x 16-in) NaI logs are housed in pods mounted on an angle-iron frame attached in place of the rear bumper. Signals from these detectors feed into a Radiation and Environmental Data Acquisition and Recorder (REDAR), Model IV, system bolted to the floor of the Suburban. Signals from the GPS constellation of satellites, received by the antenna mounted above the detectors, are preprocessed by a John Chance Corporation unit before feeding into the REDAR system. The second antenna, mounted on the roof of the Suburban, receives a correction signal from a network of GPS stations around the country. The signal is relayed through a dedicated satellite for John Chance Corporation subscribers. This correction signal reduces the uncertainty in positioning the vehicle to less than 1 m (3 ft) rather than the 3-5 m (10-15 ft) uncertainty in the earlier correction hardware employed in the helicopter system.

The Kiwi detectors are shielded on the back and sides with a sheet of cadmium (Cd) while the end-mounted photomultiplier tubes and the vehicle itself provide shielding to the front of the detectors. This shielding is more than adequate for attenuating the 60-keV gamma rays of ^{241}Am but does not significantly affect the higher energy radiation from the natural radioisotopes. The shielding produces a well-defined footprint for making assessments of the Am concentration in a given volume of soil. Thus the ^{241}Am footprint of the stationary Kiwi system is about 3 m (10 ft) in width and 1.2 m (4 ft) long. With the Kiwi traveling at 2.2 m/s (5 mph; 7 ft/s), the footprint is about 3 m (10 ft) wide by 3.4 m (11 ft) long.

Just like the aerial platforms, the REDAR system in the Kiwi was programmed with a set of "flight" lines to travel during the survey. For simplicity and to minimize the amount of time needed to turn around inside the fence, the lines were arranged parallel to the western fence making them almost due north-south. The GPS position was compared to this preferred flight path each second, and the deviation (left or right) from the line was displayed for the driver on a meter mounted above the dashboard. The flight lines were only 3 m (10 ft) apart. With the rough terrain in several spots, some deviation from the planned flight lines was necessary.

FIGURE 3. KIWI VEHICLE. Six NaI logs in the three pods on the rear of the Suburban vehicle detect gamma rays from Am. Shielding on the sides of the detectors limits the field-of-view to less than 1 m on either side of the pods. The two GPS antennas collect normal GPS signals from the satellite constellation and correction signals from the John Chance network.

For the June expedition, the barbed wire on the inner fence was removed, but the fence posts were left in the ground. The Kiwi had to occasionally be driven around rough terrain and various posts in the exclusion area. The removal of the barbed wire inner fence permitted the Kiwi to get inside the fence and gather data close to the mound. However, the terrain of the GZ mound and the depression just northeast of the mound was considered too steep and the Kiwi was not driven over that area. The mound was assumed to be an area which would have to be excavated and removed regardless of the measured level of activity, so no concerted attempt was made to collect data over the mound. This produced a "hole" in the data which needed to be addressed in the data analysis. The extensive general data analysis procedures for the Kiwi data are described later in Section 5. The specific handling of the "hole" is described in Section 6.5.

4.6 Experiment #6 (June)—HPGe *In Situ* Measurements

This experiment was a check and verification of the Kiwi system during the June expedition. The Suburban system, described in Experiment #1, made more

than 50 measurements of the ^{241}Am activity at various locations both inside the exclusion fence and around the periphery. In addition, two measurements were made in the plume which extends south of the exclusion area and one measurement was made at the revegetation site northeast of Double Tracks.

The majority of the 50 measurements were conducted to transect the site from south to north and from west to east passing through the GZ area. Since some additional time remained after these measurements were made, several additional measurements were conducted along the circular grid axes at 120°, 150°, 210°, and 240° to define the plume better in these directions.

4.7 Experiment #7 (June)—Hot-Piece Activity Measurements

This experiment was intended to measure the total ^{241}Am activity on several of the chunks of material found by either the ATV system or by technicians using hand-held FIDLERs or spotting them visually while walking around. This debris appeared to be metallic pieces from the explosion with some surface Pu contamination. Several of these pieces were weighed, photographed, and measured for activity

level using an HPGe detector. Both sides of each piece were measured and an effective activity value determined.

In addition to the metallic debris, soil samples collected from the hottest areas within the inner fence were also measured. The soil was placed inside plastic bottles approximately 5 cm (2 in) in diameter and 15 cm (6 in) tall. Measurements were made from each side of the bottle and an effective activity value determined.

5.0 DATA REDUCTION PROCEDURES

Several methods for processing the Kiwi data may be employed. The gross count rate method calculates the total counts from all gamma rays detected during each one-second sample and presents the results as a series of equal count-rate contours superimposed on a map or photograph of the survey area. With this display, large-scale variations of the radiation field within the whole survey area may be easily seen. Since the size of the Double Tracks survey area is relatively small and there are no real variations in the geology of the area, the gross count plot is quite flat—except in areas containing Pu contamination.

Variations in the total radiation field are not always of interest. At Double Tracks, the major contaminant is Pu (and its gamma-ray-emitting daughter Am). With this knowledge, the count rate in the ^{241}Am photopeak can be plotted versus position and a more sensitive plot of the contamination can be made from the isotopic count rate.

The main data reduction interest for this survey was the isotopic stripping of the ^{241}Am photopeak. The gross count rate method was principally a check to ensure that the data from adjacent "flights" matched each other and to provide a picture of the overall radiation field in the survey area.

5.1 Gross Count Rate Algorithm

The gross count rate is the sum of the counts in the energy range from 38 keV to 3,026 keV, divided by the live time, and subtracting a background term which represents all nonterrestrial sources.

$$C_G = \left(\frac{1}{t_{\text{Live}}} \sum_{E=38}^{3026} c(E) \right) - C_N \quad (2)$$

where

C_G = gross count rate at the height of the detector (counts/s)

t_{Live} = live time during collection of gamma-ray spectrum (s)

$c(E)$ = the counts in the energy spectrum at the energy E (counts)

C_N = the count rate attributable to nonterrestrial sources (counts/s)

The lower energy limit is an effective lowest energy which the detector system can reliably record. Although the detector system processes and records all detected gamma rays up to 4,000 keV, there are almost no gamma rays of interest with energies above 3,000 keV, and the higher energies are generally ignored. The total number of counts attributable to nonterrestrial sources includes gamma rays emitted by airborne Rn and its daughters, cosmic rays, and vehicle and equipment contributions.

5.2 Isotope Extraction Algorithms

Before describing these windowing techniques, a few points need to be made about the energy spectrum. In general, the gamma rays emitted by naturally occurring radioisotopes have very precise, well-defined energies. If the gamma rays could be measured ideally, the energy spectrum would consist of very tall, very narrow photopeaks centered at the total energy of the gamma ray. (Some of the peaks would be riding on top of the slowly varying distribution of Compton-scattered gamma rays from other isotopes, but the peaks would be narrow.) However, the detector and associated electronics used to measure the gamma rays have energy resolutions which broaden the photopeak distribution. The spectrum actually recorded by the measuring system will have broader, Gaussian-shaped peaks with widths equal to the resolution of the detection system.

The total number of counts contained in the Gaussian-shaped photopeak can be obtained by summing all of the counts within a specific energy range, ΔE , of the gamma-ray energy, E . The magnitude of ΔE will determine the fraction of the total counts which are summed. If $\Delta E = 3\sigma$, where σ is the standard deviation of the Gaussian distribution, then 99.7% of the total photopeak counts will be included in the sum. This is not an unreasonable assumption for HPGe detectors, which have very narrow peak shapes. However, if the standard deviation for the system is large, as is the

case for NaI detectors, then the distributions from different photopeaks can overlap significantly. This interference between peaks can be minimized by decreasing ΔE , with the knowledge that not all of the counts will be included in the sum. A correction factor, determined in a region free of conflicting peaks, can be found to relate the number of counts in the range $E \pm \Delta E$ to the total counts in the peak.

5.2.1 Two-Window Algorithm

The two-window algorithm is the simplest of several window algorithms in use. It employs a narrow window centered on the energy of the specific photopeak. A background window, located at higher energies, assumes that the background counts in the photopeak window are proportional to the total counts recorded in the background window. The background window may abut the photopeak window or may be separated from it in energy. The equation for the two-window algorithm follows:

$$C_{2-Window} = \sum_{E=E_1}^{E_2} c(E) - K_2 \sum_{E=E_3}^{E_4} c(E) \quad (3)$$

with

$$K_2 = \frac{\sum_{E=E_1}^{E_2} c_{bkg}(E)}{\sum_{E=E_3}^{E_4} c_{bkg}(E)} \quad (4)$$

where

$C_{2-Window}$ = the net counts in the photopeak from the two-window algorithm

$c(E)$ = the counts in the gamma-ray energy spectrum at the energy E

E_n = the limiting energies of the windows ($E_1 < E_2 \leq E_3 < E_4$)

K_2 = the ratio of the counts in the photopeak window to the counts in the background window in a clean region of the survey area

$c_{bkg}(E)$ = the counts in the gamma-ray energy spectrum at the energy E in a clean region of the survey area

The proportionality factor, K_2 , is determined in a region of the survey which does not contain any of the specific isotope, so that the photopeak window contains only its background counts and therefore is directly related to the number of counts in the background window. If the principle source of background gamma rays in the photopeak window is from scattered gamma rays from photopeaks at higher energies, this is a reasonable assumption. If there are isotopes other than the one of interest with photopeaks in the photopeak window, this algorithm will likely fail.

5.2.2 Three-Window Algorithm

If a region free of the specific isotope cannot be found or if the composition of the other isotopes changes drastically between the clean region and the rest of the survey area, then a simple multiplicative factor will not relate the counts in the photopeak window to the counts in the background window. To solve this problem, the three-window algorithm employs a background window on each side of the photopeak window. (In this case, the two background windows abut the photopeak window in energy.) This algorithm assumes that, for any spectrum, the number of background counts in the photopeak window is linearly related to the counts in the two background windows. The equation for the three-window algorithm follows:

$$C_{3-Window} = \sum_{E=E_2}^{E_3} c(E) - K_3 \left[\sum_{E=E_1}^{E_2} c(E) + \sum_{E=E_3}^{E_4} c(E) \right] \quad (5)$$

with

$$K_3 = \frac{\sum_{E=E_2}^{E_3} c_{bkg}(E)}{\sum_{E=E_1}^{E_2} c_{bkg}(E) + \sum_{E=E_3}^{E_4} c_{bkg}(E)} \quad (6)$$

where

$C_{3-Window}$ = the net counts in the photopeak from the three-window algorithm

E_n = the limiting energies of the windows
($E_1 < E_2 < E_3 < E_4$)

K_3 = the ratio of the counts in the photopeak window to the counts in the two background windows in a clean region of the survey area

The three-window algorithm is also very useful in extracting low-energy photopeak counts where the shape of the Compton-scatter contributions from other isotopes is changing significantly.

Both the two- and three-window algorithms were applied to the Double Tracks data. In this particular case, the three-window algorithm produced an output which was more stable with regard to statistical variations in the data set.

5.3 Gridding of Data

To produce most of the plots in this report, the Kiwi data were forced into a 9-m (30-ft) grid. Since the data were collected second-by-second, the speed of the vehicle was not constant, and the actual "flight" lines often covered the same ground, gridding was necessary for the later processing. Since the interest in the data is predominantly to determine the ^{241}Am activity over square areas of 10-m (33 ft) and 100-m (330-ft) size, the gridding does not significantly degrade the spatial resolution of the data.

Once the grid is constructed, all spectra whose positions lie inside a grid cell are summed and an average count rate is calculated for the center of the grid.

$$c_g(E, x_c, y_c) = \frac{1}{N} \sum_{i=1}^N c(E, x_i, y_i) \quad (7)$$

where

$c_g(E, x_c, y_c)$ = the average number of counts in the gamma-ray spectrum at energy E at the center of the grid cell at location (x_c, y_c)

N = the number of data samples contained within the grid cell

$c(E, x_i, y_i)$ = the number of counts in the gamma-ray spectrum at energy E from the i th spectrum collected at location (x_i, y_i)

The uncertainty in the gridded data (α_g) is roughly $1/\sqrt{N}$ of the uncertainty of one of the original measurements (σ).

5.4 Count Rate Conversion to Soil Activity Concentration

The conversion from the count rate measured by a detector system to the activity of the isotope in the soil depends on several factors involving the radiation source, the intervening material, and the detection system. These factors include (a) ground roughness, (b) the distribution of the isotope in or on the soil, (c) the energy of the gamma ray emitted by the isotope, (d) the air density, (e) the amount of moisture in the soil, (f) the sensitivity of the detector system to the incident radiation, (g) the geometry of the detector-source arrangement including the use of collimators, and (h) the amount of background radiation (principally cosmic rays, vehicle and equipment background, and airborne Rn) present.

The soil activity concentrations deduced from the Kiwi system count rate are based on a simple multiplicative factor. The Kiwi was parked over an area inside the fence, and the count rate was measured for several minutes. This was an area which produced a fairly high count rate on both the Suburban system and on a hand-held FIDLER detector. The activity in this same area was also recorded in a series of HPGe tripod system measurements. To within the accuracy in which the two systems could measure the activity of the same location, this technique ensures consistency between the activities measured by the Kiwi and tripod systems. The conversion from count rate to activity for the tripod systems has been used extensively in the past and is briefly outlined below. The major problem with the area used at Double Tracks was the nonuniformity of the activity distribution. As seen throughout the survey area, the Am was dispersed in clumps in the high activity areas. There were large variations (a factor of 2-3) between the five tripod measurements, indicating that the activity was concentrated in one or two areas.

5.4.1 Distribution of the Isotope in the Soil

Three basic types of vertical distributions are commonly observed in the course of radiological surveys. All of the models used in this work assume that extended sources are uniform in the horizontal directions. That is, the only variation in the concentration

of the isotope in the soil is with depth. The uniform distribution in the horizontal plane leads to results expressed in terms of an average value over the field-of-view of the detector.

The naturally occurring radioisotopes are distributed uniformly as a function of depth. The fallout from the aboveground nuclear tests in the 1950s and 1960s began as a surface distribution. That is, all of the radioactivity lies in a thin layer of material on the ground. After a number of years, as the radioactive material has a chance to migrate into the soil, the initial surface distribution evolves into an extended distribution which is usually modeled by an exponential function. The relaxation length for the exponential distribution is expressed as $1/\alpha$. For the Pu and Am dispersed over 30 years ago at Double Tracks, an exponential distribution is assumed.

$$S(z) = S_{E0} e^{-\alpha z} \quad (8)$$

where

$S(z)$ = the activity concentration of the isotope at the depth z

S_{E0} = the activity concentration of the isotope at the surface of the soil

α = the inverse of the exponential relaxation distance

For the exponential distribution, the volume of soil from the surface down to a depth of $1/\alpha$ contains approximately 63% of the isotope's total activity. At depths of $2/\alpha$ and $3/\alpha$ the volume of soil contains approximately 86% and 95% of the total activity, respectively. (This is different from the percent of the isotope which can be measured from a detector above the ground. If the gamma-ray energy is small, then regardless of the vertical distribution of the isotope, only the gamma rays emitted from the nuclei near the surface will be able to reach the detector with their full energy.)

5.4.2 Derivation of the Conversion Factors

The conversion factors are determined by combining a laboratory measurement of the detector's efficiency to a given gamma-ray energy with a theoretical calculation of the gamma-ray flux arriving at the detector as a function of source distribution in the soil. The derivation of these equations is given in several previous reports (for example Reference 8) which are generally

based on the assumptions and derivations in the work by Beck.⁹

The number of photopeak counts registered by the detector depends on the flux of gamma rays at the location of the detector and a quantity, which is designated as the effective detector area, A . Since the probability of a gamma ray depositing its full energy in the detector depends on the detector dimensions, orientation, and gamma-ray energy, the effective area is not easily calculable. Instead the effective area is measured in the laboratory and expressed as a zero-degree value, A_0 , multiplied by a function, $R(\theta)$, which contains all of the angular response. The effective area is measured at 10° intervals and linear interpolation is applied between the measured values.

The measured photopeak count rate can be expressed as an integral over the factors for the source activity in the soil, the detector's effective area, the distance from source to detector, and the attenuation of the gamma rays by the intervening material (air and soil). Figure 4 presents a visual representation of the detector-source geometry.

$$C_p = \int_0^\infty \int_0^\infty \frac{S(z) A_0 R(\theta)}{4\pi d^2} e^{-\left(\frac{\mu}{\rho}\right)_a \rho_a d_a} e^{-\left(\frac{\mu}{\rho}\right)_s \rho_s d_s} 2\pi r dr dz \quad (9)$$

where

C_p = the net photopeak count rate

$S(z)$ = activity per unit volume $[(\gamma/s)/\text{cm}^3]$

A_0 = the effective area of the detector at 0°

$R(\theta)$ = the angular response of the detector at the angle θ

$d = d_a + d_s$, the distance from the source element to the detector (cm)

$(\mu/\rho)_{a,s}$ = air or soil mass attenuation coefficient (cm^2/g)

$\rho_{a,s}$ = air or soil density (g/cm^3)

Before proceeding any further with the derivation, the isotopic distribution in the soil must be determined. If no soil samples are available to determine the distribution, a distribution is assumed. Knowledge of the particular isotope and some history of how it might have arrived at this location as discussed in Section 5.4.1 will determine the form of $S(z)$. For the remainder of this derivation, the exponential distribution (see Equation 8) will be assumed.

FIGURE 4. **GEOMETRY FOR RADIATION MEASUREMENTS.** The detector-soil element geometry applies to both aerial and in situ measurements. The count rate of the detector results from the integrated gamma ray flux from all of the individual source elements.

Following a change in the integration variables and for the exponential depth distribution, the count rate equation becomes

$$C_p = \frac{S_{E0} A_0}{2} \int_0^{\pi/2} \frac{R(\theta) \tan(\theta) e^{-\left(\frac{\mu}{\rho}\right)_a \rho_a h \sec(\theta)}}{\alpha + \left(\frac{\mu}{\rho}\right)_s \rho_s \sec(\theta)} d\theta \quad (10)$$

5.4.3 Conversion Factors for Selected Isotopes in the Soil

The expression in Equation 10 relates the measured photopeak count rate, C_p , to the activity per unit volume at the surface, S_{E0} . The detector parameters, A_0 and $R(\theta)$, are usually obtained empirically for a given system using standard calibration sources. Mass attenuation coefficients for air and typical soils can be found in standard reference tables. An average soil density of 1.5 g/cm^3 is usually assumed unless actual measured values are available. The air density is calculated from measurements of the temperature and barometric pressure. The detector height, h , is measured and the inverse of the exponential relaxation

length, α , is either measured or assumed. It is then a simple case of calculating the required integral numerically to obtain the conversion factor, F_E .

$$\frac{1}{F_E} = \frac{C_p}{S_{E0}} = \frac{A_0}{2} \int_0^{\pi/2} \frac{R(\theta) \tan(\theta) e^{-\left(\frac{\mu}{\rho}\right)_a \rho_a h \sec(\theta)}}{\alpha + \left(\frac{\mu}{\rho}\right)_s \rho_s \sec(\theta)} d\theta \quad (11)$$

The conversion factor relates a measured photopeak net count rate, expressed in units of counts per second, to source activity at the surface expressed in units of gamma rays per second per unit volume. For a specific isotope, the source activity is generally changed to units of curies or becquerels. The average activity per unit volume can also be converted to average activity per unit mass by dividing by the soil density.

5.4.4 Average and Total Activity

When the interest is comparing the activity measured *in situ* with the activity obtained from a series of soil sample measurements, it is more useful to relate the photopeak net count rate data to an average concentration within a given soil depth rather than as the

exponential concentration at the surface. For a source distributed exponentially with depth, the average concentration in the top z_s is calculated with the following equation:

$$\langle S_{z_s} \rangle = \frac{1}{z_s} \int_0^{z_s} S_{E0} e^{-az} dz = \frac{S_{E0}}{\alpha z_s} (1 - e^{-\alpha z_s}) \quad (12)$$

Soil samples generally collect all of the soil to a specific depth. The soil is taken to a laboratory where the contents of the sample are crushed and thoroughly mixed before a small quantity is analyzed. The above expression is valid for comparing the quantity of an exponentially distributed radioisotope measured by the *in situ* and the soil sample methods if the following two conditions are satisfied: (a) the concentration of the radioisotope at and below z_s is small compared to the quantity of the isotope at the surface and (b) the mean free path of the gamma ray is comparable to or larger than z_s . In other words, the comparison is only valid if the *in situ* measurement cannot measure any significant contribution from the radioisotopes below the cutoff depth, and it can measure all of the radioisotopes above the cutoff depth.

Another quantity often used when discussing exponentially distributed radioisotopes is the total activity per unit area. This represents all of the activity in an infinitely deep column of soil and is calculated with the following equation:

$$S_A = \int_0^{\infty} S_{E0} e^{-az} dz = \frac{S_{E0}}{\alpha} \quad (13)$$

The value of α is usually poorly known and is highly dependent upon the actual soil conditions and the isotopes which are present. Also, soil disturbance (farming, construction, etc.) will affect the relaxation depth. Variations in α can produce significant changes in the average activity.

6.0 DISCUSSION OF RESULTS

6.1 Experiment #1 (April)—HPGe *In Situ* Measurements

The ^{241}Am and TRU activity measurements made by the Suburban system are listed in Table 1 and shown

in Figure 5 where the total activity is expressed in a similar manner to the previously processed aerial data except that the TRU:Am ratio is now 16:1 for both sets of data. The two "rows" of measurements in the southern half of the exclusion area are in the area where the aerial data showed fairly low, uniform activity. Also, several measurements were made in the general area east of the inner fence and along the road between the entrance and GZ.

Table 2 summarizes the results of the two hot-spot mining operations. The first mining area shows a reduction in the before-and-after 7.5-m (25-ft) height activity measurements by approximately a factor of 10 (file numbers 2 and 29). The change in activity in the 3-m (10-ft) AGL measurements is only about a factor of two (file numbers 3 and 30). The lower height measurement started with a much lower activity and did not see as large an area as the 7.5-m (25-ft) measurement, indicating that most of the hot pieces removed during the mining operation were outside this smaller field-of-view. The second mining location also had a fairly low activity, and even though several small pieces of material were found and removed, the effect of the mining operation wasn't sufficient at this location to overcome the uncertainties from the counting statistics in the 10-minute measurements.

6.1.1 Suburban Versus Tripod Measurements

Figures 6-8 (see pages 19 and 20) compare the ^{241}Am activities measured by the Suburban HPGe system operated at 3-m (10-ft) height and the tripod HPGe system operated at 1-m (3-ft) height. The first tripod grid location (see Figure 6) exhibits a relatively uniform, high ^{241}Am activity distribution with a slight increase in activity from the southeast corner to the northwest corner. The Suburban measurement agrees quite well with the individual tripod measurements.

The second grid location (see Figure 7) shows a dramatic increase in ^{241}Am activity from the west side to the east side, and the Suburban measurement seems to be excessively high compared to the tripod measurements. This may be the result of one or more hot pieces just on the edge of the Suburban field-of-view but outside the tripod system field-of-view. The circles are a rough indication of the field-of-view of the detector but may not be exactly to scale.

The third grid location (see Figure 8) shows a very hot area in the center of the grid with a much lower, nearly

Table 1. Suburban Measurements in April. The locations, Am concentrations, and TRU concentrations are shown for the HPGe measurements made at the Double Tracks area. The TRU concentration is based on a ($^{239}\text{Pu} + ^{240}\text{Pu} + ^{241}\text{Am}$): ^{241}Am ratio of 16. Positions shown in *italics* never received a lock on the differential GPS signal, so they have a positional uncertainty on the order of 100 m.

File No.	Latitude (N)	Longitude (W)	^{241}Am (pCi/g)		TRU (pCi/g)	
2	<i>37°42'17.97"</i>	<i>116°59'18.28"</i>	24.43	± 0.68	390.9	± 10.9
3 ^a	<i>37°42'17.92"</i>	<i>116°59'18.09"</i>	3.12	± 0.44	49.9	± 7.0
4	<i>37°42'13.48"</i>	<i>116°59'19.99"</i>	33.55	± 0.77	536.8	± 12.3
5 ^a	<i>37°42'13.33"</i>	<i>116°59'19.62"</i>	39.55	± 0.73	632.8	± 11.7
6	<i>37°42'13.48"</i>	<i>116°59'21.16"</i>	3.09	± 0.54	49.4	± 8.6
7	<i>37°42'10.11"</i>	<i>116°59'22.96"</i>	< MDA ^b		< MDA ^b	
8	<i>37°42' 9.47"</i>	<i>116°59'21.30"</i>	6.88	± 0.58	110.1	± 9.3
9 ^a	<i>37°42' 9.53"</i>	<i>116°59'21.11"</i>	5.26	± 0.48	84.2	± 7.7
10	<i>37°42' 9.13"</i>	<i>116°59'19.81"</i>	20.13	± 0.67	322.1	± 10.7
11 ^a	<i>37°42' 9.20"</i>	<i>116°59'19.90"</i>	15.89	± 0.56	254.2	± 9.0
12	<i>37°42'13.37"</i>	<i>116°59'19.65"</i>	38.33	± 0.78	613.3	± 12.5
22	<i>37°42'19.90"</i>	<i>116°59'15.43"</i>	3.65	± 0.54	58.4	± 8.6
23	<i>37°42'20.67"</i>	<i>116°59'15.74"</i>	7.61	± 0.59	121.8	± 9.4
24	<i>37°42' 9.47"</i>	<i>116°59'20.92"</i>	8.22	± 0.58	131.5	± 9.3
25	<i>37°42' 8.96"</i>	<i>116°59'18.20"</i>	< MDA ^b		< MDA ^b	
26	<i>37°42' 8.89"</i>	<i>116°59'16.34"</i>	< MDA ^b		< MDA ^b	
27	<i>37°42'12.62"</i>	<i>116°59'15.22"</i>	< MDA ^b		< MDA ^b	
28	<i>37°42'13.61"</i>	<i>116°59'18.20"</i>	< MDA ^b		< MDA ^b	
29	<i>37°42'17.82"</i>	<i>116°59'17.43"</i>	2.31	± 0.77	37.0	± 12.3
30 ^a	<i>37°42'17.71"</i>	<i>116°59'16.87"</i>	1.79	± 0.66	28.6	± 10.6
31	<i>37°42'20.34"</i>	<i>116°59'14.36"</i>	3.91	± 0.76	62.6	± 12.2
32	<i>37°42'21.10"</i>	<i>116°59'16.26"</i>	23.31	± 0.98	373.0	± 15.7
33 ^a	<i>37°42'20.07"</i>	<i>116°59'16.02"</i>	9.07	± 0.73	145.1	± 11.7
34	<i>37°42'10.31"</i>	<i>116°59'20.50"</i>	6.72	± 0.81	107.5	± 13.0
42	<i>37°42'20.42"</i>	<i>116°59'15.40"</i>	8.57	± 0.58	137.1	± 9.3
43	<i>37°42'22.16"</i>	<i>116°59'15.87"</i>	15.51	± 0.63	248.2	± 10.1
44	<i>37°42'21.03"</i>	<i>116°59'13.64"</i>	< MDA ^b		< MDA ^b	
45	<i>37°42'23.99"</i>	<i>116°59'14.92"</i>	5.58	± 0.56	89.3	± 9.0

^a Measurements made at a height of 3 m versus the normal 7.5 m.

^b The Minimum Detectable Activity (MDA) is equal to 3σ where σ is the standard deviation of the counting statistics. For measurements made at a height of 3 m, the MDA is 1.0 pCi/g of ^{241}Am and 16.0 pCi/g of TRU. For measurements made at a height of 7.5 m, the MDA is 1.5 pCi/g of ^{241}Am and 24.0 pCi/g of TRU.

uniform concentration around the edge. Here the Suburban measurement appears to be close to an average of the individual tripod measurements, as would

be expected if the Suburban detector averages the inner hot spot over its full field-of-view. From these three grid measurements, it is clear that the Am

DOUBLE TRACKS Site
April Suburban HPGe Data

CONVERSION SCALE	
COLOR	TRU (pCi/g)*
Black	< 50
Blue	50 - 100
Green	100 - 200
Yellow	200 - 600
Red	> 600

*Ground-based data from Suburban HPGe system taken at a 7.5-meter height.
Conversion assumptions include:
characterized detector
3-cm relaxation length
2.5-cm sample depth
TRU: Am ratio = 16

Unsmoothed Aerial Data

CONVERSION SCALE	
LETTER LABEL	TRU (pCi/g)*
D	< 160
E	160 - 250
F	250 - 400
G	400 - 640
H	640 - 1,000
I	1,000 - 1,600
J	1,600 - 2,530

*Aerial data taken at a 30-meter altitude at 36 m/s (70 knots). The detector array consisted of eight 2- x 4- x 16-inch NaI(Tl) detectors.
Conversion assumptions include:
cosine detector response
3-cm relaxation length
2.5-cm sample depth
TRU: Am ratio = 16
Photopeak cts = 1.6 x window cts

FIGURE 5. MEASUREMENT LOCATIONS OF THE SUBURBAN SYSTEM (APRIL). The locations (by GPS coordinates) of the Suburban measurements are marked by colored dots corresponding to five bands of TRU activity. The contour data from the 1993 aerial survey are included for reference. Both sets of data use the 16:1 TRU:²⁴¹Am activity ratio.

Table 2. "Mining" Location Measurements. The locations and Am concentrations are shown for the HPGe measurements made at the hot-spot mining areas. The TRU concentration is based on a ($^{239}\text{Pu} + ^{240}\text{Pu} + ^{241}\text{Am}$) : ^{241}Am ratio of 16. Positions shown in *italics* never received a lock on the differential GPS signal, so they have a positional uncertainty on the order of 100 m (300 ft). The Suburban could easily return to the same location to make the before-and-after measurements. However, knowing its absolute position relative to latitude and longitude is where the positional uncertainty lies. The positions are provided principally to relate this data with the aerial and Kiwi data shown in the later figures.

File No.	Latitude (N)	Longitude (W)	²⁴¹ Am (pCi/g)		TRU (pCi/g)	
First mining location (7.5-m height)						
2	37°42'17.97"	116°59'18.28"	24.43	± 0.68	390.9	± 10.9
29	37°42'17.82"	116°59'17.43"	2.31	± 0.77	37.0	± 12.3
First mining location (3-m height)						
3	37°42'17.92"	116°59'18.09"	3.12	± 0.44	49.9	± 7.0
30	37°42'17.71"	116°59'16.87"	1.79	± 0.66	28.6	± 10.6
Second mining location (7.5-m height)						
22	37°42'19.90"	116°59'15.43"	3.65	± 0.54	58.4	± 8.6
31	37°42'20.34"	116°59'14.36"	3.91	± 0.76	62.6	± 12.2

distribution varies dramatically over distances of several meters (comparable to the fields-of-view of these detector systems).

6.1.2 Measurements South of the Exclusion Fence

Figure 9 (see page 21) shows the tripod measurements made south of the fence. Using the intersection of an arc road with an arroyo as a reference point (marked "REF." in figure), it was possible to establish the position and direction of the actual survey line after the measurements were completed. Measurements were made at distances of 6, 230, 460, 690, and 910 m (20, 750, 1,500, 2,250, and 3,000 ft) south of the fence. At the 910-m distance, measurements were made in an east and west direction at distances of 46 and 91 m (150 and 300 ft). The aerial data shown in this figure has been averaged over nine neighboring data points to produce a map of the lowest possible detectable activity of ^{241}Am .⁵

In comparing the data, it is important to take into account the difference in the area measured by each system. The *in situ* detector, mounted on a short tripod

only 56 cm (22 in) above the ground, provides an average concentration value over an area approximately 5 m (15 ft) across. The 9-point neighbor averaged aerial data, taken at a survey altitude of 30 m (100 ft) and a 46-m (150-ft) grid spacing, provides an average concentration value over an area about 150 m (500 ft) in diameter. Near the fence, the *in situ* data shows higher levels than indicated by the aerial data. This would indicate that the width of the plume at this location is smaller than the field-of-view of the aerial system. The aerial system would show a narrow plume as covering a larger area but at a lower concentration value than actually exists on the ground. Further out from the fence, the two sets of data agree better. This would indicate that the plume is more dispersed and covers a wider area here than closer to the fence.

Both sets of data in Figure 9 used an assumed Pu:Am ratio of 10. Measurements made in April, as well as theoretical calculations, indicate that this value is too low. As discussed in this report, a value of 16 will be used for the total alpha-emitting TRU:Am ratio for this site. Therefore, all data in Figure 9, both aerial and ground-based, should be multiplied by 1.6 before comparing to TRU data presented elsewhere.

Suburban File #5: First Tripod Grid

FIGURE 6. SUBURBAN VERSUS TRIPOD MEASUREMENTS—FIRST LOCATION. The ^{241}Am soil activity concentrations (pCi/g) as measured by the Suburban HPGe detector at a 3-m height versus the tripod detector measurements at 1-m height. Note the general increase in activity from the southeast corner to the northwest corner. Data from footprint #5 was inadvertently not written to tape and the omission was not detected until after the survey team had left the field.

6.1.3 Highest Concentration of TRU Activity

As discussed in the next section, two different HPGe detectors made measurements on the mound to assess the Pu:Am ratio. Although the experiments were designed for the less stringent requirement of calculating the Pu:Am ratio, the activity of the soil on the mound can be deduced from these measurements if a few more assumptions are included.

The first detector system made measurements in both collimated and uncollimated arrangements. The uncollimated measurements should be ignored since the detector could see a significant amount of area away from the mound. The collimated measurements provide a more accurate measurement of only the soil on the mound and produce an ^{241}Am activity in the range 1,900-2,800 pCi/g, depending on the assumption of the depth to which the Am is distributed. The second detector system had a slightly different collimation arrangement and deduced an activity of

Suburban File #11: Second Tripod Grid

FIGURE 7. SUBURBAN VERSUS TRIPOD MEASUREMENTS—SECOND LOCATION. The ^{241}Am soil activity concentrations (pCi/g) as measured by the Suburban HPGe detector at a 3-m height versus the tripod detector measurements at 1-m height. Note the dramatic increase in activity from west to the east.

about 2,500 pCi/g. Multiplying these numbers by the TRU:Am ratio of 16:1 yields a TRU activity of 30,000-45,000 pCi/g for the first system and 40,000 pCi/g for the second system. Since TRU waste is defined as having a total activity greater than 100,000 pCi/g (see DOE Order 5820.2A), the hottest portion of the mound does not exceed this level (when averaged over the field-of-view of the tripod system).

During the June expedition (see Section 6.7), measurements of individual 300-800-g soil samples from the mound and surrounding area produced TRU activities of 100,000-800,000 pCi/g. The HPGe detectors viewed an area of ground much larger than these soil samples and, as observed throughout the two expeditions, the Pu and Am contamination is not dispersed in a uniform pattern.

The activity results are close enough to the TRU limit that several ideas were proposed to ensure that the total activity of any truckload of soil removed from the Double Tracks site would not exceed the TRU limit. One of the principal means of reducing the total activity of the soil was to remove the hot pieces coated with Pu. This would make a small amount of TRU, but the

FIGURE 8. SUBURBAN VERSUS TRIPOD MEASUREMENTS—THIRD LOCATION. The ^{241}Am soil activity concentrations (pCi/g) as measured by the Suburban HPGe detector at a 3-m height versus the tripod detector measurements at 1-m height. Note the high concentration only in the center of the figure with the outer circles having much less.

many truckloads of soil would certainly be below the limit. This desire to locate the hot pieces and the success of the "mining" of the hot spots found with the hand-held FIDLER detectors were the major impetus behind the ATV hot-spot search in June.

6.2 Experiment #2 (April)—Pu:Am Ratio Measurements

For the two methods of measurement, the analysis was performed independently. The ratio calculation is based on measuring the 60-keV gamma rays emitted by ^{241}Am and three of the gamma rays emitted by ^{239}Pu (129 keV, 375 keV, and 414 keV). Within statistical uncertainties, the ratio of the Am activity relative to the Pu activities calculated from each of its gamma rays should be the same. There are differences in the activities of the two methods, principally as a result of different assumptions about the source-depth distribution, counting statistics, detector characterization, etc. As noted earlier, the attempt to measure the

39- and 51-keV X-rays from ^{239}Pu was unsuccessful, as the large Compton background from the ^{241}Am gamma rays nearly obliterated these X-ray peaks.

The results of the first method of measuring this ratio are presented in Table 3 (see page 22). A relaxation length of 20 cm (8 in) was assumed for the vertical distribution of ^{241}Am . The top portion of the table presents the average activity levels for the three sampling depths of 2.5, 5, and 20 cm. Only the longest time measurements for each arrangement are shown since the only change is a very slight improvement in counting statistics with the increasing time of the measurement. The Pu:Am ratio and the uncertainty in this ratio (based only on the counting statistics) are presented in the bottom portion of the table.

For the uncollimated data, the detector "sees" the Pu gamma rays from a larger area than it sees the Am gamma rays. Thus the Pu activities and the Pu:Am ratios for the uncollimated detector are too high. The collimators used in these measurements are very efficient at removing gamma rays at 60 keV but not as efficient at higher energies such as the gamma rays from ^{239}Pu . To reach the same fractional attenuation, about twice as much material (air, soil, Pb, etc.) is needed to attenuate the 129-keV gamma rays by the same fraction as the 60-keV gamma rays and about three times as much material for the 375- and 414-keV gamma rays. These measurements also are probably too high since a nontrivial fraction of the higher-energy Pu gamma rays can reach the detector after passing through the side of the collimator, while the Am gamma rays are completely attenuated.

Results for the second ratio measurement method, using the highly collimated HPGe detector, are given in Table 4 (see page 23) for both the 300- and 600-second measurements. Activity values, in pCi/g, are given for both Am and Pu, as determined from each individual gamma ray. The bottom of Table 4 shows the resulting ratios of $^{239}\text{Pu}:^{241}\text{Am}$ derived from each of the Pu gamma-ray lines. Ratios vary as a result of counting statistics in analyzing each gamma-ray photopeak, as well as the uncertainty in the depth distribution.

Table 5 (see page 24) shows the theoretical ratios due to decay from the original mixture of the Pu supposedly used in the test. Averaging the results from all three Pu gamma rays and from both the 300- and 600-second acquisitions leads to values of 14.91 ($1/\alpha = 3$ cm), 12.36 ($1/\alpha = 20$ cm), and 11.72 ($1/\alpha =$

FIGURE 9. TRIPOD MEASUREMENTS MADE SOUTH OF THE DOUBLE TRACKS FENCE (APRIL). Nine HPGe measurements from the April expedition are superimposed on the smoothed aerial data from December 1993. Both sets of data use the same Pu:Am ratio of 10:1, which is different from the rest of the data and figures presented in this report.

Table 3. Pu:Am Ratio Measurements for the First Method. The Pu:Am ratio is an average of the ratios based on the 60-keV ^{241}Am photopeak and three of the gamma-ray photopeaks from ^{239}Pu . Since these measurements were made on the mound near GZ, the calculations in this table assume a nearly uniform depth distribution (exponential distribution using a relaxation length of 20 cm [8 in]). Activity results for three different sampling depths are presented; the ratio calculations do not depend on the sampling depth.

	Uncollimated (1800 s) Sampling Depth (cm)			Collimated (3000 s) Sampling Depth (cm)		
	2.5	5	20	2.5	5	20
Average activity (pCi/g)						
60 keV	1,925	1,812	1,294	2,820	2,654	1,896
129 keV	32,669	30,750	21,968	42,797	40,283	28,779
375 keV	29,601	27,862	19,906	36,780	34,619	24,733
414 keV	31,381	29,538	21,102	34,774	32,731	23,384
Pu:Am ratios for each ^{239}Pu gamma ray relative to ^{241}Am						
	Ratio	Uncertainty		Ratio	Uncertainty	
129 keV	16.97	± 0.24		15.18	± 0.24	
375 keV	15.38	± 0.51		13.04	± 0.54	
414 keV	16.30	± 0.57		12.33	± 0.56	
Average	16.21	± 0.81		13.52	± 0.86	

100 cm). These results are in general agreement with the theoretical prediction of 12.53 from Table 5. The results show closer agreement for the deeper depth distributions, which are more likely in the case of contamination within the mound soil. Based on these results, the information presented in Table 5 should provide a reasonable estimate for the appropriate ratio data.

In analyzing risk associated with Pu contamination in soil, it is usual to include activity levels of all significant alpha-emitting isotopes. Alpha emitters are of most concern since inhalation into the lungs is the path leading to the highest potential dose from Pu-contaminated soil. For Pu contamination, the isotopes of concern are ^{239}Pu , ^{240}Pu , and ^{241}Am . These are usually combined and referred to as the total TRU alpha emitters.

Table 5 gives a $^{239-240}\text{Pu}:$ ^{241}Am ratio of 100/7.291645 = 13.71 which, when the Am is added, yields a TRU: ^{241}Am ratio of 14.71. Due to potential differences in migration of Pu and Am in the soil, the actual *in situ* ratio may vary somewhat from the theoretical

prediction. In order to account for potential uncertainties in the actual ratio currently existing at Double Tracks, a value of 16 is recommended for use in determining concentration values from the ^{241}Am measurements. This is approximately 10% higher than the theoretical prediction and provides a reasonable margin of error for uncertainties in the actual ratio.

6.3 Experiment #3 (April)—Depth Profiling Measurements

6.3.1 Side Wall Measurements with TLD Material

Of the three measurements made near the inner fence, the first two were in areas that showed little or no elevated activity with a FIDLER. The FIDLER measurements were not made until after the first two sets of TLD material had been placed. As expected, results from these sheets showed basically background activity. The third set was placed in an area of elevated activity as identified with a FIDLER. The

Table 4. Pu:Am Ratio Measurements for the Second Method. The Pu:Am ratio is an average of the ratios based on the 60-keV ^{241}Am photopeak and three of the gamma-ray photopeaks from ^{239}Pu . These measurements were made with a highly collimated HPGe detector placed on the mound at GZ. Activity values and the corresponding ratios for three different relaxation lengths are presented.

	300 Second Data Relaxation Length (cm)			600 Second Data Relaxation Length (cm)		
	3	20	100	3	20	100
Average activity (pCi/g)						
60 keV	2,584	2,860	2,883	2,308	2,556	2,576
129 keV	36,826	36,360	35,544	40,442	39,930	39,035
375 keV	30,899	27,397	25,865	33,708	29,887	28,216
414 keV	39,620	34,689	32,606	36,343	31,820	29,909
Pu:Am ratios for each ^{239}Pu gamma ray relative to ^{241}Am						
129 keV	14.25	12.71	12.33	17.52	15.62	15.15
375 keV	11.96	9.58	8.97	14.60	11.69	10.95
414 keV	15.33	12.13	11.31	15.75	12.45	11.61
Average	13.85	11.47	10.87	15.96	13.25	12.57
Average of 300- and 600-second results				14.91	12.36	11.72

surface sheet showed several hot spots with most of the area exhibiting background levels. The vertical sheet also showed several hot spots but with no real continuum that would lead to a profile. One hot spot was found near the surface and another approximately 10 cm (4 in) below the surface. It is most likely that the hot spot below the surface was transported there by the shovel in trying to make the side wall to sample.

The TLD material is quite valuable for showing the distribution of activity with a very high spatial resolution (1mm [0.04 in]). For depth profile studies, however, the method used to form a side wall can influence the results. Similar conclusions were reached by ORNL in their attempt to use a track etch detector for measuring alpha contamination. Although in theory the technique should work, in practice, the direct HPGe measurement technique appears to be a better solution.

6.3.2 Comparison Between the Pu X-Rays and the ^{241}Am Gamma Ray

As expected based on the FIDLER readings, no Am

activity was measured at the first two TLD measurement locations. The remaining sites showed the 60-keV gamma ray but no evidence of any X-rays. This included an extremely hot area near the mound which contained sufficient activity to allow direct measurements of the gamma rays from ^{239}Pu .

The lack of any X-rays likely resulted from three reasons: (a) the attenuation in soil, (b) the very small area actually being measured, and (c) the height of the detector above the ground. Because the collimator limited the field-of-view to a 10-cm- (4-in-) diameter circle, the actual amount of soil being measured was quite small. In addition, the detector was approximately 60 cm (24 in) above the ground. Even for the 60-keV gamma ray, only a weak signal was obtained in three of the four locations where elevated activity was measured. A better approach probably would have been to put the detector, with its sides collimated, right on the ground. This would have greatly increased the signal from the 60-keV gamma ray and might have shown the X-rays. This method definitely

Table 5. Pu:Am Ratio Calculations from Initial Composition. The Pu:Am ratio shown here is a simple decay of the Pu and Am isotopes in the initial composition. The ratio is shown as a percentage of Am:Pu, rather than as a Pu:Am ratio as in the rest of this report.

		²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	Total
Mol. Weight (g)		238	239	240	241	242	241	
Mass Fraction		3.9E-05	0.97314	0.0253	0.001487	3.1E-05	0	0.999997
Half Life (yrs)		87.75	24131	6569	14.4	376000	432	
Lambda (per yr)		0.007899	2.9E-05	0.000106	0.048135	1.8E-06	0.001605	
(Ci/g) of Pu + Am(t=0)		0.000662	0.0603	0.005735	0.153124	1.2E-07	0.000974	0.220795
Activity Fraction		0.002999	0.273102	0.025974	0.693513	5.5E-07	0.004411	
Note: All activities are nuclear transformation rates, not particle emission rates.								
Curies from 1 Ci of Pu+Am Mixture							²⁴¹ Am: ²³⁹ Pu	²⁴¹ Am: (²³⁹ , ²⁴⁰ Pu)
Time	Year	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	% Activity Ratio
0	1963	0.002999	0.273102	0.025974	0.693513	5.5E-07	0.004411	1.615281
1	1964	0.002976	0.273094	0.025971	0.660921	5.5E-07	0.00549	2.010224
2	1965	0.002952	0.273087	0.025968	0.629861	5.5E-07	0.006516	2.385876
3	1966	0.002929	0.273079	0.025965	0.600261	5.5E-07	0.007491	2.743144
4	1967	0.002906	0.273071	0.025963	0.572052	5.5E-07	0.008418	3.082893
5	1968	0.002883	0.273063	0.02596	0.545168	5.5E-07	0.0093	3.405947
6	1969	0.00286	0.273055	0.025957	0.519548	5.5E-07	0.010139	3.713092
7	1970	0.002838	0.273047	0.025954	0.495131	5.5E-07	0.010936	4.005075
8	1971	0.002816	0.273039	0.025952	0.471863	5.5E-07	0.011693	4.282609
9	1972	0.002793	0.273032	0.025949	0.449688	5.5E-07	0.012413	4.546376
10	1973	0.002771	0.273024	0.025946	0.428554	5.5E-07	0.013097	4.797022
11	1974	0.00275	0.273016	0.025944	0.408414	5.5E-07	0.013747	5.035165
12	1975	0.002728	0.273008	0.025941	0.389221	5.5E-07	0.014364	5.261393
13	1976	0.002707	0.273	0.025938	0.37093	5.5E-07	0.01495	5.476267
14	1977	0.002685	0.272992	0.025935	0.353498	5.5E-07	0.015507	5.680321
15	1978	0.002664	0.272985	0.025933	0.336885	5.5E-07	0.016035	5.874066
16	1979	0.002643	0.272977	0.02593	0.321053	5.5E-07	0.016537	6.057985
17	1980	0.002622	0.272969	0.025927	0.305965	5.5E-07	0.017013	6.232542
18	1981	0.002602	0.272961	0.025924	0.291586	5.5E-07	0.017465	6.398178
19	1982	0.002581	0.272953	0.025922	0.277883	5.5E-07	0.017893	6.555313
20	1983	0.002561	0.272945	0.025919	0.264824	5.5E-07	0.018299	6.704346
21	1984	0.002541	0.272938	0.025916	0.252379	5.5E-07	0.018684	6.845661
22	1985	0.002521	0.27293	0.025913	0.240518	5.5E-07	0.019049	6.97962
23	1986	0.002501	0.272922	0.025911	0.229215	5.5E-07	0.019395	7.10657
24	1987	0.002481	0.272914	0.025908	0.218443	5.5E-07	0.019723	7.226841
25	1988	0.002462	0.272906	0.025905	0.208177	5.5E-07	0.020033	7.340749
26	1989	0.002442	0.272898	0.025903	0.198394	5.5E-07	0.020327	7.448593
27	1990	0.002423	0.272891	0.0259	0.18907	5.5E-07	0.020605	7.550659
28	1991	0.002404	0.272883	0.025897	0.180185	5.5E-07	0.020868	7.647219
29	1992	0.002385	0.272875	0.025894	0.171717	5.5E-07	0.021117	7.738534
30	1993	0.002366	0.272867	0.025892	0.163647	5.5E-07	0.021351	7.824851
31	1994	0.002348	0.272859	0.025889	0.155957	5.5E-07	0.021573	7.906406
32	1995	0.002329	0.272851	0.025886	0.148627	5.5E-07	0.021783	7.983423
33	1996	0.002311	0.272843	0.025883	0.141643	5.5E-07	0.021981	8.056116
34	1997	0.002293	0.272836	0.025881	0.134986	5.5E-07	0.022167	8.124691
35	1998	0.002275	0.272828	0.025878	0.128642	5.5E-07	0.022343	8.189341
36	1999	0.002257	0.27282	0.025875	0.122597	5.5E-07	0.022508	8.250252
37	2000	0.002239	0.272812	0.025872	0.116835	5.5E-07	0.022664	8.307601
38	2001	0.002222	0.272804	0.02587	0.111345	5.5E-07	0.022811	8.361555
39	2002	0.002204	0.272796	0.025867	0.106112	5.5E-07	0.022948	8.412276

did not work as implemented. A modified version might be successful if the activity is very shallow. There appears to be no reason for further work in this area as the probability of success seems quite low.

6.3.3 Direct HPGe Measurements

Although not providing as fine a spatial resolution as possible with the TLD material, this is a very simple technique for field use. Results from these measurements showed that most of the activity was in the top 2-4-cm (1-2-in) region with one location exhibiting activity down to 8 cm (about 3 in). This shallow distribution is typical of that found for Pu in undisturbed areas. Additional time should be spent developing optimum methods to remove soil in thin layers. (It took several attempts to consistently remove a thin layer of soil; the first several attempts were almost always too deep.) Some additional work should also be done to determine the best detector height and field-of-view combination. Assuming 5-minute measurements, this method can provide a good estimate of the depth of contamination within approximately 30 minutes. This is far superior to the time and cost of obtaining profile samples and analyzing them in a remote laboratory. The method would be more tedious, and likely not as successful, for contaminants that are distributed more deeply into the soil, such as ^{137}Cs from typical world-wide fallout.

6.4 Experiment #4 (June)—ATV Hot-Piece Search

The ATV system was very successful in locating small areas of elevated activity which could then be surveyed with hand-held FIDLER detectors to find the hot piece. No recordable data were collected with this system; this was strictly a search and mark experiment (although the miners were able to show that these small areas could be cleaned up). The search was conducted as a series of east-west paths and covered the area from a little more than 150 m (500 ft) south of GZ to about 60 m (200 ft) north of GZ.

Since the ATV hot-piece search and the Kiwi survey (below) were conducted in parallel, some of the pieces found and removed during the ATV search had been detected earlier by the Kiwi. Therefore the small hot spots within the above distance limits from GZ and present in the Kiwi plots shown later in this report should be considered as already removed during the

ATV search and not as areas which need further cleanup.

6.5 Experiment #5 (June)—Kiwi Survey Measurements

The results of the Kiwi survey are displayed in Figures 10-13 (see pages 26-29). Figure 10 presents both the gross count and TRU activity levels on the original second-by-second locations. The ^{241}Am activity is calculated from each spectrum by extracting the net counts in a window around the 60-keV photopeak. The TRU activity is calculated from the ^{241}Am activity by multiplying by the TRU: ^{241}Am ratio of 16:1 described in Section 6.2. In addition to the color-coded points, the "flight" lines traveled by the Kiwi vehicle are clearly traceable over most of the area.

The individual second-by-second measurements are displayed as small squares which, in this display, are just slightly smaller than the actual footprint of the measurement. The displayed squares are about 2 m (7-8 ft) in length. The detector footprint is closer to 3 m (10 ft) perpendicular to the direction of travel. Along the vehicle path, the detector footprint varies with the speed of the vehicle but, in any case, would provide continuous coverage of the ground along the direction of travel. Thus the only real gaps in the coverage are those between the flight lines. Where the flight lines intersect, it is not always easy from this display to separate which set of data belongs to which flight line.

Of major interest in Figure 10 is the large hole in the data as the Kiwi had to avoid driving over the mound and the small depression just northeast of the mound. In later analysis, a linear interpolation of the measured activity filled this gap. The main effect of the linear interpolation is that, in later plots, the hottest activity location appears just east of the mound rather than on top of it. Other instrument surveys (mainly hand-held FIDLERs) indicated higher activity just east of the mound, although their results were not recorded.

Figure 11 shows the results of collecting all of the individual second-by-second measurements into a nominal 9-m (30-ft) grid and averaging the data over this interval. This plot presents the gross count data which is simply a sum of all of the gamma rays detected in each spectrum. As expected for a region this small, the gross count activity outside the area of actual contamination is quite uniform (varying by only 5%). The lack of data over the mound and the resulting linear interpolation caused the highest contour level to appear over the flight line closest to the mound on the

OBSERVED GROSS COUNTS PER SECOND
(40 keV THROUGH 3026 keV, SECOND BY SECOND)

	GRAY	< 18000
18000 <	LT BLUE	< 19000
19000 <		< 20000
20000 <	LT GRN	< 21000
21000 <		< 24000
24000 <	YELLOW	< 33000
33000 <	ORANGE	< 60000
60000 <	PINK	< 140000

TOTAL TRANSURANIC PICOCURIES/GRAM
(FROM 3 WINDOW AM-241, SECOND BY SECOND)

	GRAY	< 50
50 <	LT BLUE	< 100
100 <		< 200
200 <	LT GRN	< 400
400 <		< 800
800 <	YELLOW	< 1600
1600 <	ORANGE	< 3200
3200 <	PINK	< 6400
6400 <		< 12800
12800 <		< 25600

NAFR DOUBLE TRACKS "KIWI" DATA - JUNE 1995

MAP PRODUCED 10/6/95 EG&G/EM

FIGURE 10. KIWI POINT-BY-POINT GROSS COUNT AND TRU ACTIVITY LEVELS. The data collected by the Kiwi system each second are presented with different colors corresponding to the different gross count and TRU activity levels. The TRU:²⁴¹Am ratio is 16:1. Each square represents an individual measurement of the activity; the size of the square is about the width of the detector's footprint.

OBSERVED GROSS COUNTS PER SECOND
 (40 kev THROUGH 3026 kev, 30' GRID, 30' AVG)

18000	<	GRAY	<	18000
19000	<	LT BLUE	<	19000
20000	<		<	20000
21000	<	LT GRN	<	21000
24000	<		<	24000
33000	<	YELLOW	<	33000
60000	<	ORANGE	<	60000
	<	PINK	<	140000

TOTAL TRANSURANIC PICOCURIES/GRAM
(FROM 3 WINDOW AM-241, 30' GRID, 30' AVG)

50	<	GRAY	<	50	(189000 FT ²)
100	<	LT BLUE	<	100	(91800 FT ²)
200	<	LT GRN	<	200	(56700 FT ²)
400	<	YELLOW	<	400	(20700 FT ²)
800	<	ORANGE	<	800	(7200 FT ²)
1600	<	PINK	<	1600	(2700 FT ²)
3200	<		<	3200	(2700 FT ²)
6400	<		<	6400	(4500 FT ²)

NAER DOUBLE TRACKS "KIWI" DATA - JUNE 1995

FIGURE 12. KIWI 30-FT GRIDDED AND 30-FT AVERAGED TRU ACTIVITIES. These plots are based on the same data presented in Figure 10 except that the ^{241}Am counts have been collected into 30-ft averages and centered on a 30-ft grid. The data are presented both as squares centered on the grid loci and as contour levels derived from the gridded data.

TOTAL TRANSURANIC PICOCURIES/GRAM
(FROM 3 WINDOW AM-241, 30' GRID, 270' AVG)

50	<	GRAY	<	50
100	<	LT BLUE	<	100
200	<		<	200
400	<	LT GRN	<	400
800	<		<	800
	<	YELLOW	<	1600

NAFR DOUBLE TRACKS "KIWI" DATA - JUNE 1995

MAP PRODUCED 10/6/95 EG&G/EM

FIGURE 13. KIWI 30-FT GRIDDED AND 270-FT AVERAGED TRU ACTIVITIES. These are the same data as in Figure 12, except that the ^{241}Am counts have been collected into 270-ft averages centered on a 30-ft grid. The 270-ft averages approximate the spatial resolution of the aerial system at 100 ft AGL. The data are presented both as squares centered on the grid loci and as contour levels derived from the gridded data. Note how well the contour levels in the GZ area match those of Figure 2 in reference 6 (or the aerial data presented as part of Figure 5 in this document).

east side. Actually, this maximum contour should be much larger and encompass most if not all of the mound, but the linear interpolation distorts the values in this area. On the plots, the fence is reconstructed from the measured GPS positions of the corner positions. The jagged boundary of the data is a consequence of collecting data only inside the fence. The data are presented both as colored squares corresponding to the level of activity at each grid location and as contour levels enclosing regions of the same or higher activity.

The preparation of the data in Figure 12 is similar to that of the previous figure, except that this plot is based on the count rate in the photopeak of the 60-keV gamma rays from ^{241}Am . The TRU activity shown in the figure uses the 16:1 TRU: ^{241}Am ratio calculated earlier. Here there is a much better definition of the plume area as well as more details of hot spots within a few hundred feet of the GZ area. As discussed earlier, the Kiwi did not travel over the mound, and those grid cells were filled with a linear interpolation of the data measured around the base of the mound. Therefore, no specific conclusions should be drawn about the ^{241}Am or TRU activity from the Kiwi data on top of the mound. For these data, all grid points outside the fenced area were given ^{241}Am activities of zero. Even with this assumption, it is clear the plume extends all the way to and through the southern fence (see results of the Suburban measurements in Section 6.6).

If a second averaging scale of approximately 90 m (270 ft) is used, the size of the grid footprint approaches the size of the aerial detector system footprint. Figure 13 shows the Kiwi TRU activity data using this new footprint. Notice the similarities in the contour shapes from the Kiwi data compared to the contour shapes from the aerial data in Figure 9 (recall that Figure 9 still uses the old TRU: ^{241}Am ratio of 10:1). There is quite good agreement around GZ.

The Kiwi contours do not spread all the way to the eastern and western fences in the same way as the aerial data. This can be understood as a consequence of the aerial system not having a well-defined footprint. The Kiwi has Cd shielding on the sides of its detectors to limit detector visibility to the side. The aerial system has no shielding and the footprint is "defined" by the attenuation of the gamma rays traveling through the air to the detector. Thus a relatively weak source which is beyond the aerial system footprint can be ignored. However, a strong source (the

mound) can contribute a few percent of its gamma rays to the aerial system even when it is well beyond the normal footprint limit, and therefore, it will produce an effect at large distances.

The agreement between the Kiwi and the aerial system is not quite as remarkable in the plume area. This may just be a result of the much lower activity and the aerial system's inability to do much with measurements made at or near its minimum detectable activity limit.

6.6 Experiment #6 (June)—HPGe *In Situ* Measurements

In June, the Suburban HPGe detector system made a series of measurements to establish background levels around the outside of the fence at Double Tracks and at the revegetation site northeast of Double Tracks. The locations and activity levels measured by the Suburban system are listed in Table 6. Figure 14 (see page 33) shows the locations marked by colored dots corresponding to the TRU activity. Again, the aerial and ground-based data in this figure both use a 16:1 ratio to convert the measured ^{241}Am activity to TRU activity.

As a check on the consistency of the data, the activity of a control point was measured at the beginning and end of each day. The results of these measurements are listed in Table 7 (see page 34). Once the Suburban went inside the exclusion zone, it stayed there until the end of the week. Thus two separate control points were established: one outside, which was used on the first day, and one inside, which was used on the remaining days. The two dots in Figure 14 identify the two control points. The ^{241}Am activity at the control points is very low (below the minimum detectable activity) and counting statistics dominate. The daily comparisons were made using the ^{40}K photopeak at 1,461 keV and the ^{228}Ac pair of photopeaks around 965 keV, which had sufficient counts in the 600-second measurements.

These control points also provided a check on the variations in the GPS positioning system. One second of latitude is approximately 31 m (101 ft) while one second of longitude is only about 24 m (80 ft). While the Suburban was returned daily to what visually appeared to be the same location, the variation appears to follow the 3-5 m (10-15 ft) accuracy of this particular GPS system.

Table 6. Suburban Measurements in June. The locations and Am concentrations are shown for the HPGe measurements made at the Double Tracks area. Excluded from the table are the energy calibration measurements. The TRU concentration is based on a ($^{239}\text{Pu} + ^{240}\text{Pu} + ^{241}\text{Am}$): ^{241}Am ratio of 16. Positions shown in *italics* never received a lock on the differential GPS signal, so they have a positional uncertainty on the order of 100 m (300 ft).

File No.	Latitude (N)	Longitude (W)	^{241}Am (pCi/g)	TRU (pCi/g)
3	37°42'14.27"	116°59'14.87"	< MDA ^a	< MDA ^a
4	37°41'58.25"	116°59'18.54"	< MDA ^a	< MDA ^a
5	37°41'57.61"	116°59'23.62"	< MDA ^a	< MDA ^a
6	37°42'17.50"	116°59'22.65"	< MDA ^a	< MDA ^a
7	37°42'29.20"	116°59'21.83"	< MDA ^a	< MDA ^a
8	37°42'30.59"	116°59'14.97"	< MDA ^a	< MDA ^a
9	37°42'34.29"	116°59' 0.66"	< MDA ^a	< MDA ^a
10	37°41'57.89"	116°59'21.10"	9.37 ± 0.58	149.9 ± 9.3
11	37°41'53.04"	116°59'21.30"	5.69 ± 0.56	91.0 ± 9.0
13	37°41'58.12"	116°59'21.44"	7.49 ± 0.56	119.8 ± 9.0
14	37°42' 1.19"	116°59'21.74"	6.05 ± 0.55	96.8 ± 8.8
15	37°42' 4.28"	116°59'21.13"	9.70 ± 0.59	155.2 ± 9.4
16	37°42' 7.09"	116°59'20.11"	14.10 ± 0.62	225.6 ± 9.9
23	37°42' 7.24"	116°59'20.38"	19.19 ± 0.66	307.0 ± 10.6
24	37°42'10.09"	116°59'20.00"	30.70 ± 0.73	491.2 ± 11.7
25	37°42'13.15"	116°59'20.14"	17.32 ± 0.65	277.1 ± 10.4
26	37°42'14.84"	116°59'19.75"	22.22 ± 0.70	355.5 ± 11.2
27	37°42'17.09"	116°59'19.38"	15.63 ± 0.65	250.1 ± 10.4
28	37°42'18.12"	116°59'19.41"	6.70 ± 0.57	107.2 ± 9.1
29	37°42'19.16"	116°59'19.14"	11.57 ± 0.62	185.1 ± 9.9
30	37°42'19.40"	116°59'18.82"	19.54 ± 0.67	312.6 ± 10.7
31	37°42'19.92"	116°59'18.73"	28.34 ± 0.74	453.4 ± 11.8
32	37°42'20.42"	116°59'18.47"	52.36 ± 0.90	837.8 ± 14.4
33	37°42'20.90"	116°59'18.24"	86.12 ± 1.06	1,377.9 ± 17.0
34	37°42'23.04"	116°59'17.45"	13.69 ± 0.63	219.0 ± 10.1
35	37°42'23.78"	116°59'17.21"	3.02 ± 0.52	48.3 ± 9.3
43	37°42'24.89"	116°59'16.72"	2.77 ± 0.53	44.3 ± 8.5
44	37°42'26.53"	116°59'16.09"	< MDA ^a	< MDA ^a
45	37°42'29.33"	116°59'15.10"	< MDA ^a	< MDA ^a
46	37°42'22.82"	116°59'22.16"	1.75 ± 0.51	28.0 ± 8.2
47	37°42'22.74"	116°59'20.81"	2.15 ± 0.53	34.4 ± 8.5
48	37°42'22.50"	116°59'19.50"	2.46 ± 0.53	39.4 ± 8.5
49	37°42'22.28"	116°59'18.98"	7.38 ± 0.58	118.1 ± 9.3
50	37°42'21.59"	116°59'16.55"	75.50 ± 1.04	1,208.0 ± 16.6
51	37°42'21.42"	116°59'16.17"	11.72 ± 0.61	187.5 ± 9.8

^a The Minimum Detectable Activity (MDA) is equal to 3σ where σ is the standard deviation of the counting statistics. For measurements made at a height of 3 m, the MDA is 1.0 pCi/g of ^{241}Am and 16.0 pCi/g of TRU. For measurements made at a height of 7.5 m, the MDA is 1.5 pCi/g of ^{241}Am and 24.0 pCi/g of TRU.

Table 6. Suburban Measurements in June (continued)

File No.	Latitude (N)	Longitude (W)	²⁴¹ Am (pCi/g)	TRU (pCi/g)
52	37°42'21.19"	116°59'15.42"	6.15 ± 0.57	98.4 ± 9.1
53	37°42'21.24"	116°59'14.92"	7.57 ± 0.57	121.1 ± 9.1
54	37°42'20.91"	116°59'14.25"	4.58 ± 0.53	73.3 ± 8.5
55	37°42'20.72"	116°59'13.51"	< MDA ^a	< MDA ^a
56	37°42'21.10"	116°59'17.20"	19.43 ± 0.67	310.9 ± 10.7
57	37°42'20.34"	116°59'17.35"	46.25 ± 0.85	740.0 ± 13.6
58	37°42'20.60"	116°59'19.00"	2.57 ± 0.55	41.1 ± 8.8
59	37°42'21.63"	116°59'19.69"	1.86 ± 0.52	29.8 ± 8.3
60	37°42'20.61"	116°59'19.58"	< MDA ^a	< MDA ^a
61	37°42'19.82"	116°59'17.24"	17.50 ± 0.66	280.0 ± 10.6
73	37°42'20.04"	116°59'15.51"	4.76 ± 0.55	76.2 ± 8.8
74	37°42'18.02"	116°59'16.84"	3.54 ± 0.55	56.6 ± 8.8
75	37°42'16.67"	116°59'16.24"	1.78 ± 0.51	28.5 ± 8.2

^aThe Minimum Detectable Activity (MDA) is equal to 3σ where σ is the standard deviation of the counting statistics. For measurements made at a height of 3 m, the MDA is 1.0 pCi/g of ²⁴¹Am and 16.0 pCi/g of TRU. For measurements made at a height of 7.5 m, the MDA is 1.5 pCi/g of ²⁴¹Am and 24.0 pCi/g of TRU.

6.7 Experiment #7 (June)—Hot-Piece Activity Measurements

Results of the metallic piece measurements are given in Table 8 (see page 35). Most pieces were relatively flat and approximately 0.5 to 1.0 cm (0.2-0.4 in) thick. Assuming that the pieces were thick enough to stop the ²⁴¹Am 60-keV gamma ray, the total activity contained on a piece is the sum of that obtained from measuring each side. By dividing this total by the mass of the piece, the activity per unit mass can be determined. These results, for both ²⁴¹Am and TRU, are also presented in Table 8. As shown in this table, all these pieces greatly exceed the level (0.1 µCi/g) currently used to separate TRU waste from low-level waste.

Table 9 (see page 36) presents the results of the soil sample measurements. The lower density of the soil (compared to the metallic pieces discussed above) and the size of the bottles allow some fraction of the ²⁴¹Am 60-keV gamma rays to escape through either side of the bottle. Thus a measurement of both sides may count the activity of a location in the bottle twice. The TRU values given in the table are based on the sum of the activity measured from each side. The actual total soil activity should be somewhere between the value obtained from one side and the sum of the activity measured from both sides. The

data show that some very small areas within the inner fence have activity levels slightly greater than that used to define TRU waste. However, the areas involved are quite small compared to the total area that will have soil removed during the remediation. Most of the soil to be removed has activity levels well below the TRU level. Therefore, the bulk soil transported off-site for disposal should fall well within the classification used for low-level waste.

7.0 SUMMARY

A series of measurements were conducted at the Double Tracks site on Stonewall Flat at the NAFR. The April expedition tested a number of new techniques and performed several preliminary characterization measurements. In addition, three techniques for rapidly assessing the Am and Pu depth profiles were tested. Several plots comparing these ground-based system measurements with each other and with the 1993 aerial data show remarkable agreement.

The June expedition focused on the site characterization using the newly designed Kiwi vehicle. Another new detector platform, an ATV equipped with FIDLER detectors, performed a search for hot pieces marking the locations for later removal by teams of "miners."

DOUBLE TRACKS Site
June Suburban HPGe Data

CONVERSION SCALE	
COLOR	TRU (pCi/g)*
Black	< 50
Blue	50 - 100
Green	100 - 200
Yellow	200 - 600
Red	> 600

*Ground-based data from Suburban HPGe system taken at 7.5-meter heights.
Conversion assumptions include:
characterized detector
3-cm relaxation length
2.5-cm sample depth
TRU: Am ratio = 16

Unsmoothed Aerial Data

CONVERSION SCALE	
LETTER LABEL	TRU (pCi/g)*
D	< 160
E	160 - 250
F	250 - 400
G	400 - 640
H	640 - 1,000
I	1,000 - 1,600
J	1,600 - 2,530

*Aerial data taken at a 30-meter altitude at 36 m/s (70 knots). The detector array consisted of eight 2- x 4- x 16-inch NaI(Tl) detectors.
Conversion assumptions include:
cosine detector response
3-cm relaxation length
2.5-cm sample depth
TRU: Am ratio = 16
Photopeak cts = 1.6 x window cts

FIGURE 14. MEASUREMENT LOCATIONS OF THE SUBURBAN SYSTEM (JUNE). The locations (by GPS coordinates) of the Suburban measurements are marked by colored dots corresponding to five bands of TRU activity. The contour data from the 1993 aerial survey are included for reference. Both sets of data use the 16:1 TRU:²⁴¹Am activity ratio. The two control points (one inside the fence and one outside) are indicated by the large dots.

Both of these new systems performed better than expected.

For future site characterizations, the ATV will search for hot pieces. The tripod HPGe systems will obtain rough depth distributions in the soil and measure isotopic ratios. The Suburban system with the HPGe detector suspended on the end of a mast will make spot measurements inside the contaminated area as

well as a set of measurements to establish background radiation levels. Once all of this work is complete and these systems leave the area, the Kiwi system will perform the actual characterization measurements of the site. The Kiwi will use the depth distributions and isotopic ratios to calculate accurate soil concentration and the horizontal distribution of the contamination.

Table 7. Control Point Suburban Measurements in June. The locations and isotopic concentrations are shown for the HPGe measurements made at the daily control points. Positions shown in *italics* never received a lock on the differential GPS signal, so they have a positional uncertainty on the order of 100 m (300 ft).

File No.	Latitude (N)	Longitude (W)	²²⁸ Ac (pCi/g)		⁴⁰ K (pCi/g)	
Outside Fence						
2	37°42'18.55"	116°59'13.48"	not recorded			
12	37°42'18.44"	116°59'13.54"	3.38	± 0.24	63.5	± 1.3
Inside Fence						
22	37°42'19.25"	116°59'14.00"	not recorded			
36	37°42'18.91"	116°59'14.25"	2.92	± 0.22	57.2	± 1.3
42	37°42'20.34"	116°59'14.99"	3.15	± 0.23	60.5	± 1.3
62	37°42'18.94"	116°59'14.06"	2.71	± 0.24	57.6	± 1.3
72	37°42'18.70"	116°59'14.06"	3.33	± 0.23	58.8	± 1.2
76	37°42'18.67"	116°59'14.15"	3.00	± 0.23	57.7	± 1.3

Table 8. "Pieces" Activity Measurements from June. Selected pieces of metal, coated with an Am and Pu mixture, were collected and measured during the June survey. Their specific activity measurements place them in the TRU waste category. Note that the activities in this table are $\mu\text{Ci/g}$ rather than the pCi/g used throughout the rest of the report.

Piece Number	²⁴¹ Am Activity			Mass (g)	²⁴¹ Am	TRU ^a
	Side 1 (μCi)	Side 2 (μCi)	Total (μCi)		Act./mass (μCi/g)	Act./mass (μCi/g)
06/07/95 ^b						
1	143.7	179.5	323.2	33.25	9.7	155
2	71.4	89.0	160.4	30.68	5.2	84
3	357.1	255.5	612.6	254.01	2.4	39
4	318.3	366.1	684.4	316.4	2.2	35
5	167.0	144.5	311.5	124.12	2.5	40
6	157.8	211.3	369.1	58.87	6.3	100
7	54.2	54.2	108.4	13.41	8.1	130
10	106.2	120.4	226.6	95.55	2.4	38
11	17.7	17.6	35.3	21.33	1.7	27
12	49.6	54.8	104.4	2.4	43.5	696
06/08/95 ^c						
13	87.7	74.3	162.0	107.36	1.5	24
14	123.3	123.3	246.6	39.78	6.2	99
15	38.5	47.7	86.2	17.38	5.0	80

^a Assumed a TRU to ²⁴¹Am ratio of 16. Note: TRU waste is defined as an activity/mass greater than 0.1 $\mu\text{Ci/g}$.

^b Subtracted a background activity of 5.4 μCi .

^c Subtracted a background activity of 1.3 μCi .

Table 9. Soil Sample Activity Measurements from June. Selected soil samples measured during the June expedition exhibit Am and TRU activity levels higher than the definition of TRU waste. For soil sample counting, the actual value will probably be closer to that obtained from one side only, which would be approximately half the value quoted here. Note that the activities in this table are $\mu\text{Ci/g}$ rather than the pCi/g used throughout the rest of the report.

Sample Number	²⁴¹ Am Activity			Mass (g)	²⁴¹ Am	TRU ^a
	Side 1 (μCi)	Side 2 (μCi)	Total (μCi)		Act./mass (μCi/g)	Act./mass (μCi/g)
06/07/95 ^b						
8	2.5	3.8	6.3	796.62	0.008	0.128
9	8.2	6.0	14.2	746.97	0.019	0.304
06/08/95 ^c						
S1 ^d	2.3	2.4	4.7	558.41	0.008	0.134
S2 ^e	5.9	6.3	12.2	240.87	0.051	0.816
S3 ^f	4.6	5.0	9.6	297.77	0.032	0.512
S4 ^g	5.8	5.7	11.5	345.86	0.033	0.528

^a Assumed a TRU to ²⁴¹Am ratio of 16. Note: TRU waste is defined as an activity/mass greater than 0.1 $\mu\text{Ci/g}$.

^b Subtracted a background activity of 5.4 μCi . Samples were taken from soil previously collected from areas within the exclusion area which were identified by the FIDLER detectors on the ATV as containing elevated amounts of Am.

^c Subtracted a background activity of 1.3 μCi .

^d Sample was collected approximately 20 m (60 ft) from GZ in direction of 65°.

^e Sample taken approximately 1.6 m (5 ft) below ground level during the drilling operations to assess the contents of the mound at GZ.

^f Sample taken approximately 30 m (100 ft) east of GZ.

^g Sample taken approximately 45 m (150 ft) east of GZ.

APPENDIX A

SURVEY PARAMETERS AND RESULTS

Parameters

Survey Site:	Double Tracks Site Nellis Air Force Range near Tonopah, Nevada
Survey Dates:	April 10-13, 1995 June 5-9, 1995
Nominal Site Elevation:	1,450-1,550 m (4,800-5,000 ft) MSL
Survey Altitude:	0.75 m (30 in) Kiwi (NaI) system 0.75 m (30 in) ATV (FIDLER) system 1 m (3 ft) HPGe tripods 3 m (10 ft) and 7.5 m (25 ft) Suburban (HPGe) system
Line Spacing:	3 m (10 ft) Kiwi system 1.6 m (5 ft) ATV system
Line Direction:	Kiwi: north-south inside fenced area and approximately northwest-southeast south of fenced area. ATV: east-west inside fence.
Survey Coverage:	Approximately 0.13 km ² (0.05 mi ²) inside fenced area. Sporadic measurements outside fenced area.
Base of Operation:	Tonopah Test Range, Nevada.
Positioning System:	Differential GPS (Global Positioning System).
Detector Arrays:	Two tripod systems: approximately 86% and 107% efficiency HPGe. Suburban vehicle with approximately 98% HPGe on extendable mast. Kiwi vehicle with NaI detectors and REDAR IV. ATV with three FIDLER detectors.

Conversion Factors

$$1 \mu\text{R/h} = 8.76 \text{ mR/yr} \approx 8.37 \text{ mrem/yr}$$

APPENDIX B

This appendix is an unpublished internal report of some work performed in Area 11 of the NTS and is included here principally for its background information on the thermoluminescent detector (TLD) sheets and to highlight the discrete distribution of Pu at another site. One of the authors of this appendix (AB) assisted in the data collection at Double Tracks. Minor editorial changes have been made to the original document.

IN SITU MEASUREMENT OF ENVIRONMENTAL ALPHA ACTIVITY AT VERY HIGH SPATIAL RESOLUTION AND SENSITIVITY

A. BHATTACHARJIE AND W. QUAM
EG&G/EM SANTA BARBARA OPERATIONS

Abstract

Large (30 cm by 30 cm) TLD sheets were used to determine the surface and depth distribution of ^{239}Pu alpha contamination at a location on the Nevada Test Site. The spatial resolution was 3 mm at a signal to noise ratio exceeding 20 to 1. Depth profiles were analyzed to derive their characteristic shape. Selected graphs of the raw alpha distributions, from surface and depth distributed activities, are shown.

Introduction

Recent work by International Sensor Technology (IST) in Pullman, WA, has yielded several large area TLD products. One such TLD, a calcium sulfate (thulium activator) was used for the *in situ* alpha contamination measurements reported here. These TLD materials are provided in sheet form approximately 30 cm by 30 cm with individual TLD's located on 3-mm centers on the surface of the Kapton backing. The TLD material is held on the sheet surface with a binder of a few microns thickness. The alpha sensitivity is sufficient to activate the TLD traps in the TLD material.

The TLD sheets are robust and may be readily handled for placement. The sheets are reusable and can be read-out several hundred times. The TLD sheets are sensitive to betas and gammas as well as alphas; however, the higher linear energy transfer of the alpha produces a larger signal per incident particle. Thus the sheets can be used to discriminate between the three radiations by setting up a discrimination threshold based upon signal to noise ratio.

Calibration measurements with ^{241}Am show that the sensitivity of this TLD material was 0.3 pCi for a 20-minute exposure time. We believe that this sensitivity can be increased by a large margin by improving the readout technique. The manufacturer (Dr. Braunlich of IST) has stated that recent improvements in readout technique can yield up to a factor of 100 in alpha detection sensitivity.

Description of the Field Experiment

The measurements were performed on several occasions within the fenced Site B in Area 11 at the Nevada Test Site. This area is available for evaluation of detectors that are not usually used for *in situ* measurements. The present work was performed for a DOE environmental restoration project.

The TLD sheets were manually placed on the soil surface to create surface maps and pressed vertically into the subsurface with a hammer-driven emplacement tool to create vertical profile maps. The major objectives were to observe the detector performance in high ground temperatures with sun at zenith and to determine feasibility of locating minute plutonium "hot particles" on site. Exposure times of 15 to 70 minutes were used, with good data

obtained over this range. After exposure the TLD's were read out with an IST automatic reader using a pulsed carbon dioxide laser. The readout process takes about one hour.

The data are obtained as a three-dimensional array and can be drawn as an XYZ plot from a personal computer file with the alpha activity plotted as the Z coordinate and the soil surface shown as the XY plane. These files can readily be manipulated to determine the statistical parameters of alpha activity within user-selected XY domains.

Three different TLD sheet materials were field tested to determine noise figures and detection sensitivities. Although ground temperatures were not measured, the air temperature was in the vicinity of 108°F; *i.e.*, less than ideal for this material. Nonetheless, the data obtained were fairly noise free, with calcium sulfate (thulium activator) being the most sensitive. The figures shown are from this material.

Discussions

As mentioned earlier, the measurements were performed at Site B in Area 11 at the Nevada Test Site. This area was used many years ago for safety shots and has a surface contamination of ^{239}Pu . Cleanup of this area is currently in process.

The first plot shows the XYZ representation of data from one TLD sheet laid flat on the soil surface and exposed for 30 minutes with part of its sensitive surface covered with an alpha absorber. This measurement served to prove that the isolated large peaks were caused only by alpha. They are present in the uncovered part and not (with some exceptions) in the covered part. The peaks seen in the covered part are noise peaks caused by readout errors and would cause false alarms. The background outside the large spikes is a combination of real incident background and the noise generated during readout. These plots show nearly 10,000 pixels of data points, each the reading of an individual TLD.

The second plot is a representation of subsurface alpha activity. The TLD sheet was emplaced in the form of a cylinder about 6 cm in diameter. It was allowed to overlap and to extend above the soil surface. The plot shows a greatly reduced signal in the overlap region, again demonstrating that the origin of the spikes is incident alpha. Further, as expected, it shows a reduced signal in the above ground portion illustrating the higher alpha rate from soil. The third plot has been calculated from the subsurface data by integrating signal along the sheet's circumference and plotting versus depth. We see here that the alpha contamination is not uniform with depth but appears to be low for a few centimeters and then a sharp increase appears which gradually decreases versus depth. This behavior may be due to an uncontaminated overburden placed to minimize spread of the ^{239}Pu .

Conclusions

Our measurements have shown that the large area, high spatial resolution TLDs provide unique capabilities for environmental cleanup of plutonium and transuranics. Its *in situ* usage allows pinpointing contaminants without soil removal and processing. The disposal problem is simplified. Its large area allows large soil surface coverage in reasonable mapping times. With future improvements of TLD detection sensitivities, the mapping times would be significantly reduced. Further, the sheet TLDs provide a simple quantitative means of processing surface contamination with high spatial resolution. Minute "hot particles" would be located. Quantitative measurements of alpha contamination versus depth in soil may be readily obtained without taking soil samples for wet chemistry at a fraction of cost and time. Cost is additionally reduced by reusing the TLD sheets.

FIGURE B-1. SOIL SURFACE ALPHA MAP WITH CaSO_4Tm (Grain Size 10 to 40 microns). Plot showing three-dimensional representation of 10,000 pixels of data points with the TLD sheet flat on the soil surface and exposed for 30 minutes (a) exposed section (b) section covered with an alpha absorber.

SH460-0 Net Data

FIGURE B-2. PLOT OF SUBSURFACE ALPHA ACTIVITY. Dark spots are net signals covering several pixels each. The average background was 6,000 signal units and the largest peak was 400,000 signal units.

SH460 Average pCi/gm vs Depth
≈54' E of GZ, Site B

FIGURE B-3. THIS PLOT IS DERIVED FROM FIGURE B-2 AND REPRESENTS THE AVERAGE NET SIGNAL PER MINUTE INTEGRATED OVER THE TLD SHEET PORTION THAT WAS SUBSURFACE. Note that the signal to noise ratio is about 10:1 at 5 cm depth. The low signal between 0 and 5 cm may be due to clean soil overburden used to inhibit resuspension.

REFERENCES

1. Schoengold, C.R., M.E. DeMarre, and E.M. McDowell. *Radiological Effluents Released from Announced U.S. Continental Tests 1961 Through 1988*. REECO, Las Vegas, Nevada, 1990.
2. *Radiological Conditions at Project Roller Coaster Sites — 1966*, Report No. NVO-162-28. REECO, Mercury, Nevada, 1967.
3. Jobst, J.E. *An Aerial Radiological Survey of Clean Slates 1, 2, and 3, and Double Track*, Report No. EGG-1183-1737. EG&G, Las Vegas, Nevada, 1979.
4. Proctor, A.E., T.J. Hendricks. *An Aerial Radiological Survey of the Double Track Site and Surrounding Area*, Report No. EGG-11265-1086. EG&G/EM, Las Vegas, Nevada, 1994.
5. Hendricks, T.J. *Double Track Site*, Report No. EGG-11265-1146. EG&G/EM, Las Vegas, Nevada, 1995.
6. Lindeken, C.L., K.R. Peterson, D.E. Jones, and R.E. McMillen. "Geographical Variations in Environmental Radiation Background in the United States," *Proceedings of the Second International Symposium on the Natural Radiation Environment, August 7-11, 1972, Houston, Texas*. National Technical Information Service, Springfield, Virginia, pp 317-332, 1972.
7. Klement, Jr., A.W., C.R. Miller, R.P. Minx, and B. Shleien. *Estimates of Ionizing Radiation Doses in the United States 1960-2000*, U.S. EPA Report ORP/CSD72-1. EPA, Washington, D.C., 1972.
8. Reiman, R.T. *In Situ Surveys of the U.S. Department of Energy's Rocky Flats Plant — Golden, Colorado*, Report No. EGG-10617-1129. EG&G/EM, Las Vegas, Nevada, 1991.
9. Beck, H.L., J. DeCampo, and C. Gogolak. *In Situ Ge(Li) and NaI(Tl) Gamma Ray Spectrometry*, Report No. HASL-258, TID-4500. U.S. AEC Health and Safety, Laboratory, New York, New York, 1972.

DISTRIBUTION

DOE/DP

L. E. Gordon-Hagerty (1)
O. W. Taylor (1)

IT

J. R. McKinley (3)

DOE/HQ

OSTI (25)

BN

P.P. Guss WAMO (1)
R.E. Kelley LVAO (1)
D.S. Long LVAO (1)
C. L. Lyons LVAO (1)
T E. Richardson LVAO (1)
S.R. Riedhauser LVAO (1)
W. J. Tipton LVAO (1)

DOE/NV

M. R. Dockter (1)
M. Sanchez (1)
Public Reading Room (1)
TIO (1)
TIRC (1)

LIBRARIES

RSL (60)
WAMO (1)

IN SITU RADIOLOGICAL SURVEYING AT
THE DOUBLE TRACKS SITE
NELLIS AIR FORCE RANGE
TONOPAH, NEVADA
DOE/NV/11718-013

DATE OF SURVEY: APRIL 10-13, 1995 AND JUNE 5-9, 1995
DATE OF REPORT: MARCH 1996

Appendix E

Vertical Profile Plots for Americium and Plutonium in Soil

Figure E-1
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 1

Figure E-2
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 2

Figure E-3
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 3

Figure E-4
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 4

Figure E-5
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 5

Figure E-6
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 6

Figure E-7
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 7

Figure E-8
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 8

Figure E-9
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 9

Figure E-10
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 10

Figure E-11
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 11

Figure E-12
Vertical Distribution of Plutonium-239/240 and Americium-241 in Double Tracks Soil Characterization Event 1, Sample Location 12

Appendix F

Soil Particle-Size and Volume Reduction Data

Appendix F
Treatability Testing Results
Grain Size Analysis

IT Corporation Production Development Laboratory

Before Attrition
Scrubbing

	Plus 16000 um			1600 to 149 um		Total Minus		149 to 74 um		Minus 74 um		Total Plus
	plus #4 mesh			#4 to #100 Mesh		#100 Mesh		#100 to #200 Mesh		Minus #200 Mesh		100# Mesh
Sample Number	Total Weight	Weight	Percent	Weight	Percent	Percent	Weight	Percent	Weight	Percent	Percent	
DT 725001A	1555.71	113.14	7.27	1095.94	70.45	77.72	203.55	13.08	143.08	9.20	22.28	
DT 725002A	1444.93	104.12	7.21	1097.56	75.96	83.17	156.41	10.82	86.84	6.01	16.83	
DT 725003A	1422.84	180.23	12.67	1134.10	79.72	92.39	92.20	6.48	16.11	1.13	7.61	
DT 725004A	1587.36	94.80	5.97	1308.20	82.41	88.39	147.91	9.32	36.45	2.30	11.61	
DT 725005A	1413.19	84.92	6.01	1018.18	72.05	78.06	269.18	19.05	40.91	2.89	21.94	
DT 725006A	1636.85	78.26	4.78	1182.20	72.22	77.01	310.79	18.99	65.60	4.01	22.99	
DT 725007A	1371.49	95.56	6.97	934.08	68.11	75.07	206.37	15.05	135.48	9.88	24.93	
DT 725008A	1566.25	165.24	10.55	1262.25	80.59	91.14	121.53	7.76	17.23	1.10	8.86	
DT 725009A	1589.98	111.99	7.04	1103.72	69.42	76.46	318.10	20.01	56.17	3.53	23.54	
DT 725010A	1296.55	82.56	6.37	1186.28	91.50	97.86	22.26	1.72	5.45	0.42	2.14	
Average	1488.50	111.08	7.48	1132.25	76.24	83.73	184.83	12.23	60.33	4.05	16.27	

After Attrition
Scrubbing

DT 725001A	64.91	35.09
DT 725002A	70.25	29.75
DT 725003A	76.58	23.42
DT 725004A	61.7	38.3
DT 725005A	57.32	42.68
DT 725006A	62.47	37.53

Desert Research Institute

Before Attrition
Scrubbing

	Plus 2000 um			2000 to 250 um		250 to 125 um		125 to 75 um		75 to 38 um		Minus 38 um	
Sample Number	Total Weight	Weight	Percent	Weight	Percent	Weight	Percent	Weight	Percent	Weight	Percent	Weight	Percent
DT 725001B	197.70	43.30	21.90	77.20	39.05	28.10	14.21	19.10	9.66	18.30	9.26	11.70	5.92
DT 725002B	198.70	40.70	20.48	84.70	42.63	32.20	16.21	18.50	9.31	13.00	6.54	9.60	4.83
DT 725003B	196.30	40.00	20.38	87.70	44.68	30.10	15.33	17.40	8.86	12.20	6.21	8.90	4.53
DT 725004B	198.60	34.50	17.37	70.30	35.40	35.20	17.72	24.00	12.08	18.30	9.21	16.30	8.21
DT 725005B	198.20	24.10	12.16	66.10	33.35	36.90	18.62	31.90	16.09	26.90	13.57	12.30	6.21
DT 725006B	198.80	33.50	16.85	76.10	38.28	36.10	18.16	25.00	12.58	18.50	9.31	9.60	4.83
DT 725007B	198.70	50.90	25.62	71.30	35.88	29.90	15.05	22.60	11.37	16.50	8.30	7.50	3.77
DT 725008B	197.80	56.70	28.67	91.40	46.21	21.90	11.07	12.40	6.27	8.60	4.35	6.80	3.44
DT 725009B	198.50	31.40	15.82	70.60	35.57	35.50	17.88	27.30	13.75	20.60	10.38	13.10	6.60
DT 725010B	198.20	35.10	17.71	67.20	33.91	38.60	19.48	25.20	12.71	18.00	9.08	14.10	7.11
Average	198.15	39.02	19.70	76.26	38.49	32.45	16.37	22.34	11.27	17.09	8.62	10.99	5.55

Appendix F
Gamma Spectrography
plus 100 mesh Size Fraction
Radiological Results
(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6854	Q	SN-GG#6855	Q	SN-GG#6856	Q	SN-GG#6857	Q	SN-GG#6858	Q
Ac-228	0.0320	1.5 ± 10		1.6 ± 10		1.4 ± 10		1.4 ± 10		1.5 ± 11	
Am-241	0.0102	17.0 ± 1		5.12 ± 2		2.4 ± 6		16.2 ± 1		1.5 ± 7	
Bi-214	0.0070	0.96 ± 10		1.1 ± 8		1.1 ± 8		1.1 ± 8		1.0 ± 8	
Cs-137	0.00448	0.19 ± 19		0.14 ± 23		0.18 ± 15		0.18 ± 16		0.30 ± 13	
K-40	0.035	27 ± 6		28 ± 6		28 ± 6		25 ± 6		27 ± 6	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.1 ± 6		1.5 ± 6		1.6 ± 6		1.4 ± 6		1.6 ± 6	
Pb-214	0.0056	1.0 ± 8		1.1 ± 8		0.99 ± 9		1.1 ± 8		1.0 ± 8	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.47 ± 7		0.58 ± 6		0.55 ± 6		0.50 ± 6		0.59 ± 5	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

Appendix F
Gamma Spectrography
plus 100 mesh Size Fraction
Radiological Results

(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6859	Q	SN-GG#6860	Q	SN-GG#6861	Q	SN-GG#6862	Q	SN-GG#6863	Q
Ac-228	0.0320	1.5 ± 11		1.4 ± 11		1.4 ± 9		1.4 ± 9		1.4 ± 11	
Am-241	0.0102	10.9 ± 4		19.7 ± 1		1.91 ± 4		6.7 ± 2		7.4 ± 4	
Bi-214	0.0070	1.0 ± 9		1.1 ± 8		0.92 ± 8		0.94 ± 8		1.1 ± 8	
Cs-137	0.00448	0.33 ± 11		0.44 ± 10		< 0.00448	U	0.1 ± 24		0.26 ± 14	
K-40	0.035	26 ± 6		27 ± 6		24 ± 6		25 ± 6		24 ± 6	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.4 ± 6		1.4 ± 6		1.4 ± 6		1.4 ± 6		1.5 ± 6	
Pb-214	0.0056	1.0 ± 8		1.1 ± 8		1.0 ± 8		1.1 ± 8		1.1 ± 8	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.53 ± 6		0.53 ± 6		0.44 ± 6		0.49 ± 6		0.46 ± 7	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

Appendix F
Gamma Spectrography
After Attrition Scrubbing - plus 100 mesh Size Fraction
Radiological Results
(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6854A	Q	SN-GG#6855A	Q	SN-GG#6856A	Q	SN-GG#6857A	Q	SN-GG#6858A	Q
Ac-228	0.0320	1.4 ± 18		1.6 ± 18		1.6 ± 18		1.7 ± 21		1.7 ± 17	
Am-241	0.0102	3.0 ± 4		6.5 ± 6		2.6 ± 8		6.4 ± 6		8.2 ± 5	
Bi-214	0.0070	1.1 ± 13		1.2 ± 13		1.2 ± 13		1.3 ± 13		1.4 ± 13	
Cs-137	0.00448	0.50 ± 15		< 0.00448	U	0.16 ± 47		< 0.00448	U	0.25 ± 32	
K-40	0.035	18 ± 9		32 ± 8		33 ± 8		33 ± 8		33 ± 8	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.3 ± 9		1.7 ± 9		1.8 ± 9		1.7 ± 9		1.8 ± 8	
Pb-214	0.0056	1.1 ± 15		1.3 ± 12		1.3 ± 13		1.3 ± 12		1.3 ± 13	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	498 ± 75		< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.48 ± 12		0.63 ± 11		0.63 ± 12		0.67 ± 11		0.68 ± 17	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	0.23 ± 29		0.16 ± 32		< 0.0054	U	0.16 ± 39	

Appendix F
Gamma Spectrography
After Attrition Scrubbing - plus 100 mesh Size Fraction
Radiological Results
(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6859A	Q	SN-GG#6860A	Q	SN-GG#6861A	Q	SN-GG#6862A	Q	SN-GG#6863A	Q
Ac-228	0.0320	1.7 ± 17		1.7 ± 16		1.5 ± 18		1.6 ± 21		1.5 ± 20	
Am-241	0.0102	6.6 ± 6		16 ± 4		0.7 ± 20		4.9 ± 6		0.9 ± 24	
Bi-214	0.0070	1.2 ± 13		1.1 ± 16		1.3 ± 13		1.1 ± 16		1.2 ± 14	
Cs-137	0.00448	0.25 ± 31		0.33 ± 24		< 0.00448	U	< 0.00448	U	0.17 ± 53	
K-40	0.035	30 ± 8		33 ± 8		30 ± 8		30 ± 8		32 ± 8	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.6 ± 9		1.7 ± 9		1.8 ± 8		1.7 ± 9		1.6 ± 9	
Pb-214	0.0056	1.2 ± 12		1.2 ± 14		1.2 ± 13		1.2 ± 13		1.2 ± 12	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.49 ± 17		0.56 ± 14		0.64 ± 11		0.53 ± 12		0.59 ± 13	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.15 ± 33	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

Appendix F
Treatability Study
Isotopic Laboratory Results in Soil
(after attrition scrubbing)

Soil Fraction Type	Sample Number	Isotope	Activity	Units	2 Sigma	MDA
Coarse	DT725001A	Plutonium 238	1.3	pCi/g	5.8	17.7
Coarse	DT725001A	Plutonium 239/240	30.8	pCi/g	19.8	15.1
Coarse	DT725001A	Americium 241	1.86	pCi/g	0.58	0.16
Coarse	DT725002A	Plutonium 238	0.08	pCi/g	0.35	1.08
Coarse	DT725002A	Plutonium 239/240	4.69	pCi/g	1.98	0.79
Coarse	DT725002A	Americium 241	0.55	pCi/g	0.27	0.19
Coarse	DT725003A	Plutonium 238	2.8	pCi/g	1.58	0.75
Coarse	DT725003A	Plutonium 239/240	413	pCi/g	72	0.8
Coarse	DT725003A	Americium 241	18	pCi/g	5.4	1.6
Coarse	DT725004A	Plutonium 238	<1.76	pCi/g	0.49	1.76
Coarse	DT725004A	Plutonium 239/240	43.2	pCi/g	9.9	1.6
Coarse	DT725004A	Americium 241	2.19	pCi/g	0.65	0.17
Coarse	DT725005A	Plutonium 238	8.04	pCi/g	2.38	0.85
Coarse	DT725005A	Plutonium 239/240	1040	pCi/g	167	0.8
Coarse	DT725005A	Americium 241	43.4	pCi/g	13.9	3
Coarse	DT725006A	Plutonium 238	-0.19	pCi/g	0.08	1.63
Coarse	DT725006A	Plutonium 239/240	19	pCi/g	5.4	1.8
Coarse	DT725006A	Americium 241	1.05	pCi/g	0.41	0.17
Coarse	DT725007A	Plutonium 238	-0.07	pCi/g	0.04	1.1
Coarse	DT725007A	Plutonium 239/240	18.5	pCi/g	4.9	1.2
Coarse	DT725007A	Americium 241	0.55	pCi/g	0.25	0.13
Coarse	DT725008A	Plutonium 238	0.3	pCi/g	0.56	1.16
Coarse	DT725008A	Plutonium 239/240	2.79	pCi/g	1.59	1.34
Coarse	DT725008A	Americium 241	0.25	pCi/g	0.16	0.14
Coarse	DT725009A	Plutonium 238	0.33	pCi/g	0.54	0.98
Coarse	DT725009A	Plutonium 239/240	11.7	pCi/g	3.6	1.1
Coarse	DT725009A	Americium 241	0.32	pCi/g	0.2	0.13
Coarse	DT725010A	Plutonium 238	0.4	pCi/g	0.51	0.74
Coarse	DT725010A	Plutonium 239/240	12.1	pCi/g	3.3	0.7
Coarse	DT725010A	Americium 241	0.56	pCi/g	0.26	0.15
Coarse	QC Blank	Plutonium 238	0.16	pCi/g	0.67	1.88
Coarse	QC Blank	Plutonium 239/240	0.76	pCi/g	1.06	20.8
Coarse	QC Blank	Americium 241	0.07	pCi/g	0.69	2.34
Coarse	QC Blank	Americium 241	0.11	pCi/g	0.12	0.16

Appendix F
Treatability Study
Isotopic Laboratory Results in Soil
(after attrition scrubbing)

Soil Fraction Type	Sample Number	Isotope	Activity	Units	2 Sigma	MDA
Coarse	QCLCS	Plutonium 238	81	% recovery		
Coarse	QCLCS	Plutonium 239/240	104	% recovery		
Coarse	QCLCS	Americium 241	119	% recovery		
Coarse	QCLCS	Americium 241	79	% recovery		
Fine	DT725001A	Plutonium 238	36.6	pCi/g	36.4	57.4
Fine	DT725001A	Plutonium 239/240	1460	pCi/g	334	54
Fine	DT725001A	Americium 241	9.2	pCi/g	19.9	46.2
Fine	DT725001A RE	Americium 241	35.6	pCi/g	28.2	35.2
Fine	DT725001A DUP	Plutonium 238	19	pCi/g	25.5	49.9
Fine	DT725001A DUP	Plutonium 239/240	1260	pCi/g	273	47
Fine	DT725001A DUP	Americium 241	51.5	pCi/g	36.4	40.6
Fine	DT725001A DUP RE	Americium 241	141	pCi/g	54	28
Fine	DT725002A	Plutonium 238	5.6	pCi/g	10.2	23
Fine	DT725002A	Plutonium 239/240	334	pCi/g	76	24
Fine	DT725002A	Americium 241	4.6	pCi/g	11.3	27.5
Fine	DT725002A RE	Americium 241	-1.8	pCi/g	4.9	21.1
Fine	DT725003A	Plutonium 238	2.66	pCi/g	2.2	3.25
Fine	DT725003A	Plutonium 239/240	304	pCi/g	54	3.7
Fine	DT725003A	Americium 241	12.8	pCi/g	6	4.3
Fine	DT725003A RE	Plutonium 238	1.69	pCi/g	1.23	1.4
Fine	DT725003A RE	Plutonium 239/240	294	pCi/g	51	0.9
Fine	DT725004A	Plutonium 238	5.86	pCi/g	3.08	3.06
Fine	DT725004A	Plutonium 239/240	491	pCi/g	84	3.2
Fine	DT725004A	Americium 241	14.5	pCi/g	6.8	5.8
Fine	DT725005A	Plutonium 238	12.7	pCi/g	4.4	2.7
Fine	DT725005A	Plutonium 239/240	1880	pCi/g	307	2.5
Fine	DT725005A	Americium 241	93.5	pCi/g	22.2	4.2
Fine	DT725005A RE	Plutonium 238	3.85	pCi/g	1.68	1.02
Fine	DT725005A RE	Plutonium 239/240	661	pCi/g	110	0.9
Fine	DT725006A	Plutonium 238	-7.3	pCi/g	11.1	45.3
Fine	DT725006A	Plutonium 239/240	957	pCi/g	218	46

Appendix F
Treatability Study
Isotopic Laboratory Results in Soil
(after attrition scrubbing)

Soil Fraction Type	Sample Number	Isotope	Activity	Units	2 Sigma	MDA
Fine	DT725006A	Americium 241	35.2	pCi/g	22.9	27.8
Fine	DT725007A	Plutonium 238	-1.1	pCi/g	8.2	28.1
Fine	DT725007A	Plutonium 239/240	724	pCi/g	158	27
Fine	DT725007A	Americium 241	1.6	pCi/g	14	38.6
Fine	DT725007A RE	Americium 241	19.1	pCi/g	13.3	14.7
Fine	DT725008A	Plutonium 238	0.25	pCi/g	0.66	1.61
Fine	DT725008A	Plutonium 239/240	68	pCi/g	12.7	1.7
Fine	DT725008A	Americium 241	1.75	pCi/g	1.53	2.1
Fine	DT725008A RE	Americium 241	2.75	pCi/g	2.19	2.95
Fine	DT725009A	Plutonium 238	-0.12	pCi/g	0.3	1.3
Fine	DT725009A	Plutonium 239/240	59.4	pCi/g	11.2	1.5
Fine	DT725009A	Americium 241	2.19	pCi/g	2.04	3.08
Fine	DT725009A RE	Americium 241	3.38	pCi/g	1.94	1.72
Fine	DT725010A	Plutonium 238	2.37	pCi/g	1.25	0.89
Fine	DT725010A	Plutonium 239/240	346	pCi/g	58	1.1
Fine	DT725010A	Americium 241	9.96	pCi/g	3.48	1.88
Fine	QC Blank	Plutonium 238	0.52	pCi/g	0.84	1.69
Fine	QC Blank	Plutonium 239/240	0.15	pCi/g	0.49	1.36
Fine	QC Blank	Americium 241	1.45	pCi/g	2.2	4.47
Fine	QC Blank RE	Plutonium 238	-0.2	pCi/g	0.08	1.65
Fine	QC Blank RE	Plutonium 239/240	-0.12	pCi/g	0.06	1.4
Fine	QC Blank RE	Americium 241	0.92	pCi/g	1.01	1.69
Fine	QCLCS	Plutonium 238	86	% recovery		
Fine	QCLCS	Plutonium 239/240	95	% recovery		
Fine	QCLCS	Americium 241	125	% recovery		
Fine	QCLCS RE	Plutonium 238	82	% recovery		
Fine	QCLCS RE	Plutonium 239/240	100	% recovery		
Fine	QCLCS RE	Americium 241	85	% recovery		

MDA = Minimum Detection Activity

Dup = Duplicate Sample

RE = Sample reanalyzed because of relatively large 2-sigma error

Appendix G

Passive Alpha Detector Data Summaries and Result Discussions

Memorandum

Date: 09/22/95
To: Richard McKinley, IT Las Vegas
From: Ken Sadler, IT Knoxville
Subject: Final Report : Treatability Testing on Double Tracks Soil
(Project # 301941.03030200)

Introduction :

On 7/28/95, ten soil samples were received from the IT Las Vegas office by the Technology Development Laboratory in Knoxville, Tn. for treatability testing. In order to provide a radiological baseline and to determine if any special handling requirements might be necessary, these samples were screened for Gross Alpha/Beta and Total Specific Activity. The values are listed below:

Sample #	Gross Alpha ($\mu\text{Ci/g}$)	Gross Beta ($\mu\text{Ci/g}$)	Total Specific Activity ($\mu\text{Ci/g}$)
DT 725001A	5.95E-03	1.84E-04	6.13E-03
DT 725002A	2.27E-03	7.94E-05	2.35E-03
DT 725003A	3.78E-04	4.67E-05	4.25E-04
DT 725004A	3.51E-04	3.70E-05	3.88E-04
DT 725005A	4.29E-04	3.85E-05	4.67E-04
DT 725006A	2.64E-03	9.87E-05	2.74E-03
DT 725007A	2.30E-03	6.06E-05	2.36E-03
DT 725008A	1.90E-04	3.53E-05	2.25E-04
DT 725009A	1.99E-04	3.48E-05	2.34E-04
DT 725010A	2.29E-04	3.78E-05	2.67E-04

The purpose of this study was to evaluate the potential of a physical separation process to lower the radiological content of the soil. Physical separation techniques such as sieving and attrition scrubbing were tested in order to determine an efficient, simple, low cost remediation method. The contaminant plutonium 241 (Pu-241) was of primary concern. However, plutonium is a low gamma emitter. Therefore, americium 241 (Am-241) which is present in a "known" activity ratio to the Pu-241 in the soil, was the contaminant analyzed for. The Am-

241 is a gamma emitter which can be analyzed for by gamma spectroscopy, from which the Pu-241 activity can then be calculated. The treatability testing was broken into two separate phases, soil characterization and attrition scrubbing experiments.

Technical Approach :

Experimental Design

Soil Characterization - The characterization testing established the distribution of radiochemical contaminants in the individual size fractions. Each of the ten "as received" samples were separated into 4 different size fractions; an oversize debris fraction, a coarse sand, a fine sand, and a silt and clay fraction. Each of these fractions were to be analyzed for radiochemical content by gamma spectroscopy.

Attrition Scrubbing - The objective of these experiments were to physically remove any radiochemical contamination that was loosely bound to the surface of the soil particles. This was accomplished by violent agitation of sand particles. These sand particles "hit and scraped" one another and forced the contaminants to flake off into the fine fraction (< #100 mesh).

Experimental Procedures

Soil Characterization

Characterization testing was necessary to determine the distribution of contaminant in the various particle size fractions. The soil composite sample were divided into four size fractions using a Ro-Tap sieve shaker. The procedure is outlined in the IT "Draft" SOP *Separation of Soil Size Fractions by Sieving* which is provided in Appendix A. All soil sieving procedures were a wet sieving process. The soil types were separated into a debris and gravel fraction (> #4 sieve removed prior to homogenization), a coarse sand fraction (#4-#100 sieve), a fine sand fraction (#100-#200 sieve), and a silt and clay fraction (< #200 sieve). Each of these fractions were originally to be analyzed for radiochemical content by gamma spectroscopy, however, only the #4-#100 mesh fraction contained enough material for this procedure. This testing was to establish the initial distribution of contaminant in the individual size fractions.

Attrition Scrubbing

Attrition scrubbing uses a single agitator with two oppositely pitched propellers. During operation, the top blade forces sample down and the bottom blade forces sample up, causing an attriting action of the soil particles with each other. Therefore, if any lead contamination is physically bound to the surface an individual particle, this violent agitation might remove the contaminant. Only coarse size fractions were tested for attrition scrubbing since fines tend to buffer or "cushion" the attriting action of the particles. Each #4-#100 sieve size fraction was tested at 15 minutes scrubbing time, with an approximate 75 percent solids ratio. This procedure is outlined in the IT "draft" SOP *Bench-Scale Attrition Scrubbing* provided in Appendix A. Following each attrition experiment, the samples were sieved into two size fractions, a coarse fraction (> #100 mesh) and a fines fraction (< #100 mesh). The coarse fractions were analyzed for radiochemical content by gamma spectroscopy.

Equipment and Materials

Sieving Operations

A Ro-Tap Sieve Shaker, manufactured by W.S. Tyler, was used for all sieving operations. This shaker is the standard machine for automatically carrying out sieve test procedures with accuracy and dependability. It is designed to hold a series of 8-inch diameter sieves and imparts to the sieves both a circular and tapping motion. The speed and stroke are fixed, which ensures comparability between sieve tests. The Ro-Tap is equipped to handle from 1 to 13 sieves at a time and is equipped with a timer that will automatically terminate the test at any predetermined time. All sieves conformed to the requirements of ASTM E-11.

Attrition Scrubbing Operations

A Denver Equipment Company, D-12 Laboratory Flotation/Attrition Machine was used for all attrition scrubbing operations. This machine converts to an attrition scrubber by inserting an opposed propeller of different blade pitch. This provides a maximum movement and rubbing of the mineral particles. An attrition tank is provided to prevent any spillage due to the violent agitation of the machine. High pulp densities of 70 to 75 percent solids at an approximate speed of 800 rpm were used for efficient scrubbing.

Results :

Soil Characterization

The weight fractions from the sieving analysis are shown in Table #1. Approximately 70 to 80 percent of each sample's mass is in the #4-#100 particle size fraction. From 5 to 10 percent is in the plus #4 mesh, debris fraction; 10 to 20 percent is in the #100-#200 mesh, fine sand fraction; and 1 to 10 percent is in the minus #200 mesh, silt and clay fraction. Due to the small amount of material recovered in the plus #4 mesh, the #100-#200 mesh, and the minus #200 mesh fractions, only the #4-#100 mesh fractions were analyzed by gamma spectroscopy. A source with a different geometry for the gamma spectroscopy instrument was ordered to analyze these other size fractions, but due to the project time constraints, it was not received in time. The results of the #4-#100 fractions are shown in Table #2. The ten values for Am-241 range from 1.5 pCi/g to 19.7 pCi/g with an average value of 8.88 pCi/g.

Attrition Scrubbing

This fraction was then attritioned as described in the technical approach section. The attritioned samples were then re-sieved over a #100 mesh screen. The material balances for each sample is shown in Table #3. This table illustrates how much "as received" material is minus #100 mesh after the first sieve separation, and then how much more material is forced into this fraction by attrition scrubbing. The attritioning forced approximately 12 to 36 percent more material to the fines fraction. The attritioned, plus #100 mesh samples were then re-analyzed by gamma spectroscopy. The results are shown in Table #4. The values for Am-241 range from 0.7 pCi/g to 16 pCi/g with an average value 5.58 pCi/g. Attritioning therefore removed an average of 37 percent of the Am-241 activity in this size fraction by forcing an average of 18.7 percent of the soil into the fines fraction.

Table #1
NTS soils : Percentage of Soil in Size Fractions

G-4

Client Sample #	TDL Sample #	plus #4 mesh (g)	Percent of Total	#4 - #100 mesh (g)	Percent of Total	#100 - #200 mesh (g)	Percent of Total	minus #200 mesh (g)	Percent of Total
DT 725001A	GG6854	113.14	7.27	1095.94	70.45	203.55	13.08	143.08	9.20
DT 725002A	GG6855	104.12	7.21	1097.56	75.96	156.41	10.82	86.84	6.01
DT 725003A	GG6856	180.23	12.67	1134.1	79.72	92.2	6.48	16.11	1.13
DT 725004A	GG6857	94.8	5.97	1308.2	82.41	147.91	9.32	36.45	2.30
DT 725005A	GG6858	84.92	6.01	1018.18	72.05	269.18	19.05	40.91	2.89
DT 725006A	GG6859	78.26	4.78	1182.2	72.22	310.79	18.99	65.6	4.01
DT 725007A	GG6860	95.56	6.97	934.08	68.11	206.37	15.05	135.48	9.88
DT 725008A	GG6861	165.24	10.55	1262.25	80.59	121.53	7.76	17.23	1.10
DT 725009A	GG6862	111.99	7.04	1103.72	69.42	318.1	20.01	56.17	3.53
DT 725010A	GG6863	82.56	6.37	1186.28	91.50	22.26	1.72	5.45	0.42

TABLE 2

NTS - Site Soil
plus 100 mesh Size Fraction
Radiological Results

(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6854	Q	SN-GG#6855	Q	SN-GG#6856	Q	SN-GG#6857	Q	SN-GG#6858	Q
Ac-228	0.0320	1.5 ± 10		1.6 ± 10		1.4 ± 10		1.4 ± 10		1.5 ± 11	
Am-241	0.0102	17.0 ± 1		5.12 ± 2		2.4 ± 6		16.2 ± 1		1.5 ± 7	
Bi-214	0.0070	0.96 ± 10		1.1 ± 8		1.1 ± 8		1.1 ± 8		1.0 ± 8	
Cs-137	0.00448	0.19 ± 19		0.14 ± 23		0.18 ± 15		0.18 ± 16		0.30 ± 13	
K-40	0.035	27 ± 6		28 ± 6		28 ± 6		25 ± 6		27 ± 6	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.1 ± 6		1.5 ± 6		1.6 ± 6		1.4 ± 6		1.6 ± 6	
Pb-214	0.0056	1.0 ± 8		1.1 ± 8		0.99 ± 9		1.1 ± 8		1.0 ± 8	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.47 ± 7		0.58 ± 6		0.55 ± 6		0.50 ± 6		0.59 ± 5	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

TABLE 2

NTS - Site Soil (cont.)
plus 100 mesh Size Fraction
Radiological Results

(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6859	Q	SN-GG#6860	Q	SN-GG#6861	Q	SN-GG#6862	Q	SN-GG#6863	Q
Ac-228	0.0320	1.5 ± 11		1.4 ± 11		1.4 ± 9		1.4 ± 9		1.4 ± 11	
Am-241	0.0102	10.9 ± 4		19.7 ± 1		1.91 ± 4		6.7 ± 2		7.4 ± 4	
Bi-214	0.0070	1.0 ± 9		1.1 ± 8		0.92 ± 8		0.94 ± 8		1.1 ± 8	
Cs-137	0.00448	0.33 ± 11		0.44 ± 10		< 0.00448	U	0.1 ± 24		0.26 ± 14	
K-40	0.035	26 ± 6		27 ± 6		24 ± 6		25 ± 6		24 ± 6	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.4 ± 6		1.4 ± 6		1.4 ± 6		1.4 ± 6		1.5 ± 6	
Pb-214	0.0056	1.0 ± 8		1.1 ± 8		1.0 ± 8		1.1 ± 8		1.1 ± 8	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.53 ± 6		0.53 ± 6		0.44 ± 6		0.49 ± 6		0.46 ± 7	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

Table #3
NTS soils : Percentage of Soil in Size Fractions

Client Sample #	TDL Sample #	"As Received" Soil Wet-sieved (#100 mesh)		Wet-Sieved, Plus #100 Mesh, Attritioned, Re-sieved (#100 Mesh)	
		Percent of Total Plus #100 mesh	Percent of Total Minus #100 Mesh	Percent of Total Plus #100 mesh	Percent of Total Minus #100 Mesh
DT 725001A	GG6854	77.72	22.28	64.91	12.81
DT 725002A	GG6855	83.17	16.83	70.25	12.92
DT 725003A	GG6856	92.39	7.61	76.58	15.81
DT 725004A	GG6857	88.39	11.61	61.70	26.69
DT 725005A	GG6858	78.06	21.94	57.32	20.74
DT 725006A	GG6859	77.01	22.99	62.47	14.54
DT 725007A	GG6860	75.07	24.93	60.95	14.12
DT 725008A	GG6861	91.14	8.86	75.65	15.49
DT 725009A	GG6862	76.46	23.54	59.39	17.07
DT 725010A	GG6863	97.86	2.14	61.34	36.52

TABLE 4

NTS - Site Soil
After Attrition Scrubbing - plus 100 mesh Size Fraction
Radiological Results

(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6854A	Q	SN-GG#6855A	Q	SN-GG#6856A	Q	SN-GG#6857A	Q	SN-GG#6858A	Q
Ac-228	0.0320	1.4 ± 18		1.6 ± 18		1.6 ± 18		1.7 ± 21		1.7 ± 17	
Am-241	0.0102	3.0 ± 4		6.5 ± 6		2.6 ± 8		6.4 ± 6		8.2 ± 5	
Bi-214	0.0070	1.1 ± 13		1.2 ± 13		1.2 ± 13		1.3 ± 13		1.4 ± 13	
Cs-137	0.00448	0.50 ± 15	<	0.00448	U	0.16 ± 47	<	0.00448	U	0.25 ± 32	
K-40	0.035	18 ± 9		32 ± 8		33 ± 8		33 ± 8		33 ± 8	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.3 ± 9		1.7 ± 9		1.8 ± 9		1.7 ± 9		1.8 ± 8	
Pb-214	0.0056	1.1 ± 15		1.3 ± 12		1.3 ± 13		1.3 ± 12		1.3 ± 13	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	498 ± 75	<	15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.48 ± 12		0.63 ± 11		0.63 ± 12		0.67 ± 11		0.68 ± 17	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	0.23 ± 29		0.16 ± 32		< 0.0054	U	0.16 ± 39	

TABLE 4

NTS - Site Soil (cont.)
After Attrition Scrubbing - plus 100 mesh Size Fraction
Radiological Results

(Uncertainties reported as percent at 2-sigma)

Nuclide (pCi/g)	MDA	SN-GG#6859A	Q	SN-GG#6860A	Q	SN-GG#6861A	Q	SN-GG#6862A	Q	SN-GG#6863A	Q
Ac-228	0.0320	1.7 ± 17		1.7 ± 16		1.5 ± 18		1.6 ± 21		1.5 ± 20	
Am-241	0.0102	6.6 ± 6		16 ± 4		0.7 ± 20		4.9 ± 6		0.9 ± 24	
Bi-214	0.0070	1.2 ± 13		1.1 ± 16		1.3 ± 13		1.1 ± 16		1.2 ± 14	
Cs-137	0.00448	0.25 ± 31		0.33 ± 24		< 0.00448	U	< 0.00448	U	0.17 ± 53	
K-40	0.035	30 ± 8		33 ± 8		30 ± 8		30 ± 8		32 ± 8	
Np-237	0.0842	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U	< 0.0842	U
Pb-212	0.0104	1.6 ± 9		1.7 ± 9		1.8 ± 8		1.7 ± 9		1.6 ± 9	
Pb-214	0.0056	1.2 ± 12		1.2 ± 14		1.2 ± 13		1.2 ± 13		1.2 ± 12	
Pu-241	4095	< 4095	U	< 4095	U	< 4095	U	< 4095	U	< 4095	U
Pu-240	61.9	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U	< 61.9	U
Pu-239	15.5	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U	< 15.5	U
Th-228	0.911	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U	< 0.911	U
Th-229	0.0066	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U	< 0.0066	U
Tl-208	0.0012	0.49 ± 17		0.56 ± 14		0.64 ± 11		0.53 ± 12		0.59 ± 13	
Pa-231	0.245	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U	< 0.245	U
U-235	0.0054	< 0.0054	U	< 0.15 ± 33	U	< 0.0054	U	< 0.0054	U	< 0.0054	U

The fines fractions (the #100-#200 mesh, and the minus #200 mesh fractions) from the soil characterization were small percentages of the total. Therefore, these were combined with the fines produced from attrition scrubbing for each of the ten samples. These samples were then sent to the Quanterra Laboratory in St. Louis for analysis. These results will be used to provide a mass balance for the contaminants in order to complete the engineering assessment. The attritioned, plus #100 mesh samples were also sent to this laboratory for verification of the treatability test results.

Conclusions :

The results of the soil characterization clearly show that the plus #100 mesh material contains the bulk of the total soil for each sample. An average of the ten samples show 83.7 percent of the total "as received" mass is plus #100 mesh (150 μ m). The attrition scrubbing results looked promising. Approximately 37 percent of the Am-241 activity in this size fraction was removed by forcing an average of 18.7 percent of the soil into the fines fraction. Out of the ten samples, seven had a sizable decrease in Am-241 activity after attritioning, two remained about the same, and one sample showed an increase. The percent removals for each sample is shown below:

Sample #	Percent Removal
DT 725001A	6.7 %
DT 725002A	-27.0 %
DT 725003A	-8.3 %
DT 725004A	60.5 %
DT 725005A	-447 %
DT 725006A	39.4 %
DT 725007A	19.1 %
DT 725008A	63.4 %
DT 725009A	26.9 %
DT 725010A	87.8 %

The results for Samples DT 725002A, Dt 725003A, and DT 725005A should be discounted since the starting vallues were so low to begin with (less than 5 pCi/g). Therefore the attrition results do appear to be successful. However, once the results of the fines fractions are received from Quanterra, the benefits of sieving and attritioning can be more accurately assessed.

Distribution List

Copies

DOE/Nevada Operations Office 1
Technical Information Resource Center
P.O. Box 98518
Las Vegas, Nevada 89193-8518

U.S. Department of Energy 2
Office of Scientific and Technical Information
175 Oak Ridge Turnpike
Post Office Box 62
Oak Ridge, Tennessee 37831

OBSERVED GROSS COUNTS PER SECOND
 (40 kev THROUGH 3026 kev, 30' GRID, 30' AVG)

18000	<	GRAY	<	18000
19000	<	LT BLUE	<	19000
20000	<		<	20000
21000	<	LT GRN	<	21000
24000	<		<	24000
33000	<	YELLOW	<	33000
60000	<	ORANGE	<	60000
	<	PINK	<	140000

NAFR DOUBLE TRACKS "KIWI" DATA - JUNE 1995

MAP PRODUCED 10/6/95 EG&G/EM

FIGURE 11. KIWI 30-FT GRIDDED AND 30-FT AVERAGED GROSS COUNT DATA. The observed gross count of all gamma rays in the individual Kiwi spectra were collected into a 30-ft grid and averaged over one grid cell. Since the survey area is relatively small, the gross count rate is relatively constant, except in the heavily contaminated areas. The data are presented both as squares centered on the grid loci and as contour levels derived from the gridded data.