FINAL

CHARACTERIZATION REPORT

Schofield Barracks Davy Crockett Impact Area

Oahu, Hawaii

Prepared for:

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ASR	archives search report
bgs	below ground surface
BHHRA	Baseline human health risk assessment
Bi	Bismuth (e.g., ^{214}Bi)
CABRERA	Cabrera Services, Inc.
CERCLA	Comprehensive Environmental Restoration and Liability Act
CFD	cumulative frequency diagram
cm	square meter
cm^2	square centimeter
COC	Contaminant of Concern
DL	Detection limit qualifier
DQO	data quality objectives
DU	Depleted Uranium
EDA	exploratory data analysis
FIDLER	Field Instruments for the Detection of Low Energy Radiation
ft	foot (feet)
GIS	Graphic interface system
GPS	Global positioning system
GWS	Gamma walkover survey
lb	pound
LCS	laboratory control sample
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MB	method blank
MDC	minimum detectable concentration
MDL	minimum detection limit
mg/kg	milligrams per kilogram
NaI(Tl)	Sodium Iodide (thallium-activated)
N/A	not applicable
NIST	National Institute of Standards and Technology
OP	operating procedures
Pb	Lead (e.g. ^{214}Lead)
pCi/g	picocuries per gram
ppm	parts per million
QAPP	Quality Assurance Program Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI	Radiological investigation
SBIA	Schofield Barracks Impact Area
sec	second
SRB	spotting round body
Th	Thorium (e.g., ^{232}Th)
U	Uranium (e.g., ^{238}U)
USAG-HI	US Army Garrison, Hawaii
USEPA	U. S. Environmental Protection Agency
UXO	Unexploded ordinance
ZnS (Ag)	Zinc Sulfide (silver-activated)

EXECUTIVE SUMMARY

This report presents the characterization data collected from the impact area of the Schofield Barracks in Oahu, Hawaii, from August to October 2007. The known contaminant of concern (COC) was depleted uranium (DU) contained in the spotting round body (SRB) associated with the training rounds found during previous investigations at Schofield Barracks. The data were collected to serve as exposure point concentrations for the ingestion, inhalation, and dermal exposure pathways in the baseline human health risk assessment (BHHRA), and provide an estimate of human health risk associated with DU identified at the Schofield Barracks Impact Area (SBIA).

Data were collected from 428 acres of the SBIA. Since the SBIA includes active firing ranges, unexploded ordnance (UXO) escorts were used as a safety precaution. Three types of data were collected: (1) gamma walkover survey (GWS) data were collected to direct judgmental sampling based on gamma radiation levels; (2) exposure rate measurements were performed to evaluate external radiation exposure; and (3) soil samples were collected from systematic and judgmental locations and analyzed for DU and lead for use in the BHHRA. No surface water was present during field activities; therefore no water samples were collected.

A total of 1,226 soil samples were collected at 645 sample locations, including the reference area. Based on the soil sample results, concentrations representative of background were determined to be less than 2.57 picocuries per gram (pCi/g) (1.65 ± 0.918 pCi/g at the 95% confidence level) for Uranium-238 (^{238}U). Both systematic and biased soil sample data were found to be similar to reference area data, demonstrating the ^{238}U concentrations in soil are at or near background concentrations with approximately three percent of the samples found to contain DU or exhibit a DU influence (i.e., the reported ^{238}U concentration was above the reference area ^{238}U naturally occurring U concentrations). Concentrations of ^{238}U in soil ranged from 0 to 7,030 pCi/g.

All soil samples were screened for lead, which ranged in concentration from 0.3 to 864 milligrams per kilogram (mg/kg). Based on the results of the soil samples collected from the reference area, lead concentrations representative of background were determined to be less than 21.6 mg/kg (14.7 ± 6.86 mg/kg at 95% confidence level). The data demonstrate the lead

concentrations in soil at the SBIA are elevated above background concentrations. The higher lead concentrations are consistent with the use of the impact areas as firing ranges. No recognizable pattern between the presence of DU and lead appears to exist in the sample data.

Lead concentrations in eight soil samples (less than 1% of the soil samples) exceeded the U.S. Environmental Protection Agency (USEPA) 400 parts per million (ppm) screening level for lead in soils established for Comprehensive Environmental Restoration and Compensation Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites as published in the Office of Solid Waste and Emergency Response Directive 9355.4-12 (USEPA, 1994).

The data provide sufficient information on the nature and extent of DU and lead at SBIA and are suitable for use in the BHHRA. The data were verified to be reliable, appropriately documented, and technically defensible. All soil sample analytical (radiological and lead) results were subjected to data verification/review and soil sample analytical (radiological) results in 10% of the laboratory analytical batches received full data validation.

1.0 INTRODUCTION

This report presents the characterization data collected from the Schofield Barracks Impact Area in Oahu, Hawaii, from August to October 2007. The known contaminant of concern (COC) was depleted uranium (DU) contained in the spotting round bodies (SRBs) associated with the training rounds found during previous investigations at Schofield Barracks. The data were collected to serve as exposure point concentrations for the ingestion, inhalation, and dermal exposure pathways in the baseline human health risk assessment (BHHRA), and provide an estimate of human health risk from DU identified at the SBIA.

Gamma walkover surveys and exposure rate measurements were performed and soil samples were collected and analyzed for radionuclides and lead in accordance with the *Characterization Work Plan (WP) for Schofield Barracks Davy Crockett Impact Area, Oahu, Hawaii* (CABRERA, 2007b). Cabrera Services, Inc. (CABRERA) performed the work for the U.S. Army Sustainment Command under Contract Number W52P1J-06-D-0019, Delivery Order 0004.

1.1 Site History

Schofield Barracks, shown in Figure 1-1, is located near the town of Wahiawa in central Oahu in the Hawaiian Islands. It was declared a military reservation by Executive Order in 1899 and has remained under U.S. Army control since that date. The facility has been used for year round outdoor field training due to its mild weather conditions. The facility is currently the home of the United States Army 25th Infantry Division and the United States Army Garrison, Hawaii (USAG-HI).

1.2 Site Description

Schofield Barracks is the largest Army post in Hawaii, located on an 18,000 acre site in central Oahu. The Schofield Training Area totals 2,650 acres and consists of fee and ceded land. The Schofield Training Area, shown in Figure 1-2, is in a large valley, with a ridgeline along the north, west and southwest boundaries. The valley faces east and extends into the central Schofield saddle. The SBIA is at the western end of the valley, and the majority of the SBIA is of moderate slope increasing in steepness towards the west. Beyond the SBIA to the west and southwest, the land rises steeply and is not considered usable for maneuvers. The steep area is used as a safety zone for the SBIA. The ridge of the Waianae Range has the highest point on

Oahu, Mount Kaala, which has an elevation of over 4,000 feet. The elevation of the SBIA ranges between 800 and 1,400 feet in elevation. Vegetation varies from heavy woods on the steeper western slopes to open grassland in the SBIA. Several thickly wooded gullies with steep sides cut through the SBIA.

According to the *Archives Search Report* (ASR) *On the Use of Cartridge, 20mm Spotting M101 For Davy Crockett Light Weapon M28, Schofield Barracks and Associated Training Areas, Islands of Oahu and Hawaii* (USACE, 2007), training on the Davy Crockett weapons system was likely conducted at Schofield Barracks between 1962 and 1968. Although no range was specified for Davy Crockett system use in the available historical documents, the ASR identified the M79 grenade launcher range as the range that was likely used based on the location of the debris in the area and the designation as a secure range. While no historical information exists upon which to fix the potential firing fan for the Davy Crockett system, field observations indicated several likely areas which were all included in the characterization survey.

In August 2005, tail fin components and SRBs from the Cartridge, 20mm Spotting M101 associated with the Davy Crockett Light Weapon M28 were discovered during routine activities in the SBIA. DU fragments were found to be associated with the SRBs at several locations throughout the SBIA.

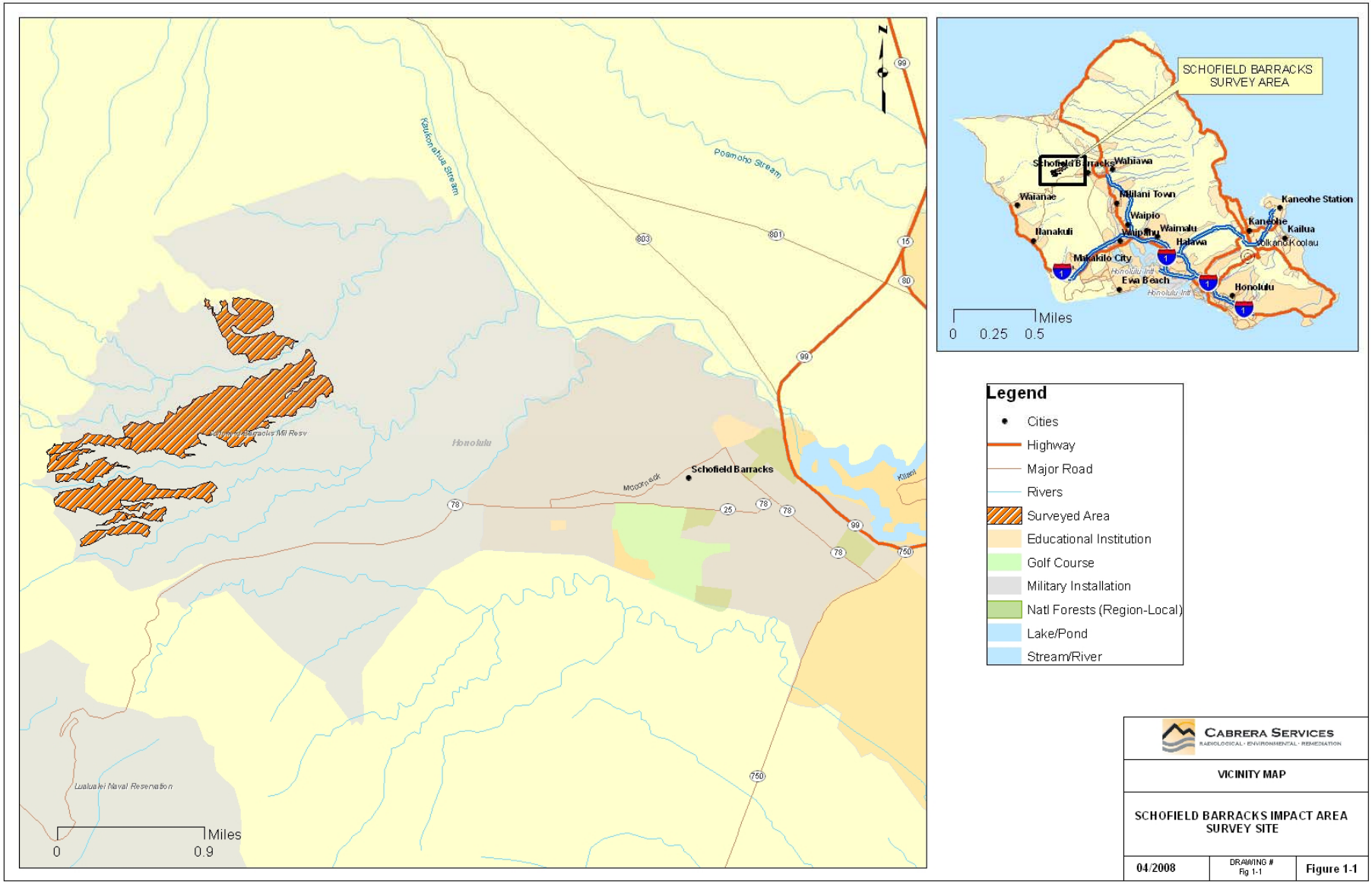

FIGURE 1-1: SCHOFIELD BARRACKS VICINITY MAP

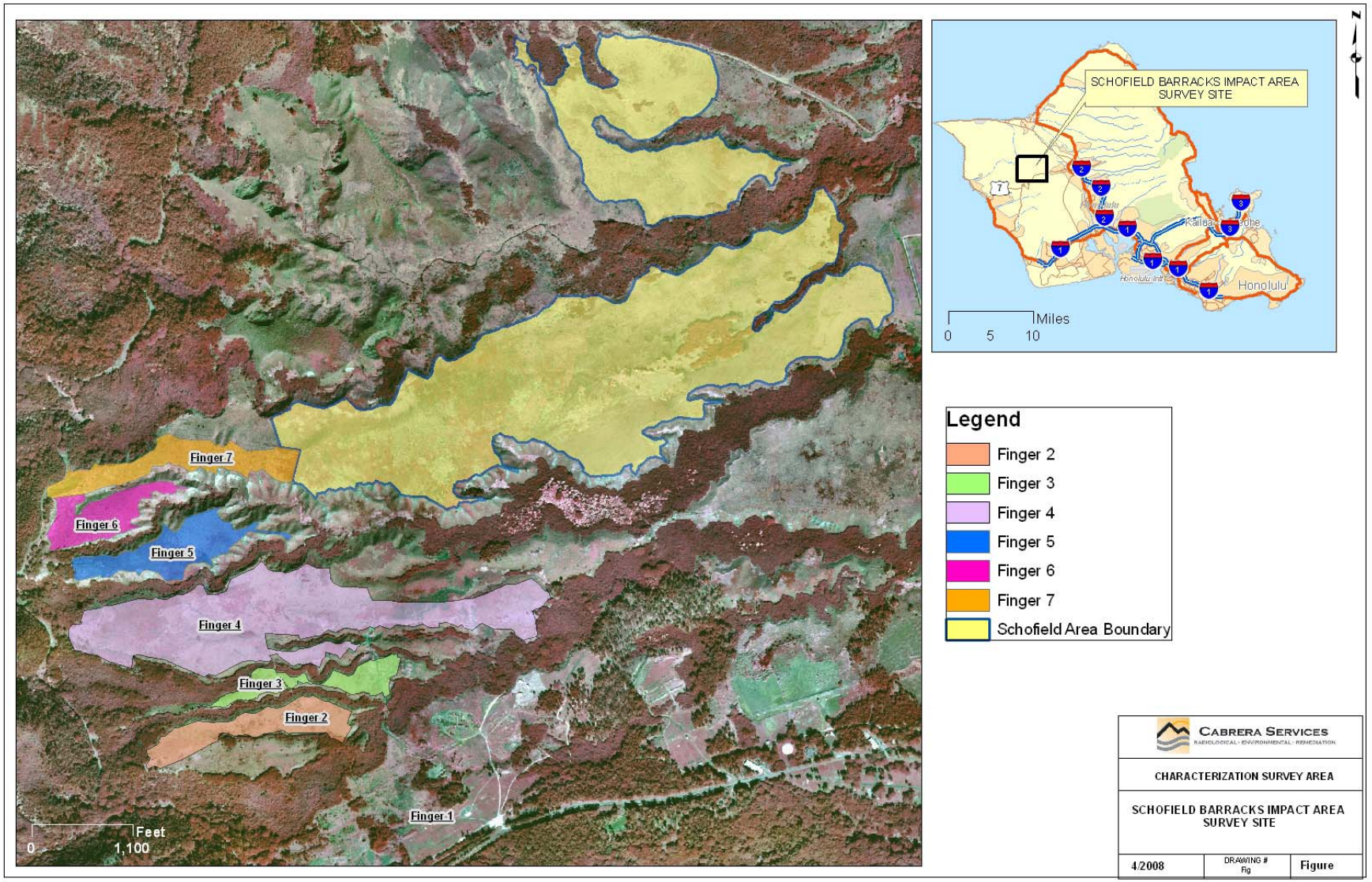

FIGURE 1-2: SCHOFIELD BARRACKS FIRING RANGE AREA

1.3 Summary of Scoping Data

The presence of DU at the firing range was the subject of a recent scoping investigation, completed in January 2007 by CABRERA and described in the *Schofield Barracks Firing Range Phase I, Depleted Uranium Investigation* (CABRERA, 2007a). The scoping effort consisted of a site visit, surface soil and debris sampling and analysis, and radiological scanning. Laboratory analyses of the samples included gamma spectrometry, alpha spectrometry for uranium (U) isotopes, total metals, and herbicides. The results of the scoping survey are summarized as follows:

- The visual and radiological scanning survey identified at least three distinct areas with yellow, oxidized metal fragments consistent with the presence of DU fragments.
- Soil samples from areas identified as potentially containing DU fragments reported elevated thorium-234 (^{234}Th)/uranium-238 (^{238}U) concentrations (i.e., activities of 21, 32, and 209 picocuries per gram [pCi/g]).
- Samples of metal debris fragments demonstrated ^{238}U to uranium-235 (^{235}U) activity ratios consistent with DU and specifically the Davy Crockett SRB.
- Total metals analysis found that copper, lead, manganese, nickel, and zinc were present at potentially elevated levels in all samples from areas areas identified as potentially containing DU fragments.
- Herbicides analysis found that no herbicides were present in the soil samples at levels above the detection limits.

The presence of DU at the firing range in north/eastern mostly flat portions of the SBIA is addressed in the *Technical Memorandum, Depleted Uranium Scoping Investigations for Makua Military Reservation, Pohakuloa Training Area, Schofield Barracks Impact Area Islands of Oahu and Hawaii* (CABRERA, 2008). The supplemental scoping survey performed in August 2007 identified ^{238}U concentrations (up to 2,180 pCi/g).

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2.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) were developed to define the purpose of the characterization effort, clarify what data should be collected to satisfy the purpose, and specify the performance requirements for the quality of information to be obtained from the data.

2.1 Step 1 – State the Problem

The problem was insufficient data about the nature and extent of DU fragments at the SBIA.

2.2 Step 2 – Identify the Decision

The principal study question and decision statement was whether the human health risks associated with DU present at the SBIA exceed USEPA regulations. Characterization data were collected for use in assessing the risk.

2.3 Step 3 – Identify Inputs to the Decision

The known COC was DU contained in the SRBs found during previous investigations at Schofield Barracks. The media of concern for the study was surface soil (0 to 6 inches below grade surface [bgs]) and shallow subsurface soil (6 to 12 inches bgs). No surface water was present during field activities; therefore no water samples were collected.

Review of historical analytical data and operations information indicate that the contaminants of concern (COCs) known or believed to be present at the Schofield Barracks impact area include DU and lead. The projectile body of the Davy Crockett M101 SRB was composed of a DU alloy known as D-38 containing 92 percent DU and 8 percent molybdenum. . Other components of the M101 SRB contained lead or lead mixtures; in addition, lead may be an indicator for the potential presence of other metals.

2.4 Step 4 – Define the Study Boundaries

The study area was the portion of the range where the training rounds containing DU could have impacted the ground. The spatial boundary of the SBIA was established based on the firing characteristics of the Davy Crockett system, the likely firing positions used for training on the Davy Crockett system, and the results of previous investigations identifying specific locations of SRBs and other components of the Davy Crockett system training rounds. Soil samples were collected to a maximum depth of 12 inches bgs.

2.5 Step 5 – Develop a Decision Rule

The decision rules leading to the investigation of areas based on the evaluation of gamma walkover survey data are given in Table 2-1.

TABLE 2-1: DECISION RULES

Parameter of Interest	***IF***	***THEN***	***Comments***
Presence of DU in the reference area	Area with z-score greater than 3.0 is identified in the reference area GWS	Investigate and make decision whether to select new reference area.	Z-score values greater than 3.0 are unexpected and potentially identify areas of elevated gamma activity caused by DU.
Presence of DU in the impact area	Area with z-score greater than 3.0 is identified in the impact area GWS	Investigate and make decision whether to perform additional scanning or soil sampling to determine nature and extent.	Z-score values greater than 3.0 are unexpected and potentially identify areas of elevated gamma activity caused by DU.

2.6 Step 6 – Specify Tolerable Limits on Decision Errors

The collection and analysis of data was designed as a graded approach using a combination of gamma walkover survey and soil sample data to manage uncertainty. Analytical uncertainty was controlled by use of appropriate instruments, methods, techniques, and quality control (QC). Minimum detectable concentrations (MDCs) for individual radionuclides using specific laboratory analytical methods were established.

2.7 Step 7 – Optimize the Design for Collecting Data

Review and analysis of visual observations and collected gamma walkover survey data from the reference and impact areas were performed to optimize the type, location, and number of judgmental samples collected during the characterization survey.

3.0 DATA COLLECTION

Data were collected over 428 acres identified in Figure 1-2 as the SBIA. Since the SBIA includes active firing ranges, a UXO visual survey was performed as a safety precaution. Three types of data were collected: (1) GWS data were collected to identify localized areas of elevated gross gamma activity to direct judgmental soil sampling, (2) exposure rate measurements were performed to evaluate external radiation exposure, and (3) soil samples were collected from systematic and judgmental locations and analyzed for DU and lead for use in the BHHRA. No surface water was present during field activities; therefore no water samples were collected.

Data were collected as described by the following survey and sampling methods. The data analysis is discussed in Section 4.0. Quality control (QC) measures implemented as part of the data collection and analysis process are discussed in Section 5.0.

3.1 UXO Visual Survey

Due to historical and ongoing activities involving munitions and explosives on the firing range at Schofield Barracks, the SBIA was considered to have potential UXO hazards. A visual survey for DU fragments and UXO was performed prior to radiological data collection. As a rule, any area with an identified explosive threat was avoided. This resulted in some soil samples being relocated minor distances (a few feet) due to potential health and safety risks.

The following data were collected as part of the UXO visual survey.

3.1.1 Davy Crockett Weapons Systems

Table 3-1 lists identified components of the Davy Crockett Weapons systems and their locations. These points indicate that the M390 practice 155mm version may have been fired from east to west at a high angle of elevation or that the 120mm version was fired from east to west. None of the smaller pistons from the 120mm version were found on this line. The 37mm DC spotter rounds were found in Fingers 5 and 6 (see Figure 1-2) which would be close to maximum range for the system if fired from east to west. All pistons found were the 6' from the 155mm version of the Davy Crockett system.

TABLE 3-1: DAVY CROCKETT DATA

Description	*Latitude/Longitude*	*Description*	*Latitude/Longitude*
piston	N21°30'18.0", W158°05'44.7"	tail ring	N21°30'13.3", W158°05'56.4"
	N21°30'15.7", W158°05'45.1"		N21°30'15.4", W158°06'01.4"
	N21°30'20.9", W158°05'46.1"		N21°30'25.6", W158°06'02.3"
	N21°30'19.1", W158°05'49.3"		N21°30'24.1", W158°06'09.1"
antennae	N21°30'24.2, W158°06'08.7"		N21°30'12.1", W158°06'06.5"
37mm spotter round	N36408.48, E487884.55 (two more found in this area)	fin	N21°30'23.3, W158°06'04.4"

3.1.2 Discovered Ordnance

Ordnance that was discovered and passed by that should be destroyed is listed in Table 3-2.

TABLE 3-2: DISCOVERED ORDNANCE

Description	*Latitude/Longitude*	*Notes*
40mm Grenade HE (8)	N36335.06, E487710.81	northing/easting
105mm HE	N21°30'24.7", W158°05'36.0"	
75mm	N21°29'57.9", W158°07'01.7"	
2.36in M6A3 Rockets Multiple	N21°30'26.8", W158°05'50.7"	
105mm HE	N21°29'39.4", W158°07'01.7"	Finger 4
155mm HE	N21°29'38.1:, W158°06'53.7 "	Finger 4
155/75/60mm	N21°29'41.4", W158°07'00.2"	Finger 5
3 in Stokes Unfuzed with Plug in Nose	N21°30'18.1", W158°05'05.0"	near MF2 CP
75mm	N21°29'37.9", W158°06'59.0"	Finger 4

3.1.3 Predominate Ordnance by Area

The predominate ordnance by area are listed in Table 3-3.

TABLE 3-3: PREDOMINATE ORDNANCE BY AREA

Description of Area	*Description of Ordnance*
Finger 2, west of road	3.5" rockets (probably mostly practice but no way to tell)
Finger 3	(nothing identified)
Finger 4, north side	90mm Heat, 84mm AT-4, Dragon missile, Davy Crockett fins, antenna, and aluminum tail ring
Finger 5	Entac missile practice, Davy Crockett 37mm spotter round, aluminum tail ring, fins
Finger 6	Entac missile practice
Finger 7	All
Finger 7, east (MF Area 1)	tow missile, 165mm HEP practice, Davy Crockett pistons and tail rings, electric/VT fuzes

MF Area 2 (Hillside)	37mm TP, HE, 4"Stokes UKN, 152mm Recoiless, Davy Crockett aluminum tail ring, antenna, and fins

3.1.4 Other Items

During the course of the GWS survey and visual UXO inspection, survey teams discovered several gauges which upon closer inspection with radiological instruments appeared to be dials and gauges with radium paint. The sites were marked and reported to USAG-HI.

3.2 Gamma Walkover Survey

A GWS was performed over approximately 25% of the accessible land area, largely on plateaus (mesas) between the ravines. Due to the steep sloops and safety considerations, a GWS was not performed of the ravines. The purpose of the GWS was to locate radiation anomalies that indicate potential areas with relatively elevated radioactivity where biased soil sampling may be warranted. An emphasis was placed on defining the boundaries of areas containing DU fragments within the SBIA, as well as demonstrating the absence of DU fragments immediately beyond the survey area boundary.

The GWS was performed using a thin crystal sodium iodide (NaI) Field Instruments for the Detection of Low Energy Radiation (FIDLER) detector with a Ludlum Model 2221 scaler/ratemeter. The detector was suspended a few inches above the ground while the surveyor walked over the area at a speed of approximately 0.5 meters per second, spacing each pass one meter from the previous pass. Each pass was marked with flags, twine, or other appropriate method to ensure straight survey paths. Measurement data were position correlated using a Trimble Pathfinder® Pro XRS global positioning system (GPS) receiver mated with a Trimble TSCe™ graphical interface system (GIS) field device. Measurement and position data were automatically logged at one-second intervals. GWS results are discussed in Section 4.1.

3.3 Soil Samples

Table 3-4 summarizes the soil sampling and analysis performed. A total of 1,226 samples were collected at 645 sample locations. For systematic samples, an initial sampling frequency of approximately one sample location per acre resulted in 416 sample locations systematically distributed across the impact areas. A surface and subsurface soil sample were collected at each location for a total of 832 systematic samples. A total of 318 soil samples were collected at 166

judgmental sample locations distributed over the impact areas. The judgmental sample locations were selected based on the GWS results and by design were intended to bound and further investigate areas of elevated gross gamma activity identified by the GWS. Fifty-two samples were collected from the ravines to locate any DU in the sediment that may have been washed down by the rain and concentrated. An additional 24 samples (12 surface and 12 subsurface) were collected from a reference area located outside the SBIA. The soil sample analytical results are discussed in Section 4.2.

A trowel was used to collect surface soil at each sample location to a depth of approximately 6 inches bgs, followed by a subsurface sample to a depth of 12 inches bgs. The sample material was mixed to homogenize it and identifiable foreign objects and debris (e.g., vegetation, rocks, metal fragments) were removed. Each sample consisted of approximately 500 grams of soil. Sampling equipment was cleaned and surveyed for radioactive contamination between each sample.

TABLE 3-4: SOIL SAMPLE SUMMARY

Sample Location	***Location Type***	***Sample Depth***	***Numbering Sequence[(a)]***		***Samples Collected***	***Radioanalysis Performed***
			Start	***Stop***		
SBIA	Systematic	Surface	2000-ST	2415-ST	416	Gamma Spec
		Subsurface	2000-SD	2415-SD	416	
	Judgmental	Surface	2000-BA	2165-BA	165	
		Subsurface	2000-BD	2165-BD	153	
Reference Area	Random	Surface	RA1-BA	RA12-BA	12	Gamma Spec
		Subsurface	RA1-BD	RA12-BD	12	
Ravines	Judgemental	Surface	3000-BA	3051-BA	52	Alpha Spec
				Total:	1,226	

Notes:
(a) Sample numbering prefix is 'SB-CZ-SS.'
(b) No sample collected and analyzed for 2100-BA.
(c) No sample collected and analyzed for 2038-BD to 2049-BD, and 2100-BD.

3.4 Exposure Rate Measurements

An exposure rate measurement was performed at each of the 582 systematic and judgmental soil sample locations and at the 12 reference area soil sample locations using a Ludlum Model 19

microR meter with a 1-inch by 1-inch NaI (thallium-activated) [NaI(Tl)] gamma scintillation detector. Measurements were taken at waist height (approximately 1 meter) using the "slow" response time constant setting. The detector was positioned and allowed to stabilize prior to observing the instrument response and recording the reading. The exposure rate measurements are discussed in Section 4.3.

3.5 Reference Area

Since there is little information available about the natural levels of U present in the environment at Schofield Barracks, a reference area approximately one acre in size was identified at Wheeler Army Airfield, which is approximately 7.5 miles east of the SBIA. The area was surveyed to ensure there was no DU. Surface and subsurface samples were collected to provide information on the levels of U and lead in the environment. The data were evaluated by exploratory data analysis (EDA) to evaluate their use as possible site background data for naturally-occurring U concentrations. The reference area soil sample results are discussed in Section 4.2.2.

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4.0 DATA ANALYSIS

Exploratory data analysis was performed on the data to identify data distribution trends and potential outliers. Statistical quantities were calculated and measurement results were visually inspected using graphing techniques such as z-score contouring, histograms, and cumulative frequency diagrams.

4.1 Gamma Walkover Survey

Gamma walkover survey data are found in Appendix A. The mean and standard deviation of each GWS data set were calculated, z-scores (the number of standard deviations the result lies from the mean) were computed, and a color-coded contour map of the survey unit created. The contouring process involves creating a regularly spaced grid and assigning values to every spot on the grid. The grid spacing and the values assigned at the grid nodes determine what the contour plot looks like. Grid node values are assigned using a weighted average based on the inverse square law, which is generally used to describe how radiation levels drop off with distance from a source. Once the grid is complete, color-coded contours are created from grid node values within the specified ranges of values. The GWS results in z-score contours for the SBIA are presented in Figures 4-1 and 4-2. The results were used to identify judgmental sample locations.

The color divisions represent various ranges of z-score values with red representing the highest values and green the lowest values. A z-score contour greater than 3 (i.e., red) was used as an indicator for investigating areas with potentially elevated residual radioactivity. Statistically, a very small number of points with z-score values above 3 are expected for a normal distribution. Approximately 0.135% of normally distributed data exceed a z-score value of 3. The contouring process tends to smooth over single data points with z-score values slightly above 3 while accentuating clustered areas or single locations with z-score values significantly above 3. This is the desired effect which aids in the data analysis by focusing attention on those areas most likely to have elevated residual radioactivity.

4.2 Soil Sample Radiological Analysis

Soil sample radiological data are found in Appendix B. The soil sample analytical results were evaluated and compared statistically to the reference area data. Soil samples collected from the ravines were analyzed by alpha spectrometry for U isotopes (^{234}U, ^{235}U, and ^{238}U).

The systematic, judgmental, and reference area samples were analyzed by gamma spectrometry. ^{235}U emits gamma radiation and is measured by gamma spectrometry, while ^{234}U and ^{238}U do not emit gamma radiation. ^{234}Th is the progeny (i.e., decay product) of ^{238}U, emits gamma radiation, and is measured by gamma spectroscopy. ^{234}Th and ^{238}U are in secular equilibrium, therefore ^{234}Th is a surrogate for ^{238}U. There are no progeny of ^{234}U that emit gamma radiation and are in secular equilibrium; therefore ^{234}U is not measured by gamma spectrometry. The gamma spectrometry results were reviewed for other identified and unidentified peaks to identify all radionuclides present in soil at the SBIA. Only naturally-occurring and ubiquitous man-made radionuclides from nuclear weapons testing were identified. None of the radionuclides reported concentrations outside the expected background range.

4.2.1 Systematic Soil Samples

An initial sampling frequency of approximately one sample location per acre resulted in 416 sample locations systematically distributed across the impact areas. A surface and subsurface soil sample were collected at each location for a total of 832 samples, all of which were analyzed by gamma spectrometry. The statistical summary of the analytical results for the two radionuclides of interest, ^{234}Th and ^{235}U, are given in Table 4-1.

The radionuclide ^{234}Th is an effective surrogate for ^{238}U found in the naturally occurring ore in the environment where the parent and progeny are found in secular equilibrium. The concentrations of the two radionuclides are equal.

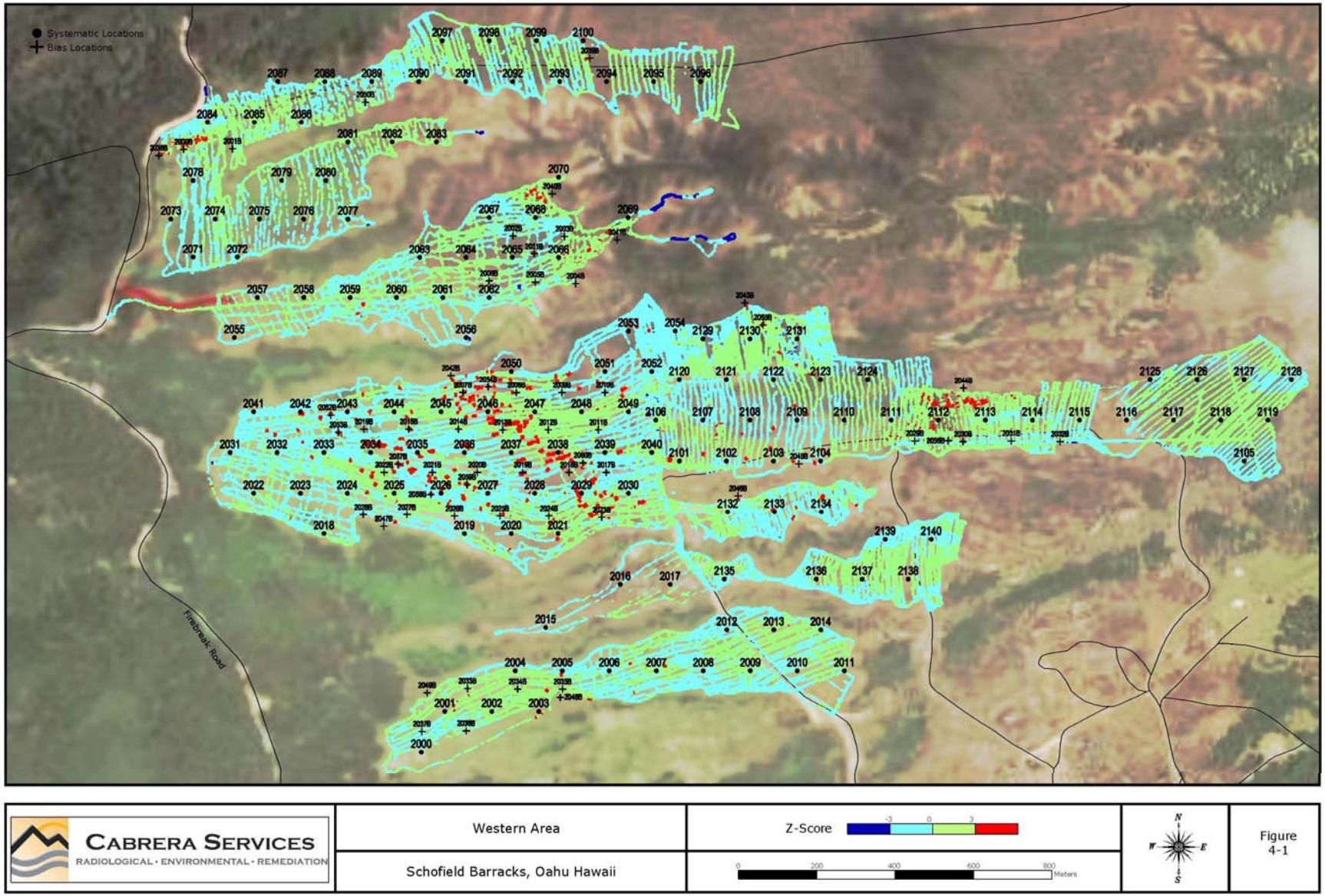


FIGURE 4-1: WESTERN AREA GWS Z-SCORE CONTOURS AND SOIL SAMPLE LOCATIONS

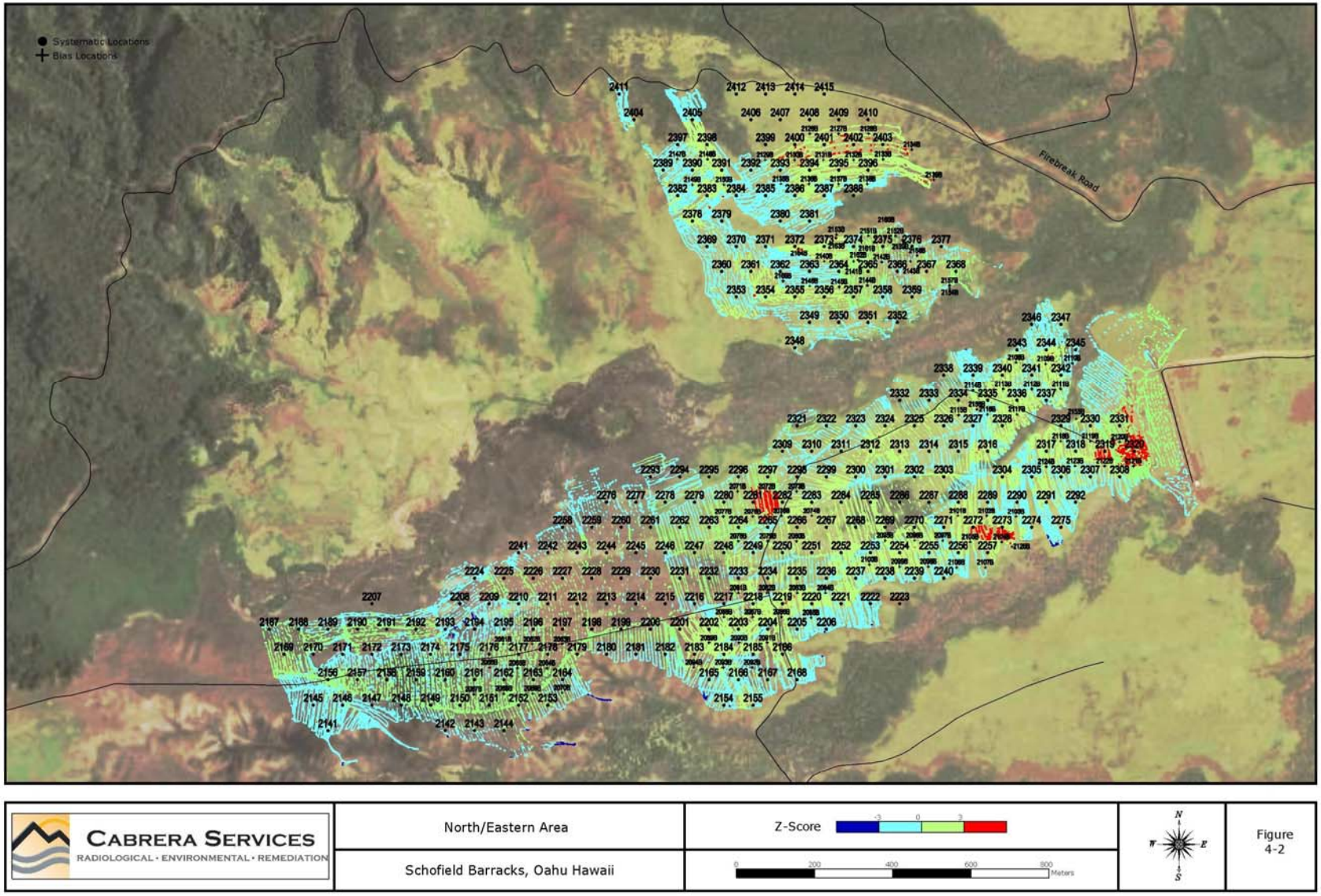


FIGURE 4-2: NORTH/EASTERN AREA GWS Z-SCORE CONTOURS AND SOIL SAMPLE LOCATIONS

TABLE 4-1: SUMMARY OF SYSTEMATIC SOIL SAMPLE RESULTS

Parameter	^{234}Th (pCi/g)			^{235}U (pCi/g)		
	Surface	Subsurface	Combined	Surface	Subsurface	Combined
Mean	0.992	0.995	0.994	0.0362	0.0372	0.0367
Std Dev	0.413	0.435	0.429	0.0604	0.0556	0.0580
Median	0.973	0.950	0.965	0.037	0.0386	0.0379
Min	0.000836	-0.275	-0.275	-0.146	-0.168	-0.168
Max	3.18	2.66	3.18	0.33	0.172	0.33
Range	3.18	2.94	3.46	0.476	0.34	0.498
Number of Samples	416	416	832	416	416	832
Results >MDC	389	378	767	3	2	5[(a)]

Note:
(a) All reported concentrations less than 2 x MDC; confidence level true concentration is below the MDC > 95%.

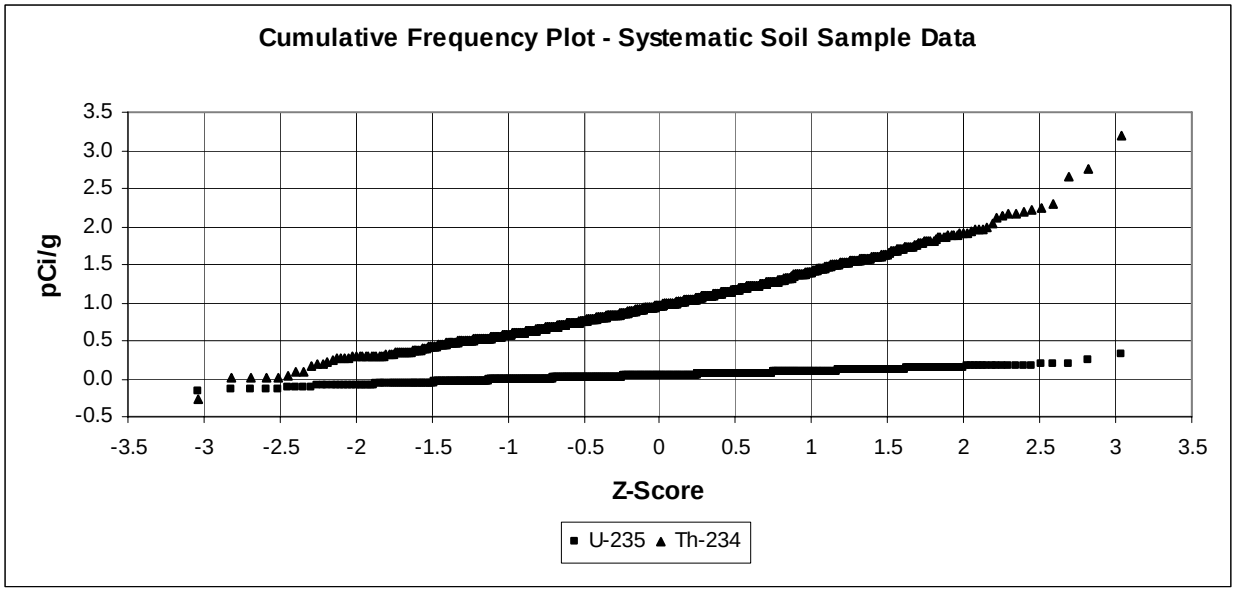
The surface and subsurface soil sample data populations were evaluated separately and combined and evaluated in aggregate. Over 90% of the soil samples reported concentrations of ^{234}Th above the MDC. For ^{235}U, only five samples reported concentrations above the MDC, and all results were less than two times the MDC.

For a normally distributed population, a range larger than five times the standard deviation is unusual, except for larger data sets. Each of the populations has an unusually large range, likely due to the influence of the DU on the sample results. The influence on the systematic soil sample results is not dramatic, unlike that observed in the judgmental soil samples discussed in Section 4.2.5. Large differences between the mean and the median are an indication of the skewness (i.e., non-symmetry) in the data. A simple test for skewness is to divide the difference between the mean and median by the standard deviation. Where the result is greater than 0.5, the data are examined for outliers or anomalies. Using this simple test, none of the data populations appear to exhibit skewness.

The soil sample data for ^{234}Th and ^{235}U were plotted on a cumulative frequency diagram (CFD) to obtain information on the general shape of the data distribution. The plotted data for each radionuclide, shown in Figure 4-3, appear in a relatively straight line, which suggests a single normally distributed data population. The three data points appearing on the right end of both

plotted data sets represent potential outliers which are possibly due to the influence of the DU on the sample results.

FIGURE 4-3: SYSTEMATIC SOIL SAMPLE CFD



4.2.2 Reference Area Soil Samples

A total of 24 soil samples were randomly collected from 12 sample locations in the reference area. A surface and subsurface soil sample was collected at each sample location, all of which were analyzed by gamma spectrometry. The analytical results and statistical summary for the two radionuclides of interest, ^{234}Th and ^{235}U, are given in Table 4-2.

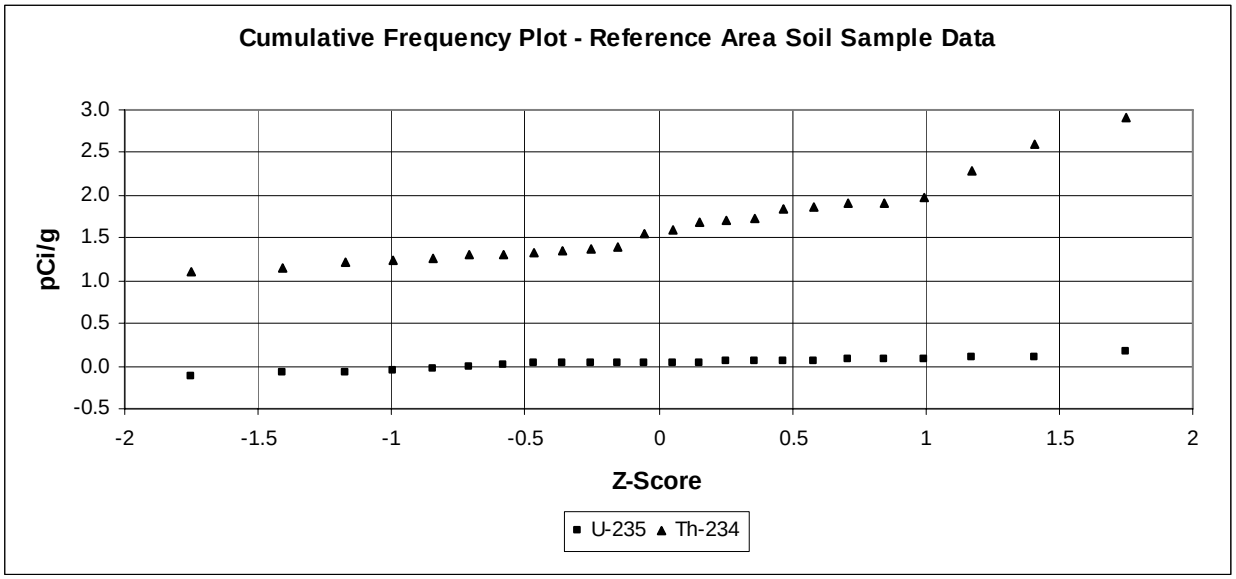
TABLE 4-2: SUMMARY OF REFERENCE AREA SOIL SAMPLE RESULTS

Parameter	^{234}Th (pCi/g)			^{235}U (pCi/g)		
	Surface	Subsurface	Combined	Surface	Subsurface	Combined
Ave MDC	0.358	0.424	0.391	0.173	0.206	0.190
Mean	1.48	1.82	1.65	0.0149	0.0478	0.0314
Std Dev	0.287	0.543	0.459	0.0665	0.0581	0.0633
Median	1.37	1.70	1.58	0.0352	0.0481	0.0352
Min	1.11	1.22	1.11	-0.115	-0.0699	-0.115
Max	1.9	2.92	2.92	0.0854	0.159	0.159
Range	0.79	1.7	1.81	0.200	0.229	0.274
Number of Samples	12	12	24	12	12	24
Results > MDC	12	12	24	0	0	0

The surface and subsurface soil sample data populations were evaluated separately and combined and evaluated in aggregate. All of the soil samples reported concentrations of ^{234}Th above the MDC. None of the soil samples reported concentrations of ^{235}U above the MDC. Therefore, the reported ^{235}U data should be used with care. For a normally distributed population, a range larger than five times the standard deviation is unusual, except for larger data sets. None of the populations has an unusually large range. Large differences between the mean and the median are an indication of the skewness (i.e., non-symmetry) in the data. A simple test for skewness is to divide the difference between the mean and median by the standard deviation. Where the result is greater than 0.5, the data are examined for outliers or anomalies. Using this simple test, none of the data populations appear to exhibit skewness.

The soil sample data for ^{234}Th and ^{235}U were plotted on a CFD, Figure 4-4, to obtain information on the general shape of the data distribution. The plotted data for each radionuclide appear in a relatively straight line, suggesting a single normally distributed data population.

FIGURE 4-4: REFERENCE AREA SOIL SAMPLE CFD



Based on the results of the evaluation, the reference area data are considered adequate for use as site background data for naturally occurring ^{238}U concentrations. For purposes of characterization, ^{238}U concentrations representative of background are considered to be less than 2.57 pCi/g (1.65 ± 0.918 pCi/g at the 95% confidence level).

4.2.3 Comparison of Systematic Soil Sample Results to Reference Area Data

The combined surface and subsurface systematic soil sample data are compared to the combined reference area soil sample data set in Table 4-3 and Figure 4-5. For the purposes of this report, it is assumed that all detected U is depleted.

TABLE 4-3: COMPARISON OF COMBINED SYSTEMATIC AND REFERENCE AREA SOIL SAMPLE RESULTS

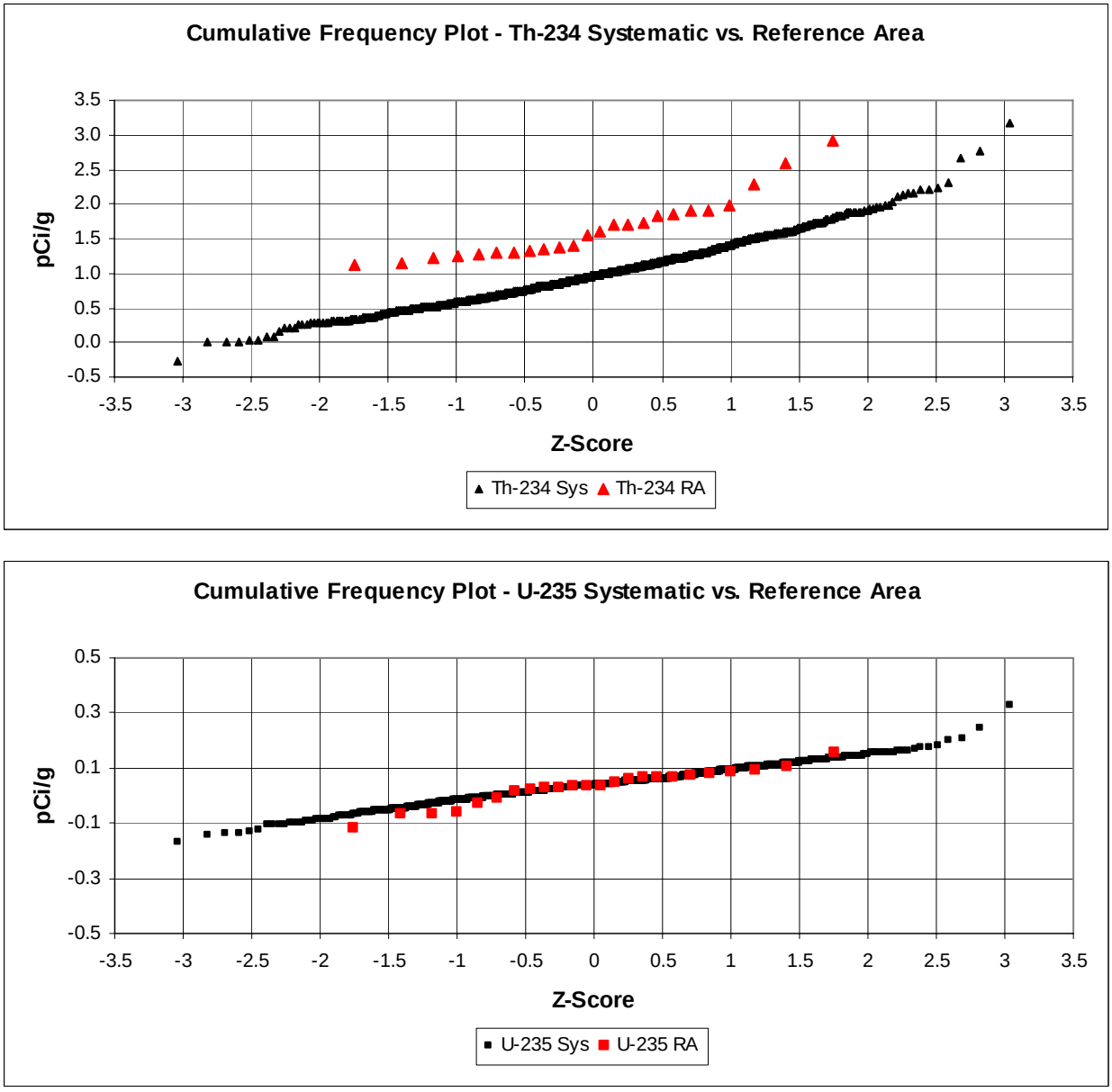
Parameter	^{234}Th (pCi/g)		^{235}U (pCi/g)	
	Systematic	Reference Area	Systematic	Reference Area
Mean	0.994	1.65	0.0367	0.0314
Std Dev	0.429	0.459	0.0580	0.0633
Median	0.965	1.58	0.0379	0.0352
Min	-0.275	1.11	-0.168	-0.115
Max	3.18	2.92	0.33	0.159
Range	3.46	1.81	0.498	0.274
Number of Samples	832	24	832	24
Results	767	24	5[(a)]	0

> MDC				

Note:
(a) All reported concentrations less than 2 x MDC; confidence level that true concentration is below the MDC > 95%.

As can be seen from the table, the mean, standard deviation, and median values of the systematic soil sample data are numerically lower than, but similar to, those of the reference background data. The systematic soil sample data exhibit a larger range of values than the reference area soil sample data, though this is expected solely based on the number of data included in the respective sample populations. Figure 4-5 graphically illustrates the similarity in the variability of both ^{234}Th sample populations while contrasting the higher concentrations found in the reference area data. Figure 4-5 also shows the pronounced similarity in both ^{235}U sample populations, which are indistinguishable.

FIGURE 4-5: SYSTEMATIC VS. REFERENCE AREA COMPARISON



4.2.4 Ravine Surface Soil Samples

A total of 52 surface soil samples were collected at sample locations in the ravines selected using professional judgment. Sample locations were selected based on accessibility, absence of UXO, and the likelihood the location was representative of surface runoff. The samples were analyzed by alpha spectrometry for U isotopes. The summarized analytical results are given in Table 4-4. The distribution of soil samples is shown in Figure 4-6.

TABLE 4-4: SUMMARY OF RAVINE SURFACE SOIL SAMPLE RESULTS

Parameter	^{234}U	^{235}U	^{238}U
Mean MDC	0.030 pCi/g	0.029 pCi/g	0.026 pCi/g
Max MDC	0.29 pCi/g	0.186 pCi/g	0.150 pCi/g
Sample Location 3016	1.2 pCi/g	0.086 pCi/g	5.69 pCi/g
Sample Location 3017	22.6 pCi/g	2.4 pCi/g	148 pCi/g
Balance of Samples	≤ 1.08 pC/g	≤ 0.077 pCi/g	≤ 1.01 pCi/g
Number of Samples	52	52	52
Results > MDC	52	22[(a)]	52

Note:
(a) With the exception of four samples confidence level that true concentration is below the MDC > 95%.

All of the soil samples reported concentrations of ^{234}U and ^{238}U above the MDC. Twenty-two samples reported concentrations of ^{235}U above the MDC; however, the associated uncertainty in the reported concentrations exceeds 90% for all but four samples. Samples 3016 and 3017 reported high U concentrations. The $^{234}U/^{238}U$ ratio and the $^{235}U/^{238}U$ ratio for these two samples are below the expected values for these ratios. Therefore, these samples indicate the presence of DU. The reported U concentrations for the other 50 samples are consistent with background concentrations.

4.2.5 Judgmental Soil Sample Results

In addition to the systematic soil samples (see Section 4.2.1), an additional 318 soil samples were collected at 165 judgmental sample locations selected based on the GWS results. Locations where high levels of gamma radiation were reported from the GWS had soil samples collected and analyzed by gamma spectrometry to identify the source of the gamma radiation. The results include 165 surface soil samples and 153 subsurface soil samples. The summarized analytical results for the two radionuclides of interest, ^{234}Th and ^{235}U, are given in Table 4-5.

TABLE 4-5: SUMMARY OF BIASED SOIL SAMPLE RESULTS

Parameter	^{234}Th (pCi/g)			^{235}U (pCi/g)		
	Surface	Subsurface	Combined	Surface	Subsurface	Combined
Max	7,030	2,670	7,030	110	41.9	110
Samples	165	153	318	165	153	318
> MDC	158	145	303	29	23	52
> Background[(a)]	17	14	31	14	10	24

Note:
(a) Concentrations exceed the reference area ^{234}Th concentration representative of background (i.e., 2.57 pCi/g) or, for ^{235}U, concentration above the MDC at the 95% confidence level.

As with the systematic soil samples, the surface and subsurface soil sample data populations were evaluated separately and combined and evaluated in aggregate. Over 95% of the soil samples reported concentrations of ^{234}Th above the MDC. For ^{235}U, less than 20% of the soil samples reported concentrations above the MDC.

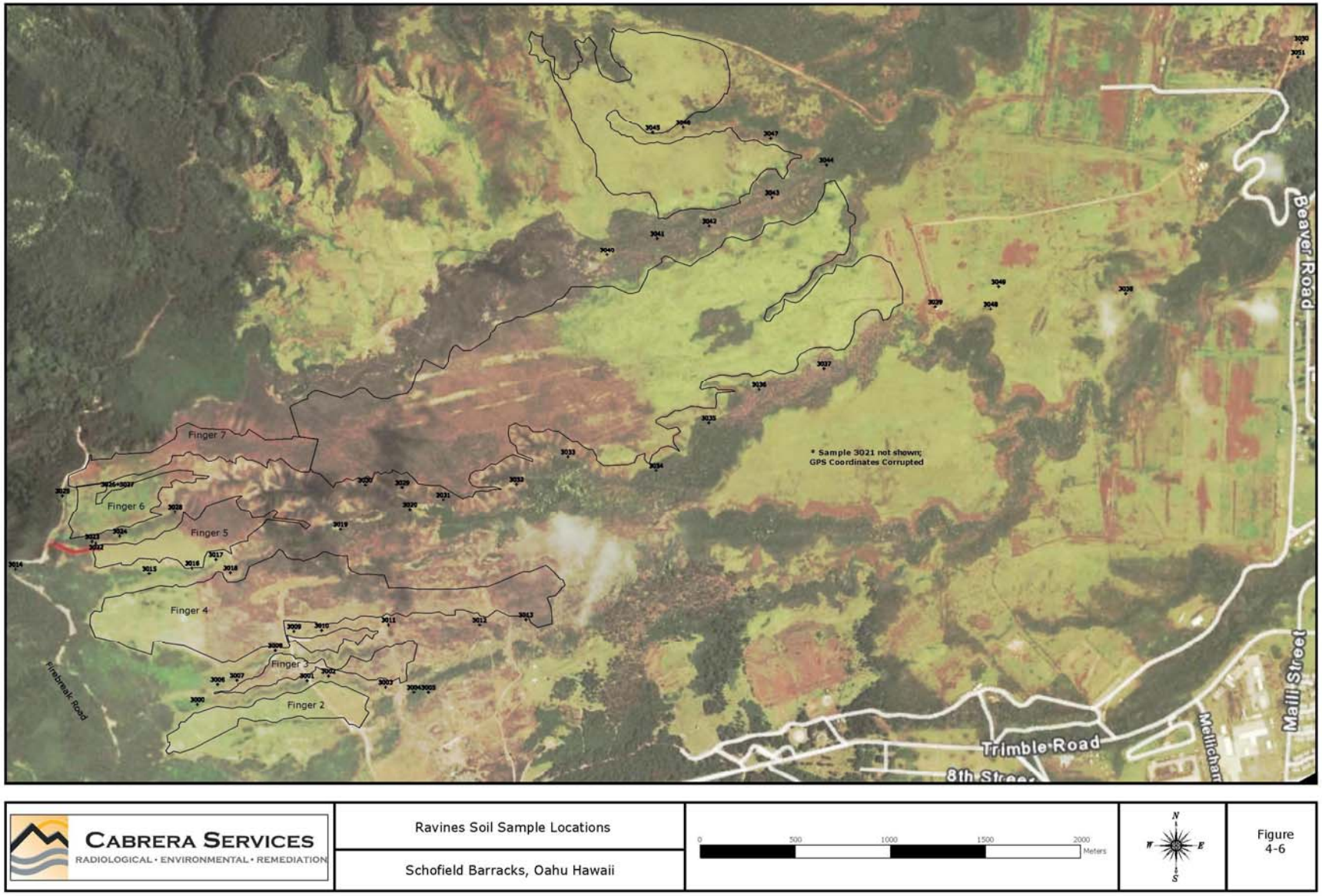
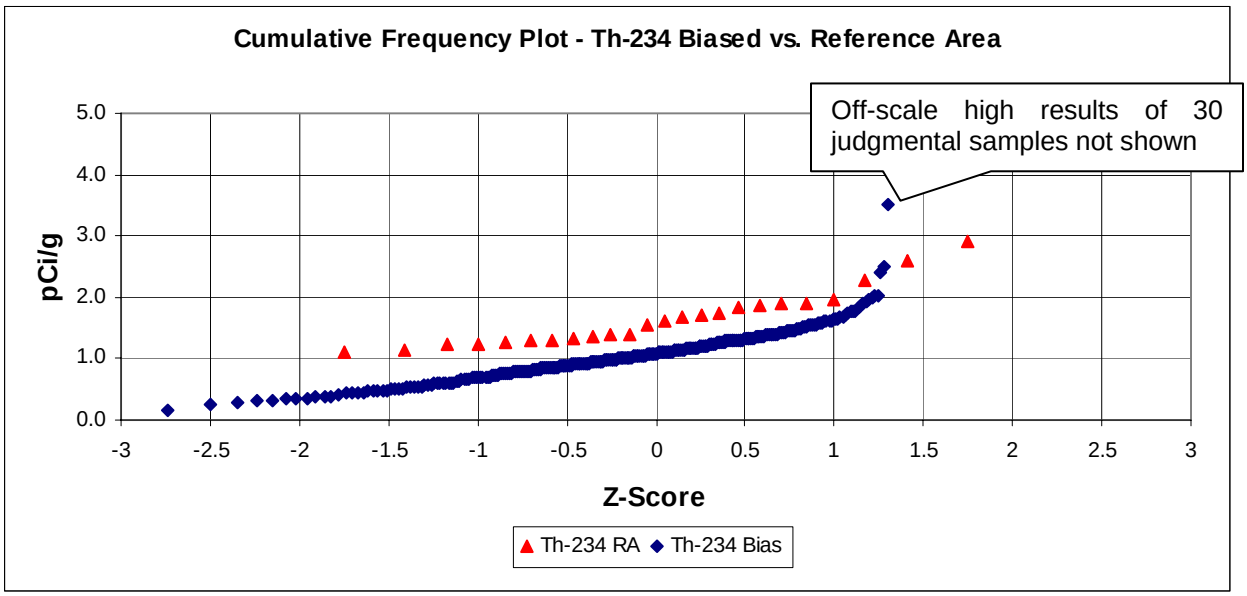


FIGURE 4-6: RAVINES SOIL SAMPLE LOCATIONS

Based on the use of the SBIA as a firing range for munitions containing DU, samples with ^{234}Th concentrations reported above the upper bound of the reference area ^{234}Th concentration (2.57 pCi/g) are assumed to be DU. This includes 31 samples whose ^{234}Th concentrations range from 2.66 to 7,030 pCi/g. The reported ^{234}Th concentrations for the other 277 biased soil samples are consistent with background concentrations. A graphical comparison of the two soil sample populations is shown in Figure 4-7.

FIGURE 4-7: JUDGMENTAL VS. REFERENCE AREA COMPARISON



Uranium in the Environment

There are several naturally occurring radionuclides with half-lives of at least the same order of magnitude as the estimated age of the earth (4.5×10^9 years). Two isotopes of U, ^{235}U and ^{238}U, are included in this list of naturally occurring primordial radionuclides. ^{238}U and ^{235}U undergo radioactive decay through a series of radionuclides before decaying a stable, non-radioactive nuclide. If not subjected to chemical or physical separation, these natural decay series are present in a state of equilibrium where each member of the decay series has equal activity concentrations. This state of equilibrium is known as secular equilibrium.

The ^{238}U decay series includes another isotope of U, ^{234}U. ^{234}U is removed from earth materials (e.g., soil and rock) at a slightly greater rate than ^{238}U, and builds up an excess activity relative to ^{238}U in the ocean. Activity ratios of ^{234}U to ^{238}U range from 0.914 for weathered soils to 1.14 for

water from the Atlantic, Pacific, and Indian Oceans (NCRP, 1975). ^{235}U has a shorter half-life than ^{238}U, and over time has decayed to a lower activity relative to ^{238}U. The activity ratio of ^{235}U to ^{238}U is 0.0455 and is fairly constant. One gram of natural U contains 0.33mCi of ^{238}U, 0.015 mCi of ^{235}U, and 0.3 mCi of ^{234}U subject to minor variations in the ^{234}U activity (NCRP, 1975).

4.3 Exposure Rate Analysis

Exposure rate measurement results were reported for each of the 416 systematic sample locations, 12 reference sample locations, and 166 judgmental sample locations (including judgmental location 2100 where no samples were collected). The results of the exposure rate measurements are found in Appendix A and summarized in Table 4-6.

TABLE 4-6: SUMMARY OF EXPOSURE RATE MEASUREMENTS

Parameter	***Systematic Locations (µR/hr)***	***Reference Area***	***Judgmental Locations (µR/hr)***
Mean:	10.8	7	7.92[(a)]
Std Dev:	9.43	1	6.95[(a)]
Median:	7	7	7[(a)]
Minimum:	3	6	2[(a)]
Maximum:	70	11	60[(a)]
Range:	67	5	58[(a)]
Number of Measurements	416	12	166

Note:
(a) Summary statistics are usually not calculated for judgmental measurements because the measurements are not independent of one another. These values should be interpreted with care.

The mean exposure rates for both the systematic and judgmental locations are approximately equal to the standard deviations, while the reference area standard deviation is much smaller than the mean. The ranges for both the systematic and judgmental locations greatly exceeds the mean, while the range for the reference area measurements is approximately equal to the mean. The maximum exposure rates for both the systematic and judgmental locations greatly exceed the mean, while the maximum reference area exposure rate is less than twice the mean. However, the median exposure rates are the same for systematic, judgmental, and reference area sample locations. These data indicate that the exposure rates in the SBIA are mostly consistent with background with some areas with higher exposure rates. This is consistent with the

conceptual site model where there are multiple locations where DU fragments are located while the majority of the SBIA has not been affected by the SRBs.

5.0 QUALITY CONTROL

Data collection activities were performed in a controlled, deliberate manner. Data were collected by trained individuals with calibrated instruments following written procedures and/or protocols. Data were recorded and reviewed, and documentation is auditable. Instrumentation capable of detecting the radiation types and energies of interest were selected, calibrated, and maintained for survey data collection and sample analysis. All soil sample analytical (radiological) results were subjected to data verification and review, and soil sample analytical (radiological) results in 10% of the laboratory analytical batches received full data validation. Field survey and analytical laboratory QC records are found in Appendices A and B, respectively. The analytical data verification and validation are found in Appendix C.

5.1 Precision, Accuracy, Representativeness, Comparability, and Completeness

Quality control measures were implemented to ensure data met known and suitable data quality criteria, i.e., precision, accuracy, representativeness, comparability, and completeness. Variables related to data precision and accuracy were monitored by instrument response checks designed to monitor the performance of the instrumentation used to collect the data. The representativeness of the data was ensured by adherence to the survey design and the use of standardized data collection methods and techniques established in written procedures, listed in Table 5-1. Routine monitoring of surveyor performance and environmental factors was performed to ensure data comparability. The type and quantity of collected data were reviewed against survey design requirements to ensure data completeness.

TABLE 5-1: CABRERA PROCEDURES USED FOR CHARACTERIZATION SURVEY

Number	Title
OP-001	Radiological Surveys
OP-005	Volumetric and Material Sampling
OP-008	Chain of Custody
OP-009	Use and Control of Radioactive Check Sources
OP-020	Operation of Contamination Survey Meters
OP-021	Alpha-Beta Counting Instrumentation
OP-023	Operation of Micro-R Meters

5.2 Field Survey Performance

Commercially available radiation detection and measurement instrumentation were selected based on reliable operation, detection sensitivity, operating characteristics, and expected performance in the field. Table 5-2 lists the types of portable survey instrumentation used.

5.2.1 Calibration and Maintenance

Survey instruments were calibrated prior to use. Radiation detection instruments were calibrated for the radiation types and energies of interest. Radioactive sources used for calibration purposes are National Institute of Standards and Technology (NIST) traceable. Instrumentation was inspected prior to use to ensure its proper working condition, and properly protected against inclement weather conditions in the operation.

5.2.2 Instrument Response

Instrument response was checked before and after instrument use each day. A check source was used that emits the same type of radiation (i.e., alpha, beta, and/or gamma) as the radiation being measured and that gives a similar instrument response. The source check was performed using a specified source-detector alignment that can be easily repeated.

TABLE 5-2: FIELD SURVEY INSTRUMENTATION

Measurement Type	Detector Type	Effective Detector Area and Window Density	Instrument Model	Detector Model
Exposure Rate	NaI(Tl) scintillation	1" diameter x 1" length N/A	Ludlum 19	N/A
Beta-Gamma	Halogen quenched G-M	15 cm^2 0.3 mg/cm^2 mica	Ludlum 12	Ludlum 44-9
Gamma	NaI(Tl) scintillation	7.6 cm dia x 7.6 cm length N/A	Ludlum 2221r	FIDLER
Alpha/Beta	Dual phosphor scintillation	100 cm^2 1.2 mg/cm^2 aluminized mylar	Ludlum 2360	Ludlum 43-93
Alpha/Beta Swipes	ZnS(Ag) scintillation	2" (5.1 cm) diameter 0.4 milligrams (mg)/cm^2	Ludlum 2929	Ludlum 43-10-1

Prior to initial instrument use, a minimum of 10 measurements were made using a source representative of the radiation types and energies of interest. A minimum of 10 one-minute measurements were also made with the source removed to determine the instrument's expected response to ambient background. Background was monitored qualitatively to assess daily variations that may have impacted instrument MDCs. From the initial source measurements, the

mean of the observed count rate was calculated. The acceptance criterion was ± 20% of the mean of the initial source counts. Source checks were monitored using a control chart, with control limits set at ± 20% of the average count rate. For the alpha/beta smear counter, the acceptance criterion for each channel was set at ± 2σ or 3σ from the mean. If an alpha/beta counting system channel falls outside 2σ of the mean but is within 3σ of the mean, the source check was repeated.

5.2.3 Minimum Detectable Concentration

The FIDLER scan MDC for DU was approximately 2.6 pCi/g. This scan MDC value was based on the assumption that ^{235}U is present at 0.35% by mass, and includes the sum of ^{234}U, ^{235}U, and ^{238}U. In addition, the calculation assumes that the DU is present as a 0.5 pound (lb) slug with approximately 1 foot (ft) of soil cover, which is a conservative estimate of actual site conditions.

5.2.4 Global Positioning System Unit

The GPS unit was used to link survey data to spatial locations (northing and easting) using state plane coordinates for Hawaii, Zone 3, North American Datum 1983. By design, the GPS unit is self-checking, using data received from the satellite constellation to determine the precision and accuracy of its readings. To provide additional QC for this system, the GPS unit was checked daily against a check point. The check point (stable site feature) was selected upon commencement of fieldwork. Prior to initial GPS use, 10 static positional readings were obtained at the check point. From these positional readings, a mean position was determined. Thereafter, the GPS unit was compared to the check point at least daily. The acceptance criterion for GPS daily checks was within 1 m of the check point, as calculated using the Pythagorean Theorem. The results of the daily checks were recorded and posted to a GPS control chart.

5.3 Analytical Laboratory Performance

Soil samples were analyzed by Sanford Cohen & Associates Southeastern Environmental Laboratory (SC&A) and GEL Laboratories, LLC, and GPL Laboratories, LLP. Analyses were performed in accordance with procedures developed by laboratories, consistent with the methods defined in the Work Plan. Offsite radiochemical analysis consisted of alpha spectrometry for U isotopes and gamma spectrometry analysis. Radiochemical target analytes and the associated required MDCs are identified in Table 5-3. The alpha spectrometry analyses were used to quantify the target analytes $^{233/234}U$, ^{235}U, and ^{238}U and the gamma spectrometry analyses

quantified the target analyte ^{234}Th. The gamma spectrometry reports included all radionuclides that were listed in the gamma library. For the purposes of data quality reviews and data validation, only the target analytes were considered.

TABLE 5-3: LABORATORY ANALYTICAL PARAMETERS

Analysis	*Analyte(s)*	*Method Reference*[(a)]	*Target MDC*
Gamma spectrometry	^{234}Th	EML HASL 300	0.5 pCi/g
Alpha spectrometry	^{234}U, ^{235}U, ^{238}U	DOE U-02	0.1 pCi/g

Sample results were subjected to validation and verification using a checklist developed by CABRERA. All radiological samples were subjected to data verification/review and radiological samples in 10% of the analytical batches received full data validation. Initial data verification was performed by the QC staffs at the analytical laboratories. A summary of the verification was included in the case narrative for each laboratory work order. The data validation and data verification/review checklists were prepared by a CABRERA senior-level staff member with experience in radiochemistry, analytical quality assurance, and data evaluation. The radiological checklists were developed in accordance with accepted industry practices. The verifications and validations were performed by CABRERA personnel experienced with radiochemistry laboratory practices and the evaluation of analytical data and provided with training on the use of the checklists. A minimum of 10% of the completed verification and validation checklists were subjected to an internal quality review.

5.3.1 Chain of Custody

Chain of custody was maintained for all samples collected during the project. No custody deficiencies that would impact the quality were identified during the course of the project. Copies of the signed chain of custody forms are maintained in the project files.

5.3.2 Instrument Calibration

The off-site laboratories calibrate their gamma spectrometers using NIST traceable mixed radionuclide standards in a soil-like matrix. The calibration geometry is identical to the counting geometry for the sample. The efficiency, energy and resolution calibrations are performed annually, when routine checks indicate a calibration problem, or following repairs to a system component. The sample densities were less than the density of the calibration standard.

Consequently, the gammas in the samples will experience greater attenuation than in the calibration standard, which may lead to an overestimation of the activity in the samples. The gamma results were qualified J+ (see Table 5-4) unless they were qualified because of another validation concern.

SC&A, the laboratory performing the alpha spectrometry analyses, calibrated the alpha spectrometers using NIST traceable U standards. The calibration geometries were identical to the sample geometries. In addition, NIST traceable ^{233}U standards were added to the samples for U analyses, as tracers to determine chemical yields. Calibration certificates were provided by the laboratories in the data packages.

5.3.3 Instrument Response

To monitor radiological instrument performance, the off-site laboratories made a series of routine measurements for both the gamma spectrometers and the alpha spectrometers. These checks included peak energy, peak resolution, efficiency and background. The results of these checks were recorded and compared against warning and action limits. Exceedance of a warning limit does not require operator response, but may be used by laboratory quality personnel to identify potential instrument problems. If an action limit is exceeded, the action must be taken and the instrument cannot be used until the problem is corrected and the checks are in control. The results of the routine instrument checks were reviewed as a part of the data validation process. No results were qualified because of any instrument performance problems.

5.3.4 Laboratory Control Sample

A laboratory control sample (LCS) is a sample that is prepared by adding a known aliquot of the analyte of interest, or a surrogate analyte to a volume of laboratory certified reagent grade water. The LCS is analyzed with the associated sample batch using the same analytical procedures and instruments. The LCS results are used as a measure of the accuracy of the analytical methods. In accordance with the Basewide and Radiological Investigation (RI) Quality Assurance Program Plan (QAPP), the analytical laboratories analyzed one LCS with each batch or for every 20 samples. If the LCS recovery is less than 70% or greater than 130%, samples in the analytical batch are typically reanalyzed. In cases where the samples are not reanalyzed, the results may be rejected (R-qualifier) or qualified as estimated (J-qualifier) during the data validation or review process. No sample results were rejected or qualified as estimated on the basis of LCS results.

5.3.5 Method Blank

A method blank (MB) is a sample, typically reagent grade water that is known to be free of the analytes of interest. The MB is analyzed along with samples of an associated analytical batch and receives the same reagents, in the same quantities, and is carried through the same sample preparation (e.g., digestion/extraction) and analysis steps as all other samples. The MB provides assurances that an analyte of interest is not inadvertently added to the samples through a reagent or analytical operation. In accordance with project requirements, the laboratories analyzed one method blank with each analytical batch or for every 20 samples. When an analyte of interest is found in the MB, there is the possibility that the sample results will be biased high. The radiological results were qualified as estimated (J) for all associated samples that have activity concentrations less than 10 times the blank value. When results are qualified as estimated, it is the responsibility of the data user to determine whether the data are acceptable for use. Results were qualified because of potential blank contamination for two target analytes, ^{234}Th (40 samples) and $^{233/234}$U (5 samples). The data for this project that were qualified as estimated because of method blank activity were determined to be useable.

5.3.6 Matrix Spike

A matrix spike is a solution of known concentrations of target analytes spiked into a field sample prior to sample preparation and analysis. The analytical results of the duplicate spiked samples would be used to identify matrix interferences that influence the recovery or measurement of the method analytes.

Matrix spike analyses are not required for gamma spectrometry analyses unless the samples are subjected to chemical separations. Because the samples associated with this project did not require chemical processing, matrix spikes were not performed for the gamma spectrometry.

Laboratories do not typically perform matrix spike analyses for alpha spectrometry, relying instead on the recovery of the tracer added to the samples. Tracer recoveries from 20 to 105% are considered acceptable. The contracts with the laboratories did not specifically require matrix spike analyses and consequently, they were not performed.

5.3.7 Evaluation of Precision

Duplicate samples are typically analyzed to provide a measure of precision of the analytical technique. The project requirements stipulate that one duplicate sample be prepared and analyzed with each analytical batch or for every 20 samples. The laboratories met this requirement for the U analysis. There was insufficient sample to allow duplicate samples to be prepared for gamma spectrometry analyses, so each prepared sample was counted twice. Such an approach is generally considered acceptable because the sample preparation is minimal, typically consisting of drying and homogenizing the sample. Counting the sample twice serves as an effective duplicate analysis because it provides a test of the counting geometry, analyte distribution in the sample, and the ability of the software to consistently identify and quantify gamma peaks. Because of the limited sample quantity, the duplicate counting for the gamma spectrometry is judged to be compliant with the requirements.

The project work plan (CABRERA, 2007b) did not specify that field QC samples be collected. Consequently, there were no field duplicates, field blanks, rinseate blanks or any other field QC samples collected during the project.

If the results of duplicate analyses are not in agreement with those of the original sample, within acceptance criteria, the results for that radionuclide in all samples in the associated batch are qualified as estimated (J). When results are qualified as estimated, it is the responsibility of the data user to determine whether the data are acceptable for use. The data for this project that were qualified as estimated (J) because of duplicate results were determined to be useable.

5.3.8 Detection Limits

Minimum detection concentrations requirements are typically established during the development of project data quality objectives and represent the sensitivity required for the analytical procedures. The MDC is a statistical parameter that represents the uncertainty associated with the measured concentration of an analyte near background concentrations. When practical, MDCs are set well below project-specific action criteria such as regulatory limits or clean-up goals. The MDCs are set sufficiently low to provide assurances that the concentrations of analytes that are "undetectable" will not exceed action limits. The MDCs applicable to this project are listed in Table 2-2 of the Work Plan. Laboratory detection limits are primarily a

function of instrument sensitivity, sample volume, sample matrix, sample geometry, target analyte, and counting time. For gamma spectrometry samples, the MDCs for some radionuclides in a sample can be elevated by the presence of one or more other radionuclides in high concentrations. In such cases, the Compton continuum is elevated, which increases the apparent background contribution to lower energy gamma peaks, making their quantification more difficult.

Samples received the detection limit qualifier (DL) when the MDCs exceeded those defined in Table 2-2 of the Work Plan. For this project, the sensitivity of the analytical procedures was excellent, with only about 1.7% of the results exceeding the established MDCs. For the ^{234}Th analyses, 41 of 1174 results were qualified "DL". The alpha spectrometry analyses all met the detection limit requirements. The spectrometry MDC exceedances were generally a consequence of elevated Compton continua. The data users evaluated the reported MDCs for all data with the DL qualifier. The reported MDCs for those results were sufficiently below project action limits that the data were useable despite the DL qualification.

5.3.9 Method Performance and Summary Assessment

Overall, the performance of the analytical methods is very good. A total of 1,174 samples were collected as a part of the characterization of the impact area at the Schofield Barracks. All 1,174 samples were analyzed for gamma-emitting radionuclides, specifically the target analyte ^{234}Th. Fifty two f the samples were analyzed for by alpha spectrometry for U isotopes. Samples were analyzed for all of the analytes required by the contracts with the laboratories. The data were subjected to data verification and validation. No results were rejected as a result of the data quality assessments.

The J+ qualifier (estimated, possibly biased high) was applied to all of the gamma spectrometry results unless they received qualifiers because of other quality parameters. The J+ qualifier was applied because of density differences between the samples and the calibration geometries. In addition, as discussed in preceding paragraphs, data were qualified as estimated because of method blank activity and duplicate sample results.

A summary of data qualifiers is presented in Table 5-4.

TABLE 5-4: SUMMARY OF QUALIFIERS APPLIED TO TARGET ANALYTES

Analyte	*Qualifier*				*Number of Samples*
	J+[(a)]	*J*[(b)]	*DL*[(c)]	*R*[(d)]	
^{234}Th	1,147	14	41		1,174
$^{233/234}$U		1			52
^{235}U					52
^{238}U					52

Notes:
(a) Result qualified as estimated; possible high bias.
(b) Result qualified as estimated.
(c) Result qualified because of a failure to achieve the required MDC.
(d) Result was qualified as rejected.

6.0 SUMMARY AND CONCLUSIONS

Data was collected from DU affected impact area approximately 428 acres in size. Since the impact areas were used as firing ranges, a UXO visual survey was performed as a safety precaution. Three types of data were collected: (1) GWS data were collected to direct biased sampling, (2) exposure rate measurements were performed to evaluate external radiation exposure, and (3) soil samples were collected and analyzed for DU for use in the BHHRA. No surface water was present during field activities; therefore no water samples were collected.

6.1 Davy Crockett System Debris

Components of the Davy Crockett Weapons system (pistons, tail rings, antennae, fins, and 37mm SRB) were found. Their locations indicate that the M390 practice 155mm version may have been fired from east to west at a high angle of elevation or that the 120mm version was fired from east to west. None of the smaller pistons from the 120mm version were found on this line. The 37mm SRBs were found in Fingers 5 and 6 (see Figure 1-2) which would be close to max range if fired from east to west. Only 6 foot pistons from the 155mm rounds were found. Also, ordnance was discovered and passed by during field activities that should be destroyed.

6.2 Radiological Analysis

Since there is little information available about the natural levels of U present in the environment at Schofield Barracks, a reference area approximately one acre in size was identified approximately 7.5 miles east of the impact areas. Based on the soil sample results, ^{238}U concentrations representative of background are considered to be less than 2.57 pCi/g (1.65 ± 0.918 pCi/g at the 95% confidence level).

A total of 1,226 soil samples were collected at 645 sample locations, including the reference area. Based on the soil sample results, concentrations less than 2.57 picocuries per gram (pCi/g) (1.65 ± 0.918 pCi/g at the 95% confidence level) for ^{238}U were determined to be consistent with background for purposes of characterization. Both systematic and judgmental soil sample data were found to be similar to reference area data, demonstrating the ^{238}U concentrations in soil are at or near background concentrations with approximately three percent of the samples found to contain DU. Sample locations found to contain DU are mostly scattered in fingers 4 and 5 as shown in Figure 6-1. While other sample results may also contain DU, their ^{238}U concentrations

cannot be distinguished from naturally occurring ^{238}U background concentrations. The exposure rate measurements indicate the majority of the SBIA has radiation levels consistent with background levels of radiation, but there are several locations with exposure rates.

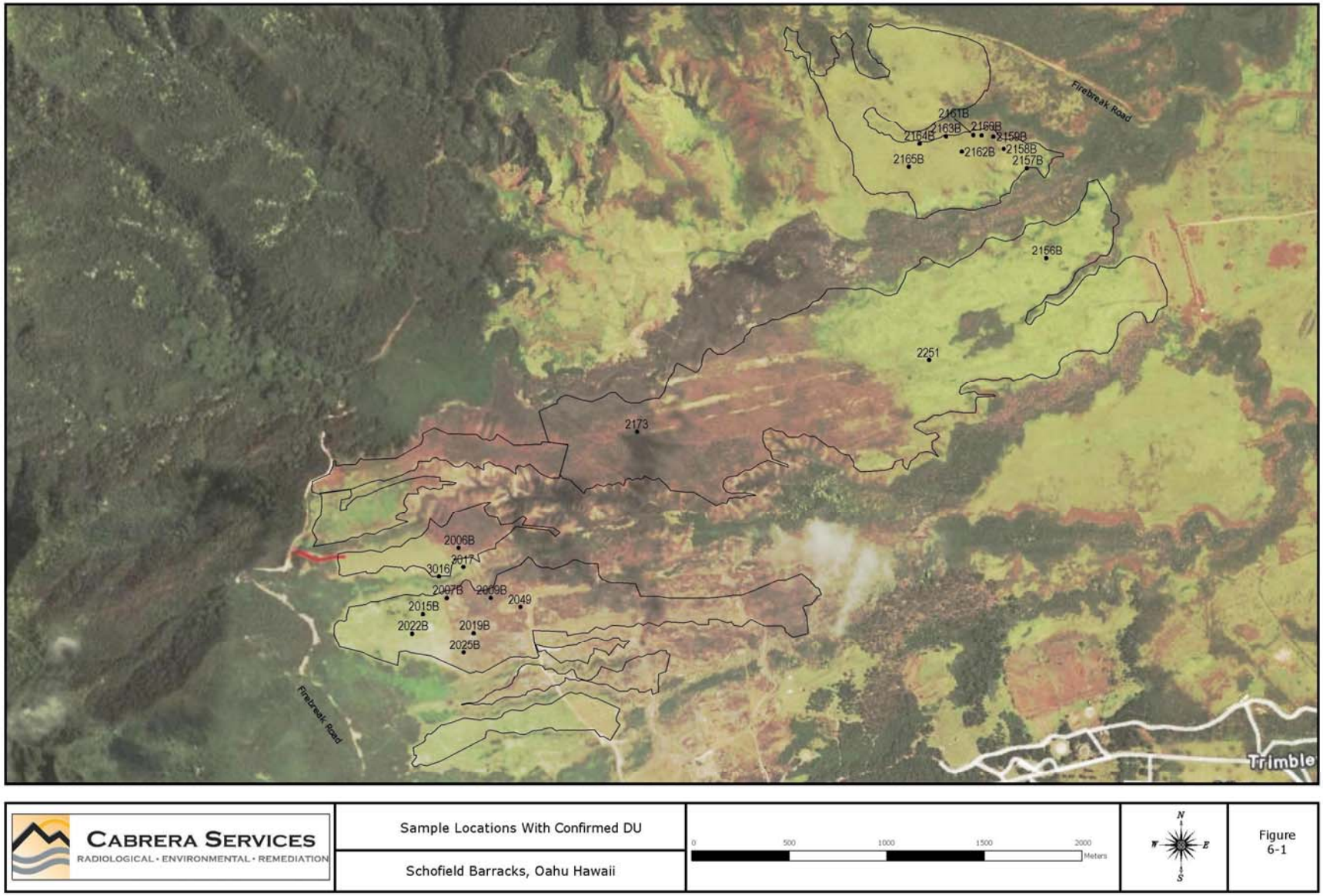


FIGURE 6-1: SAMPLE LOCATIONS WITH CONFIRMED DU

6.3 Data Quality

Survey data were verified to be reliable, appropriately documented, and technically defensible. Specifically, the following conclusions were made:

- The instruments used to collect the data were capable of detecting the radiation types and energies of interest at or below the target MDCs.
- The calibration of the instruments used to collect the data was current and radioactive sources used for calibration were NIST traceable.
- Instrument response was checked before and after instrument use each day.
- The survey methods used to collect the data were appropriate for the media and types of radiation being measured.
- The data consist of qualified measurement results that are representative of the area of interest and collected as prescribed by the survey design.

6.4 Conclusions

The data provide sufficient information on the nature and extent of DU fragments at the SBIA and is suitable for use in the BHHRA. The data were verified to be reliable, appropriately documented, and technically defensible. All soil sample analytical (radiological) results were subjected to data verification/review and soil sample analytical (radiological) results in 10% of the laboratory analytical batches received full data validation.

7.0 REFERENCES

The following documents were consulted in preparing this report.

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APPENDIX A
FIELD SURVEY DATA

This appendix presents the field survey data and corresponding field instrument QC records such as instrument calibration and source certificates, efficiency calculations, and daily response check data. The survey data are reported in electronic data files in Microsoft® Excel and Adobe® Acrobat® .pdf format found electronically on CD.

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APPENDIX B
LABORATORY ANALYTICAL DATA

This appendix presents the results of laboratory analyses performed of the soil samples and associated laboratory QC records. The laboratory analytical results are summarized in electronic datas file in Microsoft® Excel format. The full reports, including QC sample results, are in Adobe® Acrobat® .pdf format. The files are found electronically on CD.

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APPENDIX C:

LABORATORY ANALYTICAL DATA VERIFICATION AND VALIDATION

This appendix presents the laboratory analytical data verification and validation. The information is presented in electronic data files in Microsoft® Excel and Adobe® Acrobat® .pdf format found electronically on CD.

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