

FINAL REPORT

**Radiological Final Status Survey Report
Bomb Throwing Device Site - Soils**

Aberdeen Proving Ground, Aberdeen, MD

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Prepared for:



*U.S. Army Field Support Command
AMSIO-ACE-D Bldg., 350 5th Floor
Rock Island, IL 61299-6000*

Prepared by:



CABRERA SERVICES

*473 Silver Lane
East Hartford, CT 06118*

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Executive Summary

Cabrera Services, Inc. (CABRERA), under contract to the U.S. Army Field Support Command (FSC), performed remedial activities, remedial support surveys, and Final Status Surveys (FSS) for the Bomb Throwing Device (BTD) site at the Aberdeen Proving Ground (APG), Maryland. This document provides the results of post-remediation surveys designed to describe the final radiological status of the site and demonstrates that the site is suitable for release for unrestricted use.

CABRERA conducted survey activities in accordance with the U.S. Nuclear Regulatory Commission (NRC) approved Final Status Survey (FSS) work plan, prepared by CABRERA and included as Appendix B of this report. This report specifically presents the results of the BTD site FSS activities, which were designed in accordance with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NRC 2000) guidance.

The project had several major activities associated with the remediation and FSS including:

- Remediation of soils, debris, and structures within the confines of the BTD site,
- Deconstruction of structures on the BTD site,
- Removal of plate steel for on-site recycling,
- Removal and shipment of remediated soils and debris to Envirocare of Utah,
- Designation of the BTD land areas into MARSSIM Class 1 Survey Units,
- FSS of the BTD site soils and structures, and
- Determine that the dose from residual contamination at the site is not greater than the release criterion for each Survey Unit.

Final status surveys were performed over a land area of approximately 46,000 square meters and on access roads and several support buildings situated on the BTD site. This FSS report addresses only BTD site land areas; surveys performed on structures are addressed under separate cover. The radiological contaminant of concern was depleted uranium (DU). The derived concentration guideline (DCGL_w) for DU was determined to be 220 picocuries per gram (pCi/g) and, based on its isotopic weight ratio, 184 pCi/g for uranium-238 (²³⁸U). An As Low As Reasonably Achievable (ALARA) target and remediation goal of 105 pCi/g DU and 88 pCi/g ²³⁸U was established for this project as described in, "DCGL for BTD Soil Sample Area Addendum", included as Appendix A to this report.

The FSS established twenty-five (25) Class 1 survey units (SU). The final status survey consisted of a 100% gamma walkover survey and soil sample collection and laboratory analysis. Soil sample collection was limited to the surface, from 0 to 15 cm below grade.

All soil sample results are below the ALARA target of 88 pCi/g ^{238}U . The results of the soil samples areas show the highest ^{238}U soil sample result was 80 pCi/g. The FSS gamma walkover survey for the BTB site shows all remediated areas are less than 35,000 cpm or less than the ALARA target of 88 pCi/g ^{238}U . The FSS data indicates that the site is suitable for release for unrestricted use, without regard for former operations with licensed radioactive material.

Table of Contents

Section	Page
EXECUTIVE SUMMARY	i
1. INTRODUCTION	1
1.1 Site History	1
1.2 General Summary of Decommissioning Activities	2
1.3 General Approach to the BTM Remediation and FSS	3
1.4 Radionuclides of Potential Concern (ROPs)	3
2.0 SITE REFERENCE COORDINATE SYSTEM.....	4
3.0 DERIVED CONCENTRATION GUIDELINE LEVEL	5
4.0 FINAL STATUS SURVEY DESIGN	6
4.1 Survey Unit Classification and Delineation.....	6
4.2 Determination of N (Number of Required Measurement Locations)	6
4.3 Systematic Surface Soil Sampling for Sign Test	8
4.4 Gamma Walkover Surveys	9
5.0 RESULTS	10
5.1 Soil Sample Results	10
5.2 Gamma Walkover Survey Results	14
6.0 QUALITY ASSURANCE / QUALITY CONTROL	15
6.1 Field Replicate Sample Analyses.....	15
6.2 Field Instrumentation Quality Control Results	15
6.3 Digital Global Positioning System Requirements	16
7.0 REFERENCES.....	18

List of Tables

Table 3-1. BTM Volumetric DCGL	5
Table 4-1. Survey Units	8

List of Figures

Figure 1. Site Overview	20
Figure 2. Site Survey Units	21
Figure 3. Gamma Walkover Survey Results.....	22
Figure 4. Soil Sample Locations, Northwest Areas	23
Figure 5. Soil Sample Locations, Northwest Areas	24
Figure 6. Soil Sample Locations, Southwest Areas	25
Figure 7. Soil Sample Locations, Southeast Area.....	26

List of Appendices

Appendix A: APG DCGL for Depleted Uranium at the BTM Soil Sample Area, Addendum
Appendix B: Final Status Survey Plan, Bomb Throwing Device (BTD) Site
Appendix C: Soil Sample Analytical Results
Appendix D: Field Replicate Normalized Absolute Difference Results
Appendix E: Instrumentation Calibration Certificates and QC Tables

Glossary of Acronyms and Abbreviations

ALARA	As Low As Reasonably Achievable
APG	Aberdeen Proving Ground
ARL	Army Research Laboratory
ATC	Aberdeen Test Center
BARF	BTD Armor Reclamation Facility
BTD	Bomb Throwing Device
CABRERA	Cabrera Services, Inc.
cm	Centimeters
cpm	Counts Per Minute
DCGL or DCGLw	Derived Concentration Guideline Level
DU	Depleted Uranium
Enclosure	DU Test Enclosure Building
EPA	U.S. Environmental Protection Agency
FSC	U.S. Army Field Support Command
FSS	Final Status Survey
ft	Feet
GPS	Global Positioning System
GWS	Gamma Walkover Survey
HEPA	High Efficiency Particulate Air filter unit
LAB	Liquid Abrasive Blaster
LBGR	Lower Bound of the Grey Region
m	Meters
m ²	Square meters

MARSSIM	Multi-Agency Radiation Survey And Site Investigation Manual
MDC	Minimum Detectable Concentration
μ Rem	Microrem
mrem	Millirem
NAD	Normalized Absolute Difference
NIST	National Institute of Standards and Technology
NRC	U. S. Nuclear Regulatory Commission
Paragon	Paragon Analytics, Inc.
pCi/g	Pico Curies per gram
PSA	Plate Storage Area
QA	Quality Assurance
QC	Quality Control
ROPC	Radionuclides of Potential Concern
SU	Survey Unit
TEDE	Total Effective Dose Equivalent
²³⁴ U	Uranium-234
²³⁵ U	Uranium-235
²³⁸ U	Uranium-238
Wash Racks	Wash Racks #2 and #3
WESTON	Roy F. Weston

1. INTRODUCTION

Cabrera Services, Inc. (CABRERA) is under contract to the United States Army Field Support Command (FSC) to provide support to the Aberdeen Test Center (ATC) at the Aberdeen Proving Ground (APG) in Aberdeen, MD. CABRERA performed facility demolition, remediation, and site wide radiological surveys of the Bomb Throwing Device site (BTD) to support consideration for unrestricted release. The BTD site consists of approximately 46,000 square meters of land on the APG used for the testing of Depleted Uranium (DU) munitions.

This document presents the results of the BTD land area Final Status Survey (FSS) activities, performed in accordance with Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NRC, 2000) guidance. This report addresses only BTD soils of approximately 46,000 square meters. Decommissioning of the BTD Armor Reclamation Facility (BARF), the Liquid Abrasive Blaster (LAB) housed within the BARF, Building 701, DU Test Enclosure Building (Enclosure), Enclosure building high efficiency particulate air filter unit (HEPA), Plate Storage Area (PSA), two concrete pads, Wash Rack Facility #2, Wash Rack Facility #3 (Wash Racks), and two steel storage structures located within the boundary of the BTD site will be addressed under separate cover.

1.1 Site History

Aberdeen Proving Ground, located in Aberdeen, MD, is an active U.S. Army testing and research facility. The Aberdeen Proving Ground (APG) lies along the western shore of the Chesapeake Bay in Harford and Baltimore Counties, MD, approximately 15 miles northeast of Baltimore. The APG covers a total of 72,516 acres (land and water) and consists of two distinct areas: the northern portion of APG, referred to as the Aberdeen Area; and the southern portion of APG, referred to as the Edgewood Area. The Aberdeen Area became a formal military post, designated as the APG, in 1917. Figure 1 shows the location of the BTD site relative to APG and surrounding towns.

The BTD site was used between 1982 and 1993 for the testing of DU munitions. In 1993, the site consisted of the BARF, the Enclosure building, the Enclosure building HEPA, the PSA, Wash Racks 2 and 3, access roads, and several support buildings situated on approximately 46,000 square meters of land. During use, munitions were fired at steel plate and other targets inside the DU Test Enclosure Building. The ATC tested DU munitions utilizing an enclosure with HEPA equipment, used to collect potentially contaminated air exiting the building.

Roy F. Weston (Weston) provided a radiological characterization for the BTD site in 2001 (Weston, 2001). The Weston characterization encompassed the BTD site and divided the site into Class 1, 2, and 3 areas. Soil samples were taken from each area and compared to the NRC soil screening value of 14 pCi/g for uranium-238. Both surface (0-0.25 ft) and subsurface samples (1-1.5 ft) were taken. All values exceeding the soil action level as described in this report were found to exist in the surface soil (0-0.25 ft). An exception was the presence of several subsurface samples taken in the vicinity of the DU Test Enclosure Building that showed levels of soil contamination in excess of the soil action level.

Prior to remediation of the site, approximately 40 tons of DU-contaminated armor plate was located within the Enclosure Building and surrounding grounds. Heavy equipment was used to transport the armor plates between the Enclosure Building and the PSA. As part of the remedial activities and subsequent to the removal of the armor plates, the Test Enclosure Building, the HEPA ventilation system, the footings for the Test Enclosure Building, the "White" Building, the "Rust" Building, and the Sabot Stripper were removed in their entirety.

1.2 General Summary of Decommissioning Activities

The BTB site decommissioning consisted of demolition, soil excavation, and removal of contaminated soil and demolition debris. As physical decommissioning actions were completed, FSSs were performed on both structures and land areas (this report addresses only land area FSSs). Much of the plate steel that was generated during site cleanup and demolition (primarily the Enclosure Building) was transferred to the Army Research Laboratory (ARL) facility, at APG Spesutie Island, for decontamination and recycling; a cost analysis performed by the Army indicated that it was less expensive than offsite disposal to recycle the material and that there was a beneficial reuse in support of APG's mission. Other demolition debris and excavated soil was considered unwanted radioactive material and was shipped via rail to Envirocare of Utah, an NRC licensed disposal facility, for shallow land burial.

- During initial mobilization in February 2003, the CABRERA field crew entered the BARF and dismantled, surveyed and removed the DU armor plate reclamation machine (Liquid Abrasive Blaster) housed within the BARF.
- In May 2003 CABRERA re-mobilized to perform FSS on the inside of the BARF, and demolish the Enclosure building. Most steel plate removed from the Enclosure Building was moved via APG-supplied transportation to the ARL Spesutie Island Facility for decontamination and beneficial reuse. Other steel/debris was containerized in intermodals for future rail shipment to Envirocare of Utah.
- During June 2003, the CABRERA team performed remediation/FSS of Wash Racks 2 and 3, dismantled the two steel vault storage buildings (the 'White' and 'Rust' Buildings) and left the scrap steel piled for transfer to ARL or other use, as instructed by ATC personnel. Concurrent to the dismantling operations and through the month of August 2003, the CABRERA team completed the majority of the GWS, excavated contaminated soils, and stockpiled the remediated soil (approximately 1,200 cubic yards) into a laydown area within Survey Units 16 and 22. CABRERA demobilized at the end of August 2003.
- In February 2004, the CABRERA team returned to the BTB site and performed data collection for survey gaps and accomplished 95% of the remediated soil load out. The soil was packed into intermodal containers, and the intermodals were shipped via rail to Envirocare of Utah.
- In March through June 2004, the remainder of the soil was loaded/shipped to Envirocare for disposal and two concrete pad surfaces were remediated with a steel ball blast/HEPA vacuum system. One concrete pad behind Building 701 was previously covered by the

soil stockpile (in Survey Unit 16) and the other was the pad used to support the Enclosure Building HEPA system, which was removed during the Enclosure Building demolition. Following concrete cleaning, the surfaces were surveyed and land FSSs were performed in Survey Units 16 and 22.

- At the time of this writing, all soil/debris shipped via rail to Envirocare of Utah has been transferred to Envirocare of Utah and the Army is awaiting final disposition documentation.

1.3 General Approach to the BTD Remediation and FSS

The FSS investigations are designed using the approach outlined in MARSSIM (NRC, 2000).

- Development of Derived Concentrations Guideline Levels
- Selection of instrumentation and measurement techniques
- Identification of survey units and classify areas by contamination potential
- Estimation of the number of measurement locations
- Collection of data
- Evaluation of data

1.4 Radionuclides of Potential Concern (ROPCs)

Site Radionuclides of Potential Concern (ROPC) are limited to DU and short-lived progeny. The uranium ratios are based on isotopic uranium weight ratios used for shipments of routine DU waste from APG (BARG, 1995). The activity fractions are calculated from the isotopic weight ratios and the specific activity of each uranium isotope. The result is a Uranium-234 (^{234}U): Uranium-235 (^{235}U): Uranium-238 (^{238}U) ratio of 0.084 : 0.012 : 0.904. During DCGL development, a more conservative isotopic ratio was established to ensure adequate protectiveness. This composition, ^{234}U : ^{235}U : ^{238}U of 0.138 : 0.0234 : 0.839, is used to evaluate FSS data herein. See Appendix A, Section 2.1.3, for details.

2.0 SITE REFERENCE COORDINATE SYSTEM

The site reference coordinate system was designed to ensure sample and measurement locations are spatially identified such that each location is reliably reproducible. The basic unit of the coordinate system is meters. Survey unit grids, site boundaries, and other survey reference points related to land areas are described by northing and easting coordinates, in meters, tied to North American Datum 1983 State Plane Maryland.

3.0 DERIVED CONCENTRATION GUIDELINE LEVEL

The Derived Concentration Guideline Level (DCGL) for the BTM Site soil is 220 pCi/g total DU (resident scenario) and 184 pCi/g ^{238}U . The ALARA target level DCGL has been set at 88 pCi/g ^{238}U . Application of this DCGL will ensure that the potential dose to the average member of the critical group will not exceed 25 millirem (mrem) in any one year over a 1,000-year period.

Table 3-1. BTM Volumetric DCGL

Parameter	Depleted Uranium Activity Concentration (pCi/g)	
	Total Uranium	^{238}U
DCGL	220	184
ALARA Target	105	88

^{238}U derived from the isotopic activity ratio of 83.9%

The DCGL applied to the BTM Site was initially developed using data from the Transonic Range located at APG and was considered equivalent to the Transonic Range DCGL. A document submitted to the NRC (CABRERA), July 2004, "Final U.S. Army Garrison, Aberdeen Proving Ground Derived Uranium Guidelines For Depleted Uranium at the BTM Soil Sample Area Addendum" uses four assumed data sets to compare the DCGL at BTM with that at the Transonic site. These comparisons can be seen in Appendix A of this report. Using the most protective data run, APG-RES3, evaluation showed that based on the RESRAD version 6.22 computer code output, the BTM Site soil DCGL of 220 pCi/g total DU (resident scenario) is essentially equal to the Transonic Range soil DCGL. The ALARA principle of as-low-as-reasonably-achievable is applied to provide assurance that hypothetical doses are limited.

4.0 FINAL STATUS SURVEY DESIGN

4.1 Survey Unit Classification and Delineation

The focus of this FSS is the radiological assessment of surface soil over the entire 46,000 square meters BTD site. The land area associated with the BTD site consists of open grassy areas with one area of standing trees. Originating near the center of the BTD site is a wetland ravine. The ravine is approximately 140 meters in length, averaging up to several meters in width, and often has water covered surfaces. Water depths in the ravine range from several centimeters to approximately 15 centimeters. The CABRERA remediation and FSS conservatively assumes the entire site is a Class 1. As seen in Table 4-1 and in Figure 2, the BTD site was divided into 25 survey units.

4.2 Determination of N (Number of Required Measurement Locations)

The minimum number of measurement locations required is dependent on the distribution of site residual radionuclide concentrations relative to the DCGL and acceptable decision error limits (α and β).

The relative shift describes the relationship of site residual radionuclide concentrations to the DCGL and is calculated using the guidance found in Section 5.5.2.3 of MARSSIM. Since the amount of naturally occurring ^{238}U contaminant present in the soil (majority of DU) is a small fraction of the DCGL it may be considered to be insignificant. The relative shift is calculated as follows:

$$\Delta/\sigma = \frac{\text{DCGL} - \text{LBGR}}{\sigma}$$

Where: DCGL = Derived Concentration Guideline Level

LBGR = concentration at the lower bound of the gray region. The Lower Bound of the Grey Region (LBGR) is the concentration at which the survey unit has an acceptable probability of passing the statistical tests.

σ = an estimate of the standard deviation of the concentration of residual radioactivity in the survey unit (which includes real spatial variability in the concentration as well as the precision of the measurement system).

The ALARA DCGL for surface soil radioactivity is 105 pCi/g DU. The LBGR is estimated at 52.5 pCi/g DU, which is half of the DCGL as suggested by MARSSIM. Using an estimated coefficient of variation of 30 percent and the LBGR as an estimate of the sample mean, a sigma value of 15.8 pCi/g DU is calculated. Using the parameters discussed above, the relative shift is calculated as 3.3.

The number of suggested measurement locations per survey unit is 14 as provided by MARSSIM Table 5.5 (Sign Test) given a relative shift of 3.0 and an error rate for both Type I and Type II errors of five percent (i.e., $\alpha = \beta = 0.05$).

4.2.1 Elevated Measurement Criterion ($DCGL_{EMC}$)

MARSSIM states that, for Class 1 survey units, a dose area factor should be used to evaluate the magnitude by which the concentration within a small area of elevated activity can exceed the DCGL while maintaining compliance with the release criterion. For the purpose of ALARA, the DCGL will be used as the $DCGL_{EMC}$ for soil. This corresponds to an area factor of one. Since the soil MDC_{SCAN} values are sensitive enough to identify a concentration that is less than half of their respective DCGL, it is unlikely that small areas of elevated activity exceeding the release criterion would be missed during scanning.

4.2.2 Soil Sample Locations

Depending on survey unit size, 13 to 17 soil samples were collected within each survey unit for a total of 379 samples. The sample collection depths were 0-15 cm. Measurement locations in the survey units were established using a random start point in a systematic triangular grid. The grid spacing for each survey unit was determined, based on the measured area of the survey unit, using the following equation (Equation 5-7 from MARSSIM).

$$L = \sqrt{\frac{A}{0.866 N}}$$

Where: L = rectangular grid spacing for survey unit

 A = area of survey unit

 N = number measurement locations

Survey unit areas, and the associated grid spacing, (L), using the equation above are presented in Table 4-1. Maps showing the BTD soil sample location identifiers by survey unit based on this spacing are presented in Figures 4 through 7.

Table 4-1. Survey Units

SURVEY UNIT CLASS 1	AREA, m²	NUMBER OF DATA POINTS, n	GRID SPACING, L, m
#1	1235	16	10.1
#2	1596	15	11.5
#3	1558	17	11.3
#4	1835	15	12.3
#5	1944	14	12.7
#6	1995	14	12.8
#7	2000	15	12.8
#8	2000	15	12.8
#9	1461	15	10.5
#10	1652	17	11.7
#11	1899	13	12.5
#12	2000	15	12.8
#13	2000	15	12.8
#14	2000	14	12.8
#15	2000	15	12.8
#16	2188	15	12.8
#17	1588	15	11.5
#18	2000	15	12.8
#19	2000	15	12.8
#20	2000	14	12.6
#21	2050	15	12.7
#22	1968	17	12.8
#23	1303	17	10.4
#24	1993	14	12.8
#25	2009	15	12.8

4.3 Systematic Surface Soil Sampling for Sign Test

Surface soil samples (0 to 15 cm, bgs) were collected in each of the survey units, to provide inputs to the FSS data evaluation. The minimum number of systematic soil sample locations required for this evaluation, in each of the survey units, was established using MARSSIM (NRC 2000) guidance. It was determined that a minimum number of sample locations were required in each of the survey units shown in Table 4-1. No reference area was selected since the natural occurring level of ²³⁸U in the soil, (the primary constituent of DU) is a small fraction of the ALARA DCGL. For purposes of the FSS data evaluation, it is conservatively

assumed that the reference area ^{238}U concentration is zero. Thus the MARSSIM Sign Test is applicable.

Paragon Analytics Laboratory (Paragon) of Ft. Collins, Colorado performed gamma spectroscopy on soil samples. Soil samples were analyzed using gamma spectroscopy (EPA analysis methodology 901.1, Modified). Results are reported in terms of dry weight activity per gram of soil. Appendix C presents the results of the soil samples from the 25 survey units

4.4 Gamma Walkover Surveys

A GWS was performed over 100% of the accessible areas in each of the survey units. The surveys were performed following MARSSIM protocol by walking straight parallel lines over an area while moving the detector in a serpentine motion, approximately 10 cm above the ground surface. The walking speed is maintained at approximately 0.5 meters per second. Survey passes were approximately one meter apart

The purpose of the GWSs was to identify areas of elevated surface radioactivity. These surveys provide position-correlated instantaneous gross gamma count rates at a collection rate of one record per second. This was accomplished using a Global Positioning System (GPS) with sub-meter accuracy coupled to a 3-inch by 3-inch NaI detector and ratemeter/scaler. Calculated detection sensitivity described in the Final Status Survey Plan, Appendix C, for the GWS is approximately 38 pCi/gram for surficially deposited (0 to 15 cm) DU in 50-year equilibrium with its radioactive daughter products. The calculation is based on the methodology described by NUREG-1507 (NRC 1997).

5.0 RESULTS

5.1 Soil Sample Results

As shown in Figure 3 soil survey areas were divided into 25 survey units, all of which were designated as Class 1. A minimum of thirteen soil samples were collected from each SU and sent to Paragon Analytics (a division of Data Chem Laboratories, Inc) for gamma spectroscopy analysis. EPA analysis methodology 901.1 Modified, was utilized for the analysis. Results are reported in terms of dry weight activity per gram of soil. Sample activity for ^{238}U is inferred via the direct measurement of Th-234 decay progeny using gamma spectroscopy analysis. Appendix C presents the results of 379 soil samples from the 25 survey units and ravine area. Samples are shown as sample points 6000 through 6386 in Figures 4 through 7.

The results of the soil samples areas show the highest ^{238}U soil sample result was 80 pCi/g. All soil sample results are below the ALARA target of 88 pCi/g ^{238}U . The soil samples meet FSS release criterion. Statistical results for these 25 survey units are presented below.

5.1.1 SU-1 Results

The results for the 16 samples (Field ID 6000-6015) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 0.88 pCi/g, with a standard deviation of 1.3 pCi/g, and a maximum of 3.8 pCi/g. See Appendix C for the full list of soil sample results and Figure 5 for the location of each sample.

5.1.2 SU-2 Results

The results for the 15 samples (Field ID 6017-6031) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 16.3 pCi/g, with a standard deviation of 25 pCi/g, and a maximum of 80 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.3 SU-3 Results

The results for the 17 samples (Field ID 6032-6048) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 0.95 pCi/g, with a standard deviation of 0.93 pCi/g, and a maximum of 2.5 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.4 SU-4 Results

The results for the 15 samples (Field ID 6050-6064) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.0 pCi/g, with a standard deviation of 1.0 pCi/g, and a maximum of 3.0 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.5 SU-5 Results

The results for the 14 samples (Field ID 6066-6079) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 2.1 pCi/g, with a standard deviation of 3.5 pCi/g, and a maximum of 12 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.6 SU-6 Results

The results for the 14 samples (Field ID 6065, 6080-6092) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 5.4 pCi/g, with a standard deviation of 8.2 pCi/g, and a maximum of 26 pCi/g. See Appendix C for the full list of soil sample results and Figure 5 for the location of each sample.

5.1.7 SU-7 Results

The results for the 15 samples (Field ID 6093-6107) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.5 pCi/g, with a standard deviation of 1.0 pCi/g, and a maximum of 4.3 pCi/g. See Appendix C for the full list of soil sample results and Figure 5 for the location of each sample.

5.1.8 SU-8 Results

The results for the 15 samples (Field ID 6108-6122) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.2 pCi/g, with a standard deviation of 1.4 pCi/g, and a maximum of 3.3 pCi/g. See Appendix C for the full list of soil sample result and Figure 5 for the location of each sample s.

5.1.9 SU-9 Results

The results for the 15 samples (Field ID 6123-6137) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 14 pCi/g, with a standard deviation of 18 pCi/g, and a maximum of 57 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.10 SU-10 Results

The results for the 16 samples (Field ID 6138-6154) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 11 pCi/g, with a standard deviation of 12 pCi/g, and a maximum of 41 pCi/g. See Appendix C for the full list of soil sample results and Figure 7 for the location of each sample.

5.1.11 SU-11 Results

The results for the 13 samples (Field ID 6155-6167) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 3.6 pCi/g, with a standard deviation of 5.1 pCi/g, and a maximum of 18 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

SU-12 Results

The results for the 15 samples (Field ID 6168-6182) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 6.2 pCi/g, with a standard deviation of 9.3 pCi/g, and a maximum of 37 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.12 SU-13 Results

The results for the 15 samples (Field ID 6185-6199) collected and analyzed in this Class 1 SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 4.8 pCi/g, with a standard deviation of 7.6 pCi/g, and a maximum of 26 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.13 SU-14 Results

The results for the 14 samples (Field ID 6200-6213) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 3.3 pCi/g, with a standard deviation of 6.9 pCi/g, and a maximum of 27 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.14 SU-15 Results

The results for the 15 samples (Field ID 6214-6228) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 0.81 pCi/g, with a standard deviation of 0.63 pCi/g, and a maximum of 1.8 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.15 SU-16 Results

The results for the 15 samples (Field ID 6229-6248) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 7.8 pCi/g, with a standard deviation of 9.7 pCi/g, and a maximum of 32 pCi/g. See Appendix C for the full list of soil sample results and Figure 4 for the location of each sample.

5.1.16 SU-17 Results

The results for the 15 samples (Field ID 6249-6263) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.2 pCi/g, with a standard deviation of 1.5 pCi/g, and a maximum of 4.6 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.17 SU-18 Results

The results for the 15 samples (Field ID 6264-6278) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 0.93 pCi/g, with a standard deviation of 0.78 pCi/g, and a maximum of 2.3 pCi/g. See Appendix C

for the full list of soil sample results and Figure 6 for the location of each sample.

SU- 19 Results

The results for the 15 samples (Field ID 6279-6293) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 3.2 pCi/g, with a standard deviation of 7.0 pCi/g, and a maximum of 28 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.19 SU-20 Results

The results for the 14 samples (Field ID 6294-6307) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 2.3 pCi/g, with a standard deviation of 3.1 pCi/g, and a maximum of 12 pCi/g. See Appendix C for the full list of soil sample results and Figure 4 for the location of each sample.

5.1.20 SU-21 Results

The results for the 15 samples (Field ID 6308-6322) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.4 pCi/g, with a standard deviation of 1.1 pCi/g, and a maximum of 3.6 pCi/g. See Appendix C for the full list of soil sample results and Figure 4 for the location of each sample.

5.1.21 SU-22 Results

The results for the 17 samples (Field ID 6323-6339) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 10 pCi/g, with a standard deviation of 13 pCi/g, and a maximum of 47 pCi/g. See Appendix C for the full list of soil sample results and Figure 4 for the location of each sample.

5.1.22 SU-23 Results

The results for the 17 samples (Field ID 6340-6356) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 0.95 pCi/g, with a standard deviation of 1.2 pCi/g, and a maximum of 3.1 pCi/g. See Appendix C for the full list of soil sample results and Figure 6 for the location of each sample.

5.1.23 SU-24 Results

The results for the 13 samples (Field ID 6357-6371) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.7 pCi/g, with a standard deviation of 1.8 pCi/g, and a maximum of 6.9 pCi/g. See Appendix C for the full list of soil sample results and Figure 5 for the location of each sample.

5.1.24 SU-25 Results

The results for the 15 samples (Field ID 6372-6386) collected and analyzed in this SU are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this SU average 1.3 pCi/g,

with a standard deviation of 1.0 pCi/g, and a maximum of 3.3 pCi/g. See Appendix C for the full list of soil sample results and Figure 5 for the location of each sample.

5.1.25 Ravine Results

The results for the 3 samples (Field ID RAVINE1-RAVINE3) collected and analyzed in this location are below the ALARA target of 88 pCi/g for ^{238}U . The ^{238}U results for this location average 1.8 pCi/g, with a standard deviation of 0.95 pCi/g, and a maximum of 2.5 pCi/g. See Appendix C for the full list of soil sample results.

5.2 Gamma Walkover Survey Results

Figure 3 shows the FSS gamma walkover survey results for the BTB site. Individual FSS GWS data was contoured in ESRI ArcView™ using an inverse distance weighting technique. All contoured data was less than 35,000 cpm, the action level established in the workplan. The GWS included approximately 143,000 individual data points spread over the 25 survey units. The upper range of the GWS cpm legend shown on Figure 2 is equivalent to 105 pCi/g DU based on sensitivity calculations.

6.0 QUALITY ASSURANCE / QUALITY CONTROL

6.1 Field Replicate Sample Analyses

CABRERA collected and had the offsite laboratory perform replicate analyses for approximately 10% (39 replicates) of the soil samples. Duplicate analysis entailed repeating the analysis on a split sample and comparing the results statistically. The results are presented in Appendix D. These samples were numbered using a unique identifier to support blind submittal to the laboratory. In accordance with the workplan, field replicate analyses were compared to the initial analytical results by determining a NAD value for each data set by the following equation:

$$NAD = \frac{|Sample - Duplicate|}{\sqrt{\sigma_{Sample}^2 + \sigma_{Duplicate}^2}}$$

Where: Sample = first sample value (original),
 Duplicate = second sample value (duplicate),
 σ_{Sample} = 2σ counting uncertainty of the sample, and,
 $\sigma_{Duplicate}$ = 2σ counting uncertainty of the duplicate

The calculated NAD results are compared to a performance criteria of less than or equal to 1.96. Calculated NAD values less than 1.96 are generally considered acceptable and values greater than 1.96 are investigated for possible discrepancies in analytical precision, or for sources of disagreement with the following assumptions of the test:

- the sample measurement and duplicate or replicate measurement are of the same normally distributed population.
- the standard deviations, σ_{Sample} and $\sigma_{Duplicate}$, represent the true standard deviation of the measured population.

The results, shown in Appendix D, show one of the replicate samples did not pass the NAD value. This, however, is not unexpected due to the inhomogeneity of the DU contaminant. Much of the DU contamination was observed as small fragments in the field.

6.2 Field Instrumentation Quality Control Results

Data collection activities were performed in accordance with written procedures and/or protocols in order to ensure consistent, repeatable results. The Project Engineer ensured that individuals were appropriately trained to use project instrumentation and other equipment, and that instrumentation met the required detection sensitivities.

6.2.1 Calibration Requirements

Radiological instruments were used to scan equipment, personnel, and clothing for radiological contamination and for performance of the GWS. This equipment included Geiger-Mueller detectors, alpha-beta scintillation probes, NaI scintillation detectors, and smear count rate instrumentation. Many of these instruments were used for health and safety purposes and to guide remediation activities, while NaI detectors and GPS units were used directly to generate FSS data and establish FSS sample locations.

Current calibration/maintenance records were kept on site for review and inspection (included in Appendix E). The records include, at a minimum, the following:

- name of the equipment
- equipment identification (model and serial number)
- manufacturer
- date of calibration
- calibration due date

Instrumentation was maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy and precision of the equipment/instruments were maintained. Instruments were calibrated at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using National Institute of Standards and Technology (NIST) traceable sources.

6.2.2 Sodium Iodide (NaI) Gross Gamma Systems

Sodium iodide detectors were used directly to generate FSS data. Ludlum 44-20 NaI detectors coupled to count rate meters and GPS were used to perform gamma walk-over surveys. Instruments were calibrated within one year of the FSS at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable standards.

Instruments were response checked daily for quality control by comparing the instrument response to a designated cesium-137 (^{137}Cs) source. Response checks consisted of a one-minute integrated count of the ^{137}Cs source positioned in a reproducible geometry (i.e., a jig). The acceptance criterion for these instrument response checks is within +/- 20% of the mean response generated using ten initial source checks. Results of daily response checks are provided, along with calibration certificates, as Appendix E to this report.

6.3 Digital Global Positioning System Requirements

6.3.1 Daily Field Checks

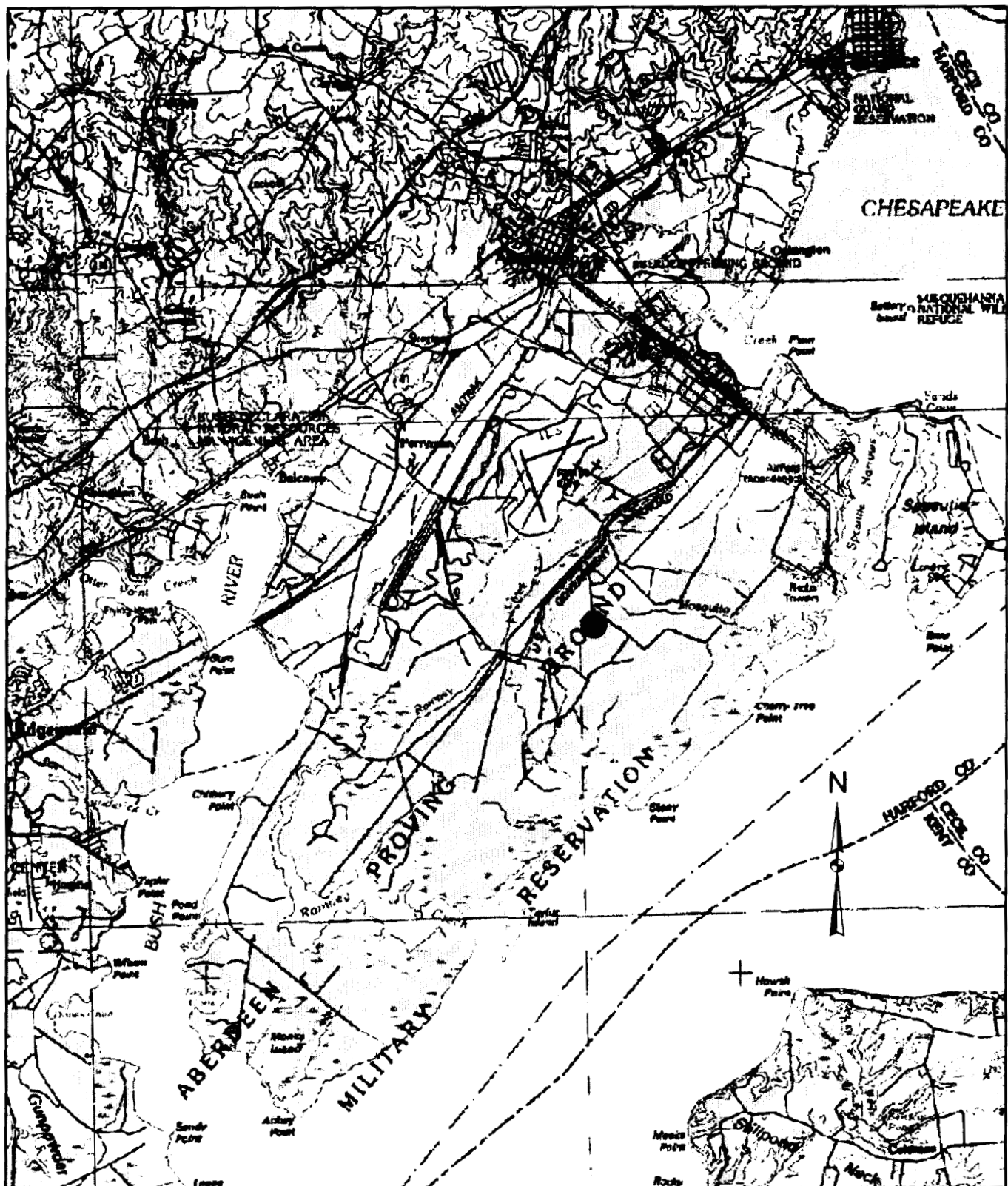
GPS units were used directly to generate FSS data and locate FSS sample locations. GPS point features was collected at the beginning and end of the day at a fixed location established

at the beginning of the FSS. Results of these feature counts were compared to the mean of a series of sequential initial positions. This data was entered into a spreadsheet and examined to ensure less than one-meter variability. Results of daily field checks are provided as Appendix E to this report.

7.0 REFERENCES

- (ANL 1999) ANL Environmental Assessment Department Health Risk Report, *"Derived Uranium Guidelines for the Depleted Uranium Study Area of the Transonic Range, Aberdeen Proving Ground, Maryland"*, M. Picel and S. Kamboj, Argonne National Laboratory, April 1999
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- (ATG 2000) Allied Technology Group, Inc Report, *"APG – DUSA Decommissioning Plan"*, Rev 1, March 24, 2000
- (BARG 1995) Specific Manufacturing Capability Program, *Depleted Uranium Constituents and Decay Heating*, Lockheed, Idaho presentation, dated October 3, 1995.
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- (CABRERA 2000c) CABRERA OP-023, *"Operation of micro-R Meters"*, Rev 0
- (CABRERA 2003) CABRERA Report, *"U.S. Army Garrison, Aberdeen Proving Ground Derived Uranium Guidelines For Depleted Uranium at the BTD Soil Sample Area"*, Contract DAAA09-00-G-0002/039
- (CABRERA 2004) CABRERA Report, *"Final U.S. Army Garrison, Aberdeen Proving Ground Derived Uranium Guidelines For Depleted Uranium at the BTD Soil Sample Area, Addendum"*, Contract DAAA09-00-G-0002/039
- (NRC 1997) NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, December 1997.
- (NRC 1999) *Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination*, Federal Register, Volume 64, Number 234, Tuesday, December 7, 1999, 68396-68396.
- (NRC 2000) NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, Revision 1, August 2000.

FIGURES 1 THROUGH 7



0 900 1,800 3,600 5,400 7,200
Meters

● BTD Site



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Site Overview

BTD - APG

Date: 10-12-04

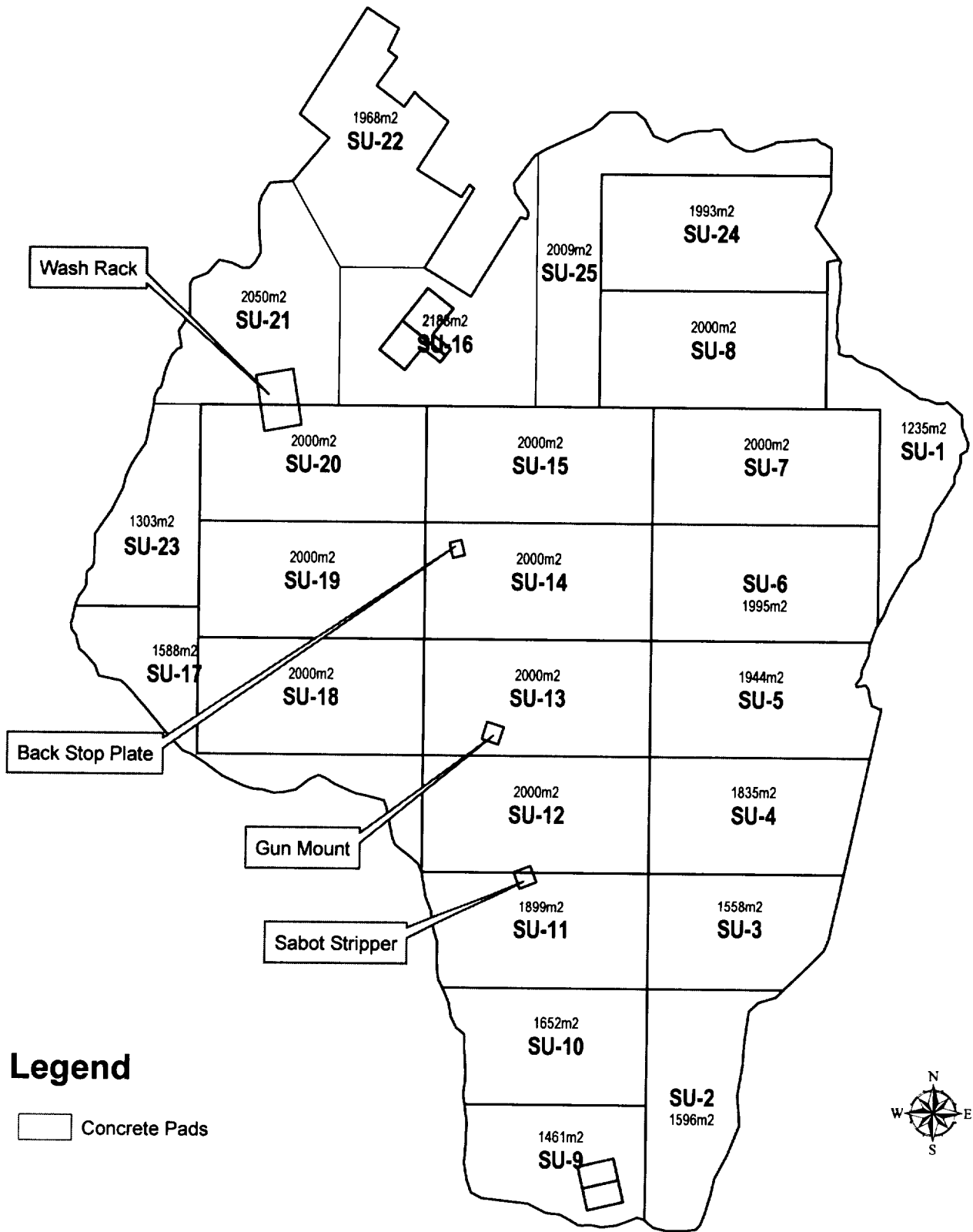
Project #: 01-3030.39

File Name:

Prepared By: JTM

Figure

1



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Site Survey Units

BTD-APG

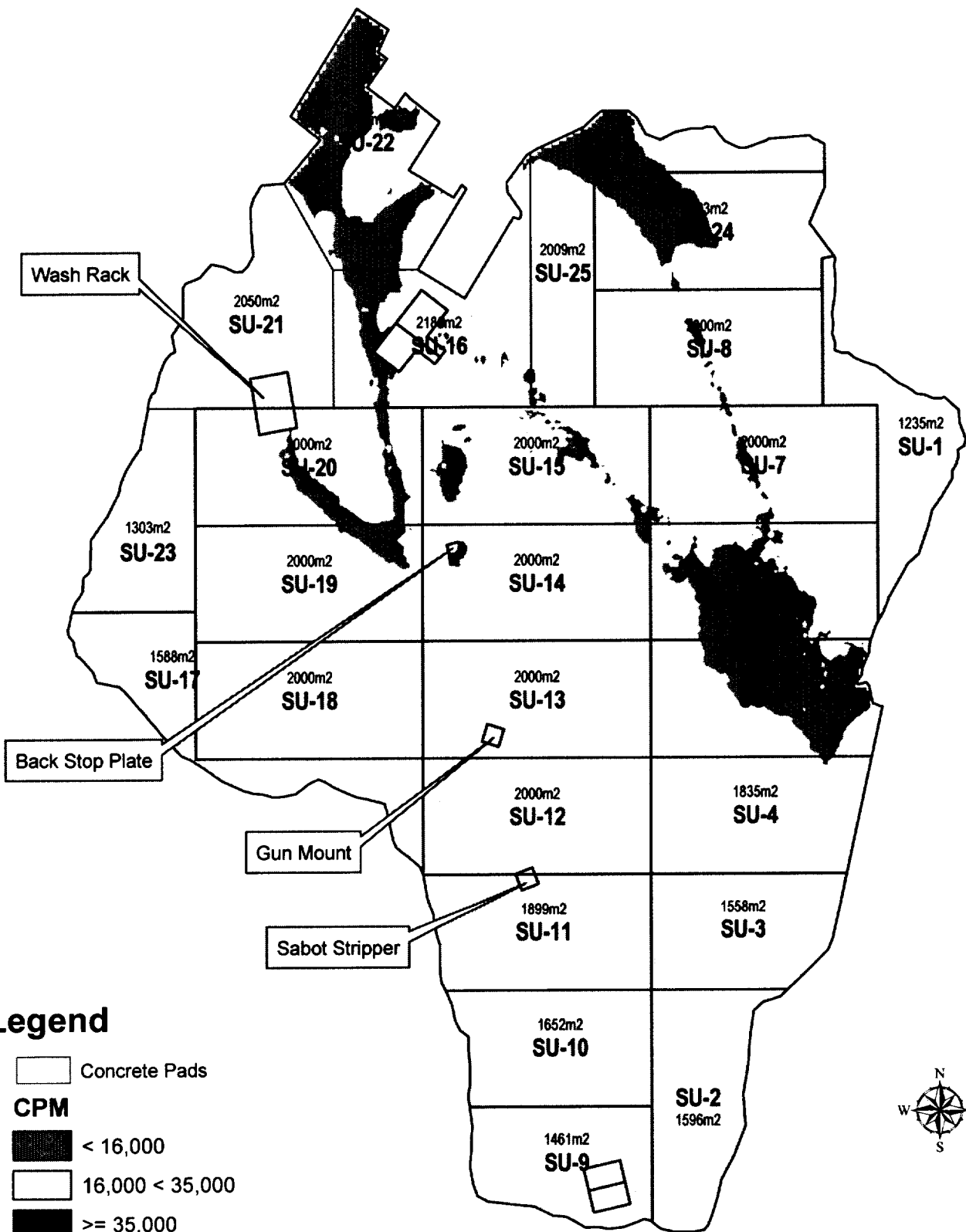
Date: 10-31-04

Project #: 01-3030-39

File Name

Prepared By: JTM

Figure
2



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Gamma Walkover Survey Results

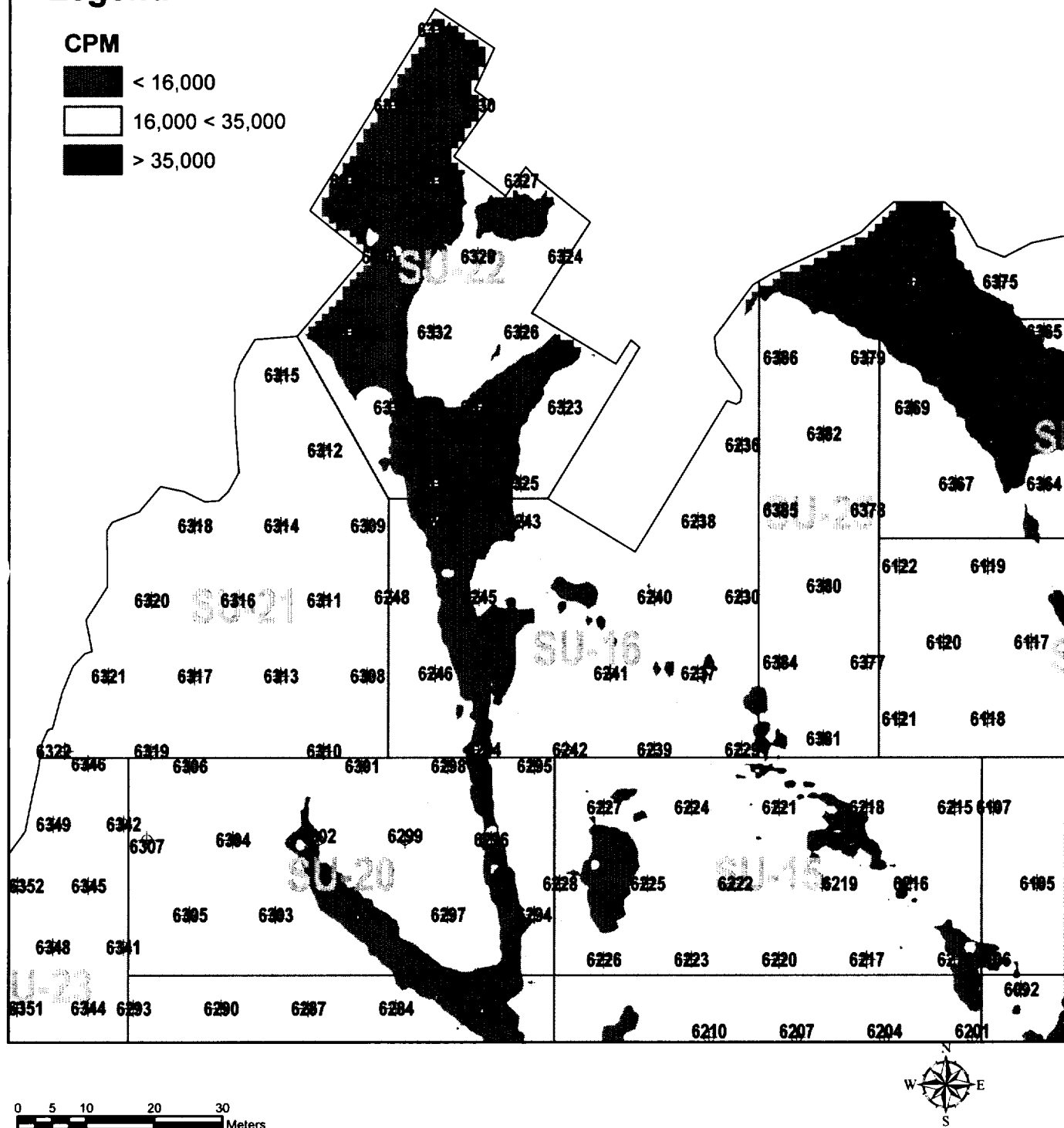
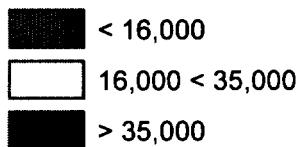
BTD-APG

Date: 10-31-04
 Project #: 01-3030-39
 File Name:
 Prepared By: JTM

Figure
3

Legend

CPM



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Soil Sample Locations
 North West Areas

BTD-APG

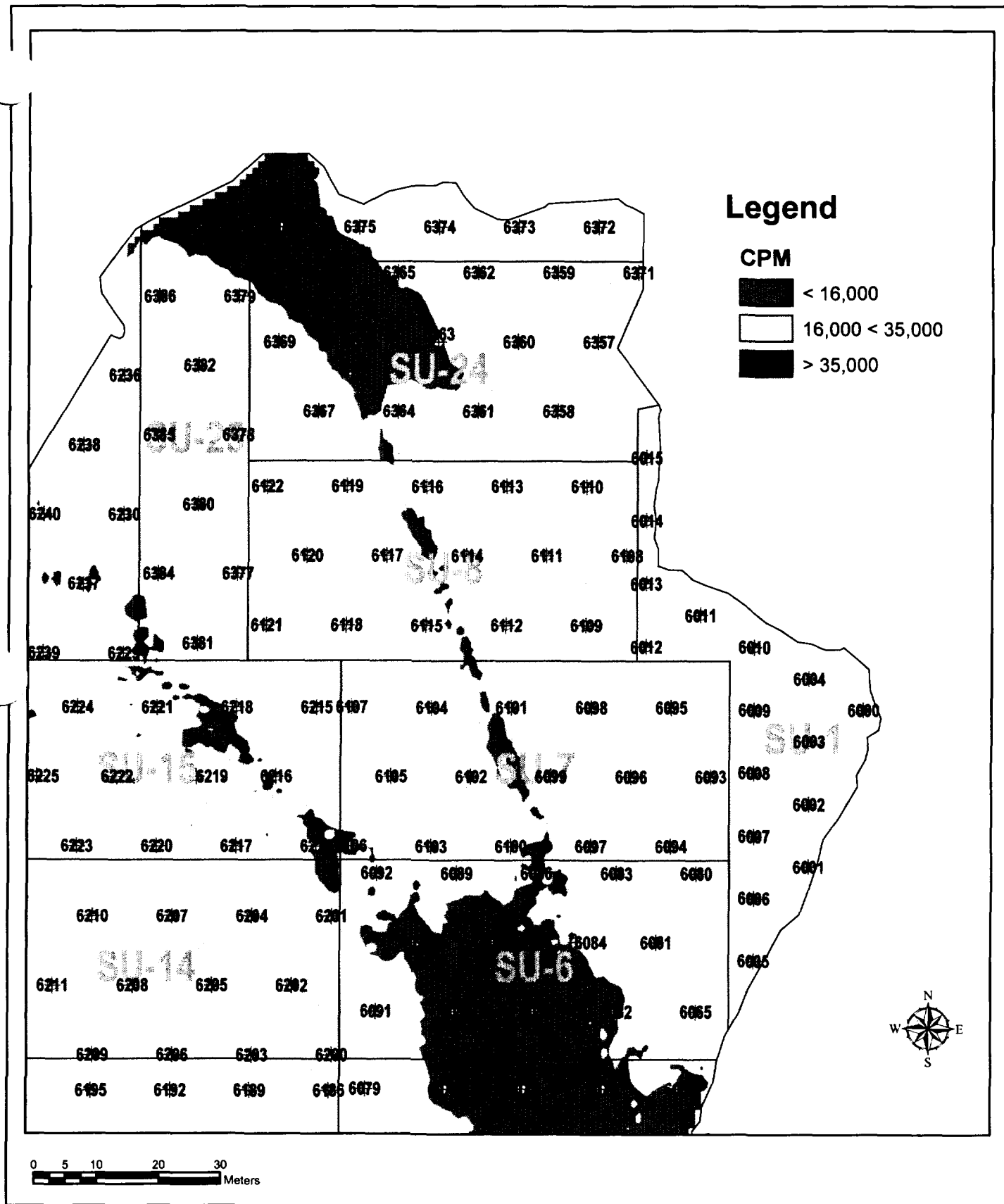
Date: 10-31-04

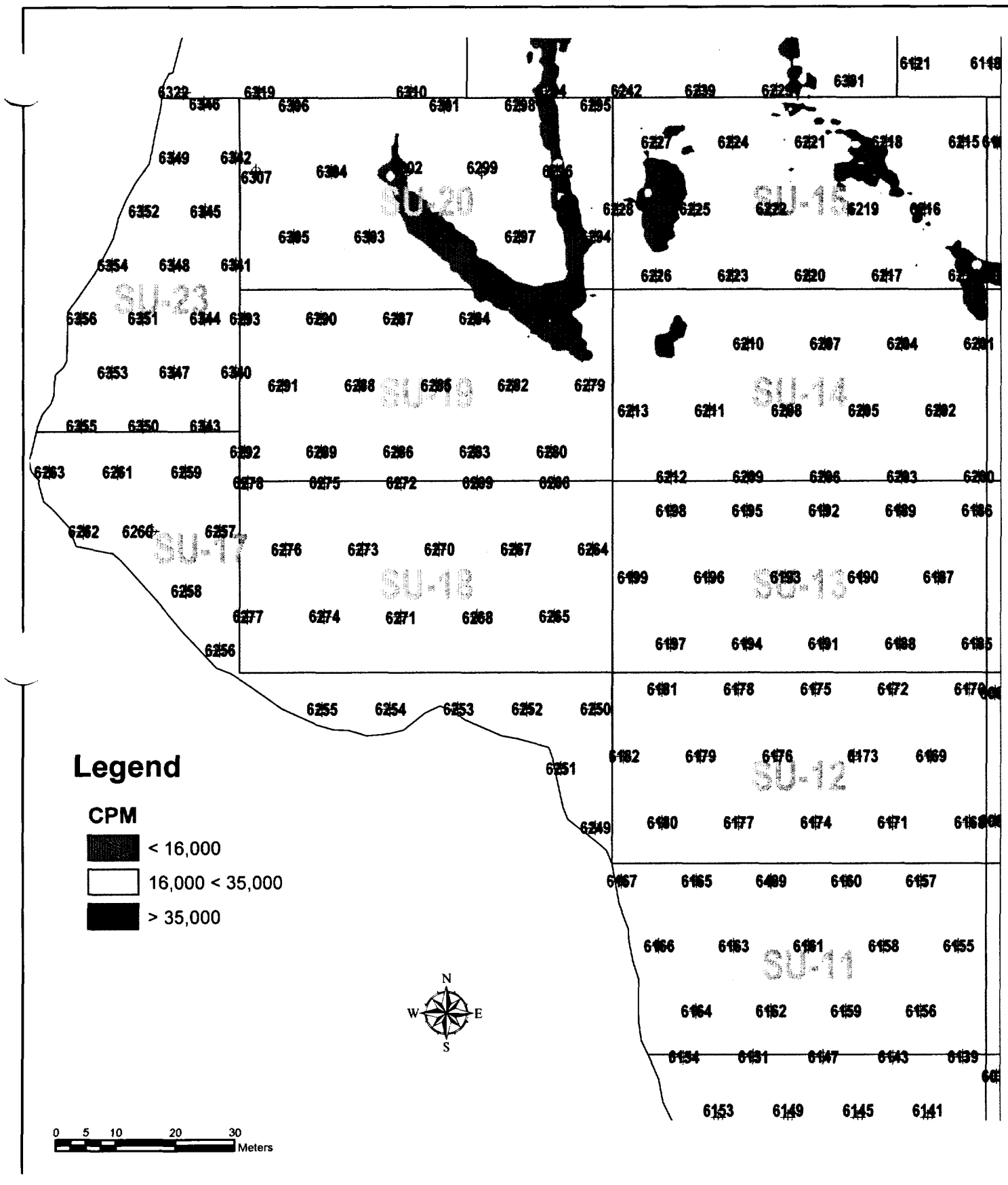
Project #: 01-3030-39

File Name:

Prepared By: JTM

**Figure
 4**





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Soil Sample Locations South West Areas

BTD-APG

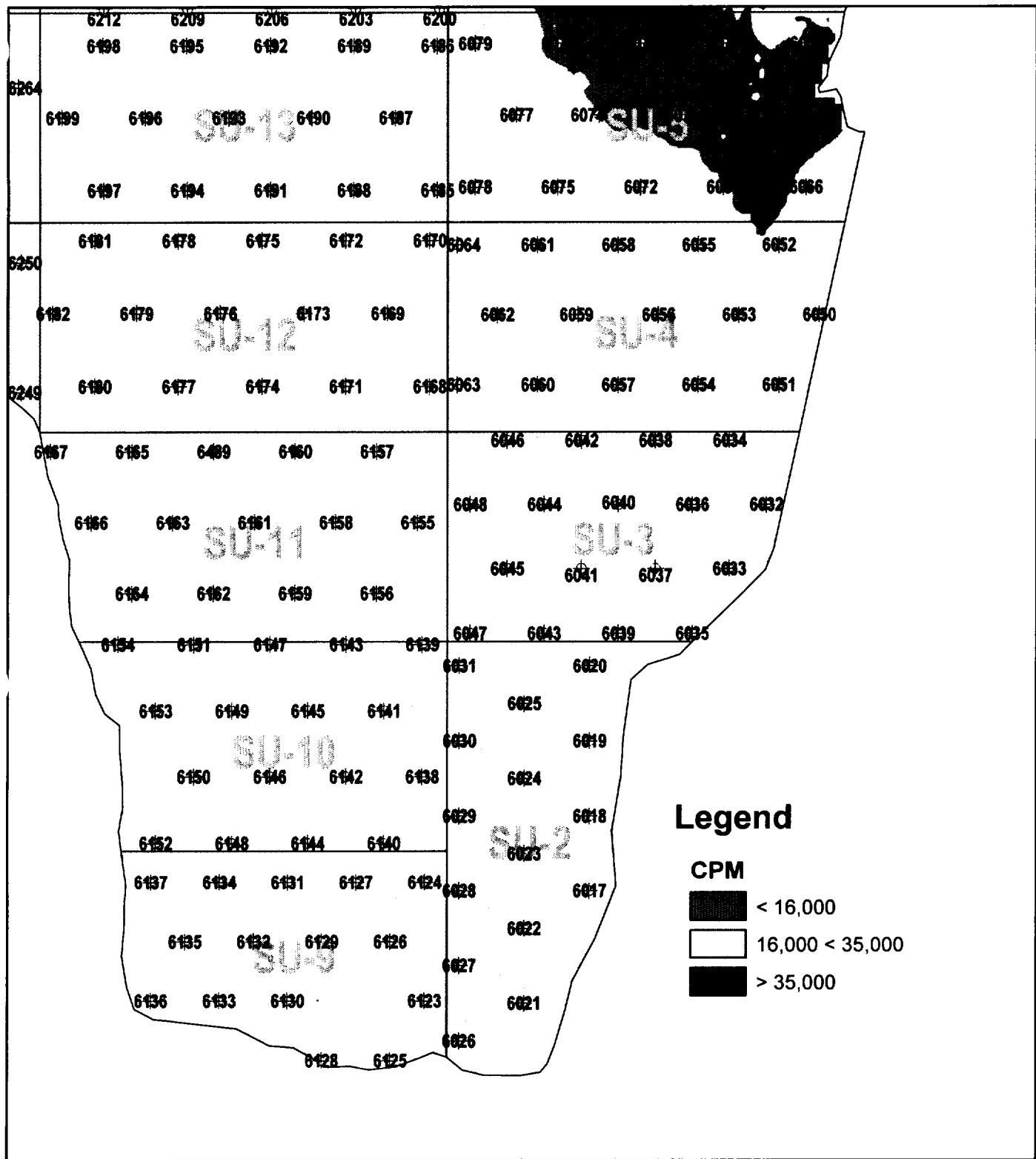
Date: 10-31-04

Project #: 01-3030-39

File Name

Prepared By: JTM

Figure
6



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Soil Sample Locations
South East Areas

BTD-APG

Date: 10-31-04

Project #: 01-3030-39

File Name

Prepared By: JTM

Figure
7

**Appendix A: APG DCGL for Depleted Uranium at
the BTB Soil Sample Area, Addendum**

Restricted Data, Removed

**Appendix B: Final Status Survey Plan, Bomb
Throwing Device (BTD) Site**

Restricted Data, Removed

Appendix C: Soil Sample Analytical Results

**Appendix C
BTD Soil Sample Results**

SU	FieldID	Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
1	6000	U-238	1.6	pCi/g		1.1	1.6	Average 0.88
1	6001	U-238	-1.2	pCi/g	U	1.9	3.4	Std Dev 1.3
1	6002	U-238	3.8	pCi/g	U	4.6	7.5	Max 3.8
1	6003	U-238	0.9	pCi/g	U	2.8	4.8	Min -1.6
1	6004	U-238	0.4	pCi/g	U	2.4	4.2	# Samples 16
1	6005	U-238	0.1	pCi/g	U	1	1.8	
1	6006	U-238	2.3	pCi/g		1.2	1.8	
1	6007	U-238	0.9	pCi/g	U	1.4	2.2	
1	6008	U-238	1.6	pCi/g	U	2.9	4.9	
1	6009	U-238	1.7	pCi/g	U	1.4	2.2	
1	6010	U-238	0.52	pCi/g	U	0.96	1.6	
1	6011	U-238	0.3	pCi/g	U	2.7	4.6	
1	6012	U-238	-0.1	pCi/g	U	2.5	4.4	
1	6013	U-238	1.3	pCi/g	U	1.4	2.2	
1	6014	U-238	1.6	pCi/g	U	1.2	1.8	
1	6015	U-238	-1.6	pCi/g	U	2.7	5	
2	6017	U-238	2.4	pCi/g	U	3	4.9	Average 16
2	6018	U-238	0.9	pCi/g	U	1.2	1.9	Std Dev 25
2	6019	U-238	2.6	pCi/g		1.2	1.6	Max 80
2	6020	U-238	0.75	pCi/g	U	0.73	1.1	Min 0.75
2	6021	U-238	0.8	pCi/g	U	2.4	4	# Samples 15
2	6022	U-238	11.9	pCi/g		3.8	4.3	
2	6023	U-238	13.8	pCi/g		3	2.2	
2	6024	U-238	2.9	pCi/g		1.2	1.6	
2	6025	U-238	1	pCi/g	U	2.4	4.1	
2	6026	U-238	31	pCi/g		10	13	
2	6027	U-238	16.9	pCi/g		5.9	7.4	
2	6028	U-238	68	pCi/g		13	8.3	
2	6029	U-238	80	pCi/g	G	12	8	
2	6030	U-238	9	pCi/g		3.6	4.8	
2	6031	U-238	1.9	pCi/g		1.2	1.9	
3	6032	U-238	2.2	pCi/g	U	2.5	4	Average 0.95
3	6033	U-238	2.5	pCi/g		1.6	2.4	Std Dev 0.93
3	6034	U-238	1.1	pCi/g	U	1.8	3.1	Max 2.5
3	6035	U-238	2.2	pCi/g	U	2.6	4.2	Min -0.4
3	6036	U-238	-0.4	pCi/g	U	3.2	5.7	# Samples 17
3	6037	U-238	0.6	pCi/g	U	2.5	4.3	
3	6038	U-238	0.4	pCi/g	U	2.6	4.5	
3	6039	U-238	0.94	pCi/g	U	0.78	1.2	
3	6040	U-238	2	pCi/g	U	3.2	5.4	
3	6041	U-238	-0.4	pCi/g	U	2.5	4.4	
3	6042	U-238	1.6	pCi/g	U	2.3	3.8	
3	6043	U-238	1	pCi/g	U	1.3	2.1	
3	6044	U-238	0.75	pCi/g	U	0.82	1.3	
3	6045	U-238	0.9	pCi/g	U	1.5	2.5	
3	6046	U-238	-0.2	pCi/g	U	2.6	4.7	
3	6047	U-238	-0.2	pCi/g	U	2.6	4.6	
3	6048	U-238	1.1	pCi/g	U	1.2	1.9	
4	6050	U-238	0.87	pCi/g	U	0.99	1.6	Average 1.0
4	6051	U-238	1.8	pCi/g		1.2	1.8	Std Dev 1.0
4	6052	U-238	0.4	pCi/g	U	1.5	2.5	Max 3
4	6053	U-238	3	pCi/g	U	2.9	4.6	Min -1.1
4	6054	U-238	1.2	pCi/g	U	2.1	3.5	# Samples 15
4	6055	U-238	0.6	pCi/g	U	1.2	2	
4	6056	U-238	0.8	pCi/g	U	1.2	2	
4	6057	U-238	0.83	pCi/g	U	0.94	1.5	
4	6058	U-238	1	pCi/g	U	1.8	3	
4	6059	U-238	2.8	pCi/g	U	2.7	4.3	
4	6060	U-238	-1.1	pCi/g	U	2.5	4.6	
4	6061	U-238	0.4	pCi/g	U	1.1	1.9	
4	6062	U-238	0.3	pCi/g	U	1.4	2.4	
4	6063	U-238	0.6	pCi/g	U	1.2	2.1	
4	6064	U-238	1.8	pCi/g	U	1.8	2.8	

Appendix C
BTD Soil Sample Results

SU	FieldID	*Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
5	6066	U-238	-1.5	pCi/g	U	2	3.9	Average 2.1
5	6067	U-238	0.1	pCi/g	U	0.52	0.91	Std Dev 3.5
5	6068	U-238	2	pCi/g	U	1.8	2.8	Max 12
5	6069	U-238	0.45	pCi/g	U	0.66	1.1	Min -1.5
5	6070	U-238	4.8	pCi/g	U	4.4	6.9	# Samples 14
5	6071	U-238	0.79	pCi/g	U	0.58	0.86	
5	6072	U-238	1.1	pCi/g	U	3.9	6.7	
5	6073	U-238	0.7	pCi/g	U	2.2	3.9	
5	6074	U-238	7.1	pCi/g	U	4.2	6.1	
5	6075	U-238	0.5	pCi/g	U	1.2	2	
5	6076	U-238	11.6	pCi/g	U	3.7	4	
5	6077	U-238	1	pCi/g	U	2.4	4.1	
5	6078	U-238	1.1	pCi/g	U	1.2	1.9	
5	6079	U-238	-0.8	pCi/g	U	3.4	6.3	
6	6065	U-238	0.42	pCi/g	U	0.62	1	Average 5.4
6	6080	U-238	0.9	pCi/g	U	1.1	1.8	Std Dev 8.2
6	6081	U-238	-1.6	pCi/g	U	3.5	6.4	Max 27
6	6082	U-238	4.2	pCi/g	U	3.4	5.1	Min -1.6
6	6083	U-238	0.5	pCi/g	U	2.5	4.3	# Samples 14
6	6084	U-238	0.1	pCi/g	U	2.2	3.9	
6	6085	U-238	0.3	pCi/g	U	1.8	3.2	
6	6086	U-238	2.7	pCi/g	U	1.9	2.9	
6	6087	U-238	26.5	pCi/g	U	7.3	7.4	
6	6088	U-238	16.6	pCi/g	U	6	6.9	
6	6089	U-238	1.1	pCi/g	U	1.2	1.9	
6	6090	U-238	13.4	pCi/g	U	5.2	6.2	
6	6091	U-238	9.6	pCi/g	U	2.8	3.3	
6	6092	U-238	0.4	pCi/g	U	3.4	6.1	
7	6093	U-238	1.3	pCi/g	U	3	5	Average 1.5
7	6094	U-238	0.61	pCi/g	U	0.81	1.3	Std Dev 1.0
7	6095	U-238	1.1	pCi/g	U	1.2	1.9	Max 4.3
7	6096	U-238	2.6	pCi/g	U	2.6	4.1	Min 0.6
7	6097	U-238	4.3	pCi/g	TI	2.7	3.9	# Samples 15
7	6098	U-238	0.9	pCi/g	U	1.2	2	
7	6099	U-238	1.06	pCi/g	U	0.96	1.5	
7	6100	U-238	1.5	pCi/g	U	3.3	5.7	
7	6101	U-238	0.6	pCi/g	U	2.6	4.4	
7	6102	U-238	1	pCi/g	U	1.5	2.4	
7	6103	U-238	0.7	pCi/g	U	1.1	1.8	
7	6104	U-238	1.4	pCi/g	U	2.9	4.8	
7	6105	U-238	1.1	pCi/g	U	1.2	1.9	
7	6106	U-238	2.5	pCi/g	U	1.4	2	
7	6107	U-238	1.1	pCi/g	U	1.7	2.7	
8	6108	U-238	-0.6	pCi/g	U	3.9	7	Average 1.2
8	6109	U-238	1.4	pCi/g	U	1.1	1.6	Std Dev 1.4
8	6110	U-238	0.8	pCi/g	U	1.5	2.5	Max 3.3
8	6111	U-238	2	pCi/g	U	4.2	7.1	Min -2.3
8	6112	U-238	1.4	pCi/g	U	2.7	4.6	# Samples 15
8	6113	U-238	1	pCi/g	U	1.5	2.4	
8	6114	U-238	1.1	pCi/g	U	1.5	2.5	
8	6115	U-238	-2.3	pCi/g	U	3	5.8	
8	6116	U-238	3	pCi/g	U	3.6	5.9	
8	6117	U-238	0.8	pCi/g	U	2.6	4.4	
8	6118	U-238	2.6	pCi/g	U	2.8	4.5	
8	6119	U-238	1.5	pCi/g	U	1.2	1.9	
8	6120	U-238	0.8	pCi/g	U	1	1.7	
8	6121	U-238	0.5	pCi/g	U	1.7	2.9	
8	6122	U-238	3.3	pCi/g	U	3.8	6.1	

**Appendix C
BTD Soil Sample Results**

SU	FieldID	Isotope	Final Result (pCi/g)	Units	Flag¹	TPU (+/-)	MDC	Summary
9	6123	U-238	9.2	pCi/g		5	7.1	Average 14
9	6124	U-238	8	pCi/g		2.2	2.5	Std Dev 18
9	6125	U-238	55.5	pCi/g		9.8	3.1	Max 57
9	6126	U-238	4.3	pCi/g	U	3.2	4.9	Min 0.50
9	6127	U-238	10.2	pCi/g		2.4	2	# Samples 15
9	6128	U-238	57	pCi/g		10	3.2	
9	6129	U-238	11.3	pCi/g		2.8	2.2	
9	6130	U-238	25.1	pCi/g	G	3.7	2.3	
9	6131	U-238	1.7	pCi/g	U	1.5	2.4	
9	6132	U-238	19	pCi/g		3.8	2.5	
9	6133	U-238	0.5	pCi/g	U	1.2	2	
9	6134	U-238	2.4	pCi/g		1.3	1.9	
9	6135	U-238	0.9	pCi/g	U	2.5	4.2	
9	6136	U-238	3.7	pCi/g	U	3	4.7	
9	6137	U-238	4.3	pCi/g		1.8	2.5	
10	6138	U-238	28.6	pCi/g	G	4.1	2.3	Average 11
10	6139	U-238	3.5	pCi/g	U	3.6	5.8	Std Dev 12
10	6140	U-238	8.1	pCi/g		2	1.8	Max 41
10	6141	U-238	5.7	pCi/g		3.1	4.5	Min 0.40
10	6142	U-238	18.6	pCi/g		4.8	4.8	# Samples 17
10	6143	U-238	6.7	pCi/g		2	2.3	
10	6144	U-238	30.4	pCi/g		9.9	12	
10	6145	U-238	1.7	pCi/g	U	1.8	2.9	
10	6146	U-238	6.2	pCi/g	U	5.1	7.9	
10	6147	U-238	17.9	pCi/g		6.1	7.2	
10	6148	U-238	4.8	pCi/g		2.7	3.9	
10	6149	U-238	2.5	pCi/g	U	2.6	4.2	
10	6150	U-238	41.2	pCi/g		8.4	5.4	
10	6151	U-238	15.6	pCi/g		3.1	1.8	
10	6152	U-238	1.1	pCi/g	U	1.1	1.9	
10	6153	U-238	0.8	pCi/g	U	3.3	5.6	
10	6154	U-238	0.4	pCi/g	U	2.2	3.9	
11	6155	U-238	0.9	pCi/g	U	2.5	4.3	Average 3.6
11	6156	U-238	0.6	pCi/g	U	1.2	2.1	Std Dev 5.1
11	6157	U-238	0.6	pCi/g	U	2.5	4.4	Max 18
11	6158	U-238	-1.2	pCi/g	U	2.4	4.3	Min -1.2
11	6159	U-238	3.1	pCi/g		1.3	1.7	# Samples 13
11	6160	U-238	1.8	pCi/g	U	3.9	6.5	
11	6161	U-238	4.5	pCi/g	U	3.1	4.8	
11	6162	U-238	10.7	pCi/g		2.5	2.1	
11	6163	U-238	17.7	pCi/g		5	5.1	
11	6164	U-238	2.8	pCi/g	U	2.8	4.5	
11	6165	U-238	3.2	pCi/g		1.6	2.2	
11	6166	U-238	2.4	pCi/g	U	3.7	6.1	
11	6167	U-238	0.1	pCi/g	U	2.6	4.5	
12	6168	U-238	3	pCi/g	U	2.9	4.5	Average 6.2
12	6169	U-238	1.48	pCi/g		0.97	1.4	Std Dev 9.3
12	6170	U-238	1.3	pCi/g	U	3	5.2	Max 37
12	6171	U-238	1.5	pCi/g	U	1.5	2.4	Min 0.6
12	6172	U-238	3.1	pCi/g	U	3.8	6.2	# Samples 15
12	6173	U-238	1.6	pCi/g	U	1.2	1.9	
12	6174	U-238	5.4	pCi/g		3.3	4.8	
12	6175	U-238	0.6	pCi/g	U	1.3	2.2	
12	6176	U-238	8	pCi/g		2.1	2	
12	6177	U-238	14.6	pCi/g		5.3	6.3	
12	6178	U-238	36.6	pCi/g		8.2	6.7	
12	6179	U-238	11.2	pCi/g		2.8	2.5	
12	6180	U-238	2	pCi/g		1.3	1.9	
12	6181	U-238	1.8	pCi/g	U	1.6	2.5	
12	6182	U-238	1.5	pCi/g	U	3.8	6.5	

Appendix C
BTD Soil Sample Results

SU	FieldID	Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
13	6185	U-238	-0.9	pCi/g	U	3.8	6.9	Average 4.8
13	6186	U-238	0.9	pCi/g	U	2.8	4.8	Std Dev 7.6
13	6187	U-238	1.3	pCi/g	U	1.6	2.6	Max 26
13	6188	U-238	0.39	pCi/g	U	0.89	1.5	Min -0.9
13	6189	U-238	1.3	pCi/g	U	1.1	1.8	# Samples 15
13	6190	U-238	1.1	pCi/g	U	1.5	2.5	
13	6191	U-238	-0.4	pCi/g	U	3.9	7	
13	6192	U-238	1.5	pCi/g	U	2.6	4.4	
13	6193	U-238	1.6	pCi/g		1.1	1.6	
13	6194	U-238	3.4	pCi/g		1.4	1.9	
13	6195	U-238	0.7	pCi/g	U	1.1	1.9	
13	6196	U-238	12.7	pCi/g		4.2	4.9	
13	6197	U-238	25.9	pCi/g		6.5	5.8	
13	6198	U-238	5.6	pCi/g		1.9	2.3	
13	6199	U-238	16.3	pCi/g		3.4	2.2	
14	6200	U-238	1.8	pCi/g	U	1.3	1.9	Average 3.3
14	6201	U-238	1.4	pCi/g	U	1.6	2.5	Std Dev 6.9
14	6202	U-238	1.1	pCi/g	U	2.5	4.3	Max 27
14	6203	U-238	1.2	pCi/g	U	2.2	3.6	Min 0.5
14	6204	U-238	0.82	pCi/g	U	0.93	1.5	# Samples 14
14	6205	U-238	1	pCi/g	U	1.4	2.2	
14	6206	U-238	0.6	pCi/g	U	1.4	2.3	
14	6207	U-238	0.5	pCi/g	U	4.2	7.3	
14	6208	U-238	0.9	pCi/g	U	2.8	4.8	
14	6209	U-238	0.6	pCi/g	U	2.5	4.2	
14	6210	U-238	1.3	pCi/g	U	1.2	1.8	
14	6211	U-238	1.2	pCi/g	U	1.1	1.8	
14	6212	U-238	26.6	pCi/g		5.3	3.8	
14	6213	U-238	7.1	pCi/g		3.7	5.3	
15	6214	U-238	0.5	pCi/g	U	2.4	4.1	Average 0.81
15	6215	U-238	1.1	pCi/g	U	1.1	1.7	Std Dev 0.63
15	6216	U-238	1.7	pCi/g	U	2.3	3.7	Max 1.8
15	6217	U-238	0.2	pCi/g	U	1.1	1.9	Min -0.10
15	6218	U-238	-0.1	pCi/g	U	2.7	4.8	# Samples 15
15	6219	U-238	0.87	pCi/g	U	0.84	1.3	
15	6220	U-238	1.4	pCi/g	U	2.5	4.2	
15	6221	U-238	-0.1	pCi/g	U	3.5	6.3	
15	6222	U-238	1	pCi/g	U	1.1	1.8	
15	6223	U-238	0.78	pCi/g	U	0.99	1.6	
15	6224	U-238	1.6	pCi/g	U	2.3	3.8	
15	6225	U-238	0.7	pCi/g	U	1	1.7	
15	6226	U-238	0.58	pCi/g	U	0.86	1.4	
15	6227	U-238	0.12	pCi/g	U	0.74	1.3	
15	6228	U-238	1.8	pCi/g	U	2.4	3.9	
16	6229	U-238	17.90	pCi/g	G	4.1	5	Average 8.3
16	6230	U-238	1.40	pCi/g	U,G	3.8	6.3	Std Dev 10
16	6236	U-238	1.20	pCi/g	U,G	2.9	4.8	Max 32
16	6237	U-238	28.00	pCi/g	G	5.2	5.6	Min -1.7
16	6238	U-238	0.50	pCi/g	U,G	3.3	5.6	# Samples 15
16	6239	U-238	13.70	pCi/g	G	5.1	7.4	
16	6240	U-238	6.80	pCi/g	LT,G	2.6	3.8	
16	6241	U-238	32.10	pCi/g	G	4.6	2.4	
16	6242	U-238	4.30	pCi/g	U,G	3.3	5.3	
16	6243	U-238	2.10	pCi/g	U,G	2.2	3.6	
16	6244	U-238	5.30	pCi/g	LT,G	2.4	3.7	
16	6245	U-238	3.10	pCi/g	U	2	3.2	
16	6246	U-238	5.50	pCi/g	U,G	3.7	5.8	
16	6247	U-238	4.60	pCi/g	U,G	3.1	4.9	
16	6248	U-238	-1.7	pCi/g	U,G	3.3	5.7	

Appendix C
BTD Soil Sample Results

SU	FieldID	*Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
17	6249	U-238	-0.4	pCi/g	U	3.9	6.9	Average 1.2
17	6250	U-238	4.6	pCi/g	U	3.6	5.6	Std Dev 1.5
17	6251	U-238	3.4	pCi/g	U	3.3	5.2	Max 4.6
17	6252	U-238	1.1	pCi/g	U	2.4	4.1	Min -1.0
17	6253	U-238	0.28	pCi/g	U	0.83	1.4	# Samples 15
17	6254	U-238	1.2	pCi/g	U	1.1	1.7	
17	6255	U-238	1.1	pCi/g	U	1.7	2.8	
17	6256	U-238	0.6	pCi/g	U	3.7	6.5	
17	6257	U-238	1.1	pCi/g	U	2.5	4.3	
17	6258	U-238	2.9	pCi/g	U	2.6	4	
17	6259	U-238	2	pCi/g	U	1	1.4	
17	6260	U-238	1.2	pCi/g	U	1.5	2.4	
17	6261	U-238	-1	pCi/g	U	1.7	3	
17	6262	U-238	0.2	pCi/g	U	3.4	5.8	
17	6263	U-238	-0.5	pCi/g	U	2.8	5	
18	6264	U-238	1.6	pCi/g	U	1.4	2.1	Average 0.9
18	6265	U-238	2.3	pCi/g	U	1.5	2.2	Std Dev 0.8
18	6266	U-238	0.6	pCi/g	U	1.2	2	Max 2.3
18	6267	U-238	0.3	pCi/g	U	2.7	4.7	Min -0.70
18	6268	U-238	0.8	pCi/g	U	1	1.7	# Samples 15
18	6269	U-238	0.9	pCi/g	U	1.2	2	
18	6270	U-238	1.4	pCi/g	U	2.5	4.1	
18	6271	U-238	2.1	pCi/g	U	1.5	2.2	
18	6272	U-238	-0.7	pCi/g	U	3.8	6.8	
18	6273	U-238	-0.1	pCi/g	U	1.7	2.9	
18	6274	U-238	0.62	pCi/g	U	0.81	1.3	
18	6275	U-238	0.8	pCi/g	U	1	1.7	
18	6276	U-238	1.1	pCi/g	U	2.9	4.9	
18	6277	U-238	1.27	pCi/g	U	1	1.5	
18	6278	U-238	0.9	pCi/g	U	1.1	1.9	
19	6279	U-238	28.3	pCi/g	U	5.8	3.1	Average 3.1
19	6280	U-238	-0.7	pCi/g	U	3.7	6.6	Std Dev 7.0
19	6281	U-238	1.5	pCi/g	U	3.2	5.4	Max 28
19	6282	U-238	2.9	pCi/g	U	3.4	5.5	Min -0.7
19	6283	U-238	1.2	pCi/g	U	4	6.9	# Samples 15
19	6284	U-238	3.7	pCi/g	U	3.2	4.9	
19	6285	U-238	1.3	pCi/g	U	1.5	2.4	
19	6286	U-238	1	pCi/g	U	3	5	
19	6287	U-238	1.9	pCi/g	U	2.6	4.2	
19	6288	U-238	0.4	pCi/g	U	1.1	1.9	
19	6289	U-238	1	pCi/g	U	2.7	4.7	
19	6290	U-238	1.8	pCi/g	U	1.5	2.3	
19	6291	U-238	1.1	pCi/g	U	1.1	1.8	
19	6292	U-238	0	pCi/g	U	2.7	4.7	
19	6293	U-238	1.7	pCi/g	U	1.6	2.6	
20	6294	U-238	0.1	pCi/g	U	3.8	6.7	Average 2.3
20	6295	U-238	1.3	pCi/g	U	2.9	4.9	Std Dev 3.1
20	6296	U-238	11.9	pCi/g	U	4.7	6.2	Max 12
20	6297	U-238	1.2	pCi/g	U	4.2	7.1	Min 0.10
20	6298	U-238	6	pCi/g	U	2	2.4	# Samples 14
20	6299	U-238	1.8	pCi/g	U	4.1	7	
20	6300	U-238	3.2	pCi/g	U	2.8	4.4	
20	6301	U-238	1.5	pCi/g	U	3.9	6.7	
20	6302	U-238	0.4	pCi/g	U	4.2	7.4	
20	6303	U-238	0.8	pCi/g	U	2.7	4.7	
20	6304	U-238	1	pCi/g	U	2.9	5	
20	6305	U-238	1	pCi/g	U	1	1.6	
20	6306	U-238	0.3	pCi/g	U	2.5	4.4	
20	6307	U-238	1.9	pCi/g	U	3.1	5.2	

Appendix C
BTD Soil Sample Results

SU	FieldID	*Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
21	6308	U-238	3.6	pCi/g	U	2.8	4.3	Average 1.4
21	6309	U-238	1.4	pCi/g	U	2.9	4.9	Std Dev 1.1
21	6310	U-238	1.1	pCi/g	U	1.1	1.8	Max 3.6
21	6311	U-238	3.3	pCi/g	U	4.6	7.6	Min -0.2
21	6312	U-238	0	pCi/g	U	2.7	4.7	# Samples 15
21	6313	U-238	1.9	pCi/g	U	1.6	2.4	
21	6314	U-238	2	pCi/g	U	1.7	2.7	
21	6315	U-238	2.1	pCi/g	U	1.4	2	
21	6316	U-238	1.2	pCi/g	U	1.2	1.9	
21	6317	U-238	0.9	pCi/g	U	1	1.7	
21	6318	U-238	1.1	pCi/g	U	2.4	3.9	
21	6319	U-238	1.5	pCi/g	U	4.2	7.1	
21	6320	U-238	-0.2	pCi/g	U	2.6	4.7	
21	6321	U-238	0.7	pCi/g	U	1.4	2.4	
21	6322	U-238	0.4	pCi/g	U	1.4	2.4	
22	6323	U-238	0.4	pCi/g	U,G	2.4	4	Average 11
22	6324	U-238	2	pCi/g	U,G	3.6	5.9	Std Dev 13
22	6325	U-238	46.9	pCi/g	G	7.4	6.5	Max 47
22	6326	U-238	9.4	pCi/g	G	4.7	7.1	Min -0.15
22	6327	U-238	27	pCi/g	G	5.5	6.2	# Samples 17
22	6328	U-238	11.6	pCi/g	G	3.4	4.7	
22	6329	U-238	19.9	pCi/g	G	5.8	7.9	
22	6330	U-238	2.2	pCi/g	U,G	2.2	3.6	
22	6331	U-238	4.6	pCi/g	LT,G	1.3	1.6	
22	6332	U-238	6.7	pCi/g	LT,G	3.8	5.9	
22	6333	U-238	6.3	pCi/g	LT	2.3	3.4	
22	6334	U-238	0.02	pCi/g	U,G	0.79	1.38	
22	6335	U-238	28.9	pCi/g	G	4.3	2.6	
22	6336	U-238	7	pCi/g	LT,G	3.9	6.1	
22	6337	U-238	-0.15	pCi/g	U,G	0.54	1.03	
22	6338	U-238	5.6	pCi/g	LT,G	2.9	4.4	
22	6339	U-238	2.8	pCi/g	U,G	2.9	4.6	
23	6340	U-238	-1.9	pCi/g	U	2.6	4.9	Average 1.0
23	6341	U-238	2.1	pCi/g	U	2.7	4.4	Std Dev 1.2
23	6342	U-238	1.46	pCi/g	U	0.95	1.4	Max 3.1
23	6343	U-238	1.2	pCi/g	U	2.4	4	Min -1.9
23	6344	U-238	-1	pCi/g	U	2.7	4.9	# Samples 17
23	6345	U-238	1.9	pCi/g	U	1.6	2.5	
23	6346	U-238	-0.1	pCi/g	U	3	5.2	
23	6347	U-238	0.4	pCi/g	U	3.7	6.5	
23	6348	U-238	1.4	pCi/g	U	2.8	4.6	
23	6349	U-238	-0.1	pCi/g	U	2.8	4.9	
23	6350	U-238	1.2	pCi/g	U	1.3	2.2	
23	6351	U-238	0.8	pCi/g	U	1.1	1.9	
23	6352	U-238	0.9	pCi/g	U	1.3	2.1	
23	6353	U-238	1.1	pCi/g	U	3.1	5.2	
23	6354	U-238	3.1	pCi/g	U	3.3	5.3	
23	6355	U-238	1.2	pCi/g	U	1.2	1.9	
23	6356	U-238	2.5	pCi/g	U	3.3	5.3	
24	6357	U-238	1.5	pCi/g	U	3.9	6.7	Average 1.7
24	6358	U-238	2	pCi/g	U	3.4	5.7	Std Dev 1.8
24	6359	U-238	2.3	pCi/g	U	2.7	4.3	Max 6.9
24	6360	U-238	1.1	pCi/g	U	3.6	6.2	Min -1.2
24	6361	U-238	1.9	pCi/g	U	2.8	4.6	# Samples 14
24	6362	U-238	1.3	pCi/g	U	4	6.9	
24	6363	U-238	-1.2	pCi/g	U	3.2	5.8	
24	6364	U-238	0.6	pCi/g	U	2.9	5.1	
24	6365	U-238	1.5	pCi/g	U	4.1	7	
24	6366	U-238	6.9	pCi/g	TI	4.8	6.8	
24	6367	U-238	2.7	pCi/g	U	2.4	3.7	
24	6368	U-238	0.8	pCi/g	U	1.8	3	
24	6369	U-238	0.8	pCi/g	U	1	1.7	
24	6371	U-238	3.8	pCi/g	LT,G	1.6	2.2	

**Appendix C
BTD Soil Sample Results**

SU	FieldID	*Isotope	Final Result (pCi/g)	Units	Flag ¹	TPU (+/-)	MDC	Summary
25	6372	U-238	3.3	pCi/g	U,G	3.5	5.6	Average 1.4
25	6373	U-238	2.4	pCi/g	U,G	4	6.7	Std Dev 1.0
25	6374	U-238	1.4	pCi/g	U,G	2.8	4.7	Max 3.3
25	6375	U-238	0.9	pCi/g	U,G	0.9	1.43	Min 0
25	6376	U-238	0.15	pCi/g	U,G	0.65	1.14	# Samples 15
25	6377	U-238	2.8	pCi/g	U,G	3.1	5.1	
25	6378	U-238	0.9	pCi/g	U,G	1.1	1.9	
25	6379	U-238	1.1	pCi/g	U,G	3.2	5.5	
25	6380	U-238	1	pCi/g	U,G	1.3	2.2	
25	6381	U-238	1.4	pCi/g	U,G	1.6	2.6	
25	6382	U-238	0	pCi/g	U,G	3	5.4	
25	6383	U-238	0.63	pCi/g	U	0.64	1.03	
25	6384	U-238	0	pCi/g	U,G	3.4	6.1	
25	6385	U-238	2.4	pCi/g	LT,G	1.5	2.3	
25	6386	U-238	2.2	pCi/g	U,G	3.3	5.5	
	RAVINE 1	U-238	2.1	pCi/g	U	4.2	7	Average 1.8
	RAVINE 2	U-238	0.7	pCi/g	U	2.6	4.6	Std Dev 0.95
	RAVINE 3	U-238	2.5	pCi/g	U	3.1	5.1	Max 2.5
								Min 0.70

Average 4.25
Maximum 80

*U-238 value is inferred using Th-234 progeny value assuming secular equilibrium.

¹ U - Result is less than the sample specific MDC or less than the associated TPU

LT - Result is less than the requested MDC, greater than sample specific MDC

G - Sample density differs by more than 15% of the Lab Control Sample

TI - Nuclide identification is tentative

MDC - Minimum detectable concentration

TPU - Total propagated uncertainty

APG-BTD-WAC-1	U-238	402	pCi/g	69	17
APG-BTD-WAC-2	U-238	223	pCi/g	37	5.9

**Appendix D: Field Replicate Normalized Absolute
Difference Results**

Appendix D

Field Replicate Normalized Absolute Difference Results

Sample ID	Paragon Initial Sample Value ²³⁴ Th, pCi/g	Two σ Error of Sample	Paragon Duplicate ^{1,2} Sample Value ²³⁴ Th, pCi/g	Two σ Error of Duplicate	NAD	Fail if NAD > 1.96
6005	1.00E-01	1.00E+00	9.00E-01	1.30E+00	0.49	Pass
6020	7.50E-01	7.30E-01	6.00E-01	3.00E+00	0.05	Pass
6025	1.00E+00	2.40E+00	6.20E-01	9.00E-01	0.15	Pass
6035	2.20E+00	2.60E+00	4.20E-01	7.40E-01	0.66	Pass
6060	-1.10E+00	2.50E+00	8.40E-01	9.70E-01	0.72	Pass
6065	4.20E-01	6.20E-01	-4.00E-01	1.20E+00	0.61	Pass
6070	4.80E+00	4.40E+00	2.70E+00	1.30E+00	0.46	Pass
6075	5.00E-01	1.20E+00	2.60E+00	3.80E+00	0.53	Pass
6105	1.10E+00	1.20E+00	1.20E+00	1.80E+00	0.05	Pass
6115	-2.30E+00	3.00E+00	0.00E+00	2.40E+00	0.60	Pass
6120	8.00E-01	1.00E+00	1.10E+00	1.80E+00	0.15	Pass
6125	5.55E+01	9.80E+00	6.00E+01	1.10E+01	0.31	Pass
6130	1.17E+02	2.00E+01	1.27E+02	2.20E+01	0.34	Pass
6140	8.10E+00	2.00E+00	1.97E+01	5.00E+00	2.15	Fail
6150	4.12E+01	8.40E+00	6.10E+01	1.20E+01	1.35	Pass
6160	1.80E+00	3.90E+00	4.10E+00	2.10E+00	0.52	Pass
6170	1.30E+00	3.00E+00	2.20E+00	2.50E+00	0.23	Pass
6185	-9.00E-01	3.80E+00	-2.10E+00	3.50E+00	0.23	Pass
6190	1.10E+00	1.50E+00	4.00E-01	3.50E+00	0.18	Pass
6200	1.80E+00	1.30E+00	5.00E-01	1.20E+00	0.73	Pass
6215	1.10E+00	1.10E+00	-1.00E-01	2.50E+00	0.44	Pass
6220	1.40E+00	2.50E+00	-4.00E-01	9.60E-01	0.67	Pass
6250	4.60E+00	3.60E+00	1.40E+00	2.60E+00	0.72	Pass
6252	1.10E+00	2.40E+00	1.00E-01	1.00E+00	0.38	Pass
6270	1.40E+00	2.50E+00	-1.60E+00	4.00E+00	0.64	Pass
6275	8.00E-01	1.00E+00	1.40E+00	1.40E+00	0.35	Pass
6280	-7.00E-01	3.70E+00	3.00E+00	4.70E+00	0.62	Pass
6290	1.80E+00	1.50E+00	-1.10E+00	2.80E+00	0.91	Pass
6300	3.20E+00	2.80E+00	1.70E+00	1.10E+00	0.50	Pass
6310	1.10E+00	1.10E+00	8.00E-01	1.70E+00	0.15	Pass
6315	2.10E+00	1.40E+00	3.60E+00	3.20E+00	0.43	Pass
6345	1.90E+00	1.60E+00	5.00E-01	1.10E+00	0.72	Pass
6355	1.20E+00	1.20E+00	6.20E-01	8.40E-01	0.40	Pass
6359	2.30E+00	2.70E+00	2.60E+00	3.20E+00	0.07	Pass
6365	1.50E+00	4.10E+00	-1.20E+00	2.70E+00	0.55	Pass
6230	1.40E+00	3.80E+00	-1.20E+00	3.80E+00	0.48	Pass
6238	5.00E-01	3.30E+00	4.50E+00	3.30E+00	0.86	Pass
6326	9.40E+00	4.70E+00	6.10E+00	4.70E+00	0.50	Pass
6386	2.20E+00	3.30E+00	1.00E+00	3.30E+00	0.26	Pass

¹ Duplicates used for NAD analysis were those split samples obtained in the field.

² The duplicate samples generated via second counts of the same samples at Paragon Labs were not used here, as those apply only to the lab's QAPP.

**Appendix E: Instrumentation Calibration
Certificates and QC Tables**



Designer and Manufacturer
of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.

POST OFFICE BOX 810 PH. 325-235-5494

501 OAK STREET

FAX NO. 325-235-4672

SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER CABRERA SERVICES

ORDER NO. 210994/279195

Mfg. Ludlum Measurements, Inc. Model 2221

Serial No. 97841

Mfg. Ludlum Measurements, Inc. Model 44-20

Serial No. PR183405

Cal. Date 12-Feb-04 Cal Due Date 12-Feb-05 Cal. Interval 1 Year Meterface 202-159

Check mark ☒ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 20 % Alt 710.8 mm Hg

☐ New Instrument ☐ Instrument Received ☒ Within Toler. +10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☒ Mechanical ck. ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Linearity

☒ F/S Resp. ck. ☒ Reset ck. ☒ Window Operation ☒ Geotropism

☒ Audio ck. ☐ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 4.4 VDC

☒ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set 100.0 V Input Sens. 10 mV Det. Oper. 1000 V at 10 mV Threshold Dial Ratio 100 = 10 mV

☒ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 2000 / 2003 V

COMMENTS:

Peak settings
High Voltage: 681V
Threshold dial: 642
Window dial: 40
Window Position: "IN"
Resolution for Cs137: ~9.52 %
Cal'd with a 6' cable.

Gross Counts
1000V
100 (10mv)
n/a
"OUT"
n/a

Model 2221 currently set
for gross counts.
High voltage set with detector
connected.
Firmware: 261027

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1K	400 Kcpm	400	400
X 1K	100 Kcpm	100	100
X 100	40 Kcpm	400	400
X 100	10 Kcpm	100	100
X 10	4 Kcpm	400	400
X 10	1 Kcpm	100	100
X 1	400 cpm	400	400
X 1	100 cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20%

Range(s) Calibrated Electronically

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400 Kcpm	40045(0)	Log Scale	500 Kcpm	500K
	40 Kcpm	4005		50 Kcpm	50K
	4 Kcpm	400		5 Kcpm	5K
	400 cpm	40		500 cpm	500
	40 cpm	4		50 cpm	50

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ 720 ☐ 734 ☐ 1616 ☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☒ Other Am-241 @ ~0.92 µCi

☒ m 500 S/N 132899 ☐ Oscilloscope S/N ☒ Multimeter S/N 82080087

Calibrated By: Josh Boston

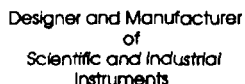
Date 12 Feb 04

Reviewed By: WJ Robison

Date 13 Feb 04

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 11/26/2003

AC Inst. ☐ Passed Dielectric (Hi-Pot) and Continuity Test
Only ☐ Failed:



POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Detector 44-20 Serial No. PR183405

Customer CABRERA SERVICES

Order #. 210994/279195

Counter 2221 Serial No. 97841

Counter Input Sensitivity 10 mV

Count Time 6 seconds Distance Source to Detector Surface

Other

High
Voltage

Background

Isotope Am-241
Size $\approx 0.92 \mu\text{C}$

Isotope
SizeIsotope
SizeIsotope
Size[illegible]

Signature

Josh Boston

Date _____

12 Feb 04



Designer and Manufacturer
of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.

POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER CABRERA SERVICES

ORDER NO. 297073/272297

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 161581
Mfg. Ludlum Measurements, Inc. Model 44-20 Serial No. PR182743
Cal. Date 15-May-03 Cal Due Date 15-May-04 Cal. Interval 1 Year Meterface 202-159

Check mark ☒ applies to applicable instr. and/or detector IAW mfg. spec. T. 71 °F RH 46 % Alt 699.8 mm Hg

☐ New Instrument ☐ Instrument Received ☒ Within Toler. $\pm 10\%$ ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☒ Mechanical ck. ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Linearity
☒ F/S Resp. ck. ☒ Reset ck. ☒ Window Operation ☒ Geotropism
☒ Audio ck. ☐ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 5.0 VDC
☒ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments Threshold Dial Ratio = mV

☒ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 2000 / 2000 V

COMMENTS:

Peak settings Gross Counts Model 2221 currently set
High Voltage: 796 1100 for Gross counts
Threshold dial: 642 100 (10mv) High voltage set with detector
Window dial: 40 n/a connected.
Window Position: "IN" "OUT"
Resolution for Cs137: ≈ 9.8 % n/a Firmware: 26 10 27

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1000	400 Kcpm	400	400
X 1000	100 Kcpm	100	100
X 100	40 Kcpm	400	400
X 100	10 Kcpm	100	100
X 10	4 Kcpm	400	400
X 10	1 Kcpm	100	100
X 1	400 cpm	400	400
X 1	100 cpm	100	100

*Uncertainty within $\pm 10\%$ C.F. within $\pm 20\%$

ALL Range(s) Calibrated Electronically

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout			Log Scale		
400 K cpm	39911(6)	39911(6)	500 K cpm	450 k	450K
40 K cpm	3965(6)	3965(6)	50 K cpm	50 K	50K
4 K cpm	394(6)	394(6)	5 K cpm	5 K	5 K
400 cpm	40(6)	40(6)	500 cpm	500	500
40 cpm	4(6)	4(6)	50 cpm	55	55

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551

☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☐ Other

☒ m 500 S/N 81084 ☐ Oscilloscope S/N ☒ Multimeter S/N 80040300

Calibrated By: Michael J Thomas

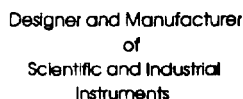
Date 15-May-03

Reviewed By: WJ K. G. 1516

Date 21 May 03

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 04/09/2003

AC Inst. ☐ Passed Dielectric (Hi-Pot) and Continuity Test
Only ☐ Failed:



LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Detector 44-20 Serial No. PR 182743

Customer CABRERA SERVICES

Order #. 297073/272297

Counter 2221 Serial No. 161581

Counter Input Sensitivity 10 mV

Count Time 6 sec

Distance Source to Detector Surface

Other

High
Voltage

Background

Isotope Am 241
Size 20.77u

Isotope
Size

Isotope
SizeIsotope
Size

Signature Michael J Thomas

Date 15-May-03



Designer and Manufacturer
of
Scientific and Industrial
Instruments

Revised June 6 2003 By MTT
CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.

POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER CABRERA SERVICES

ORDER NO. 297073/272297

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 174945

Mfg. Ludlum Measurements, Inc. Model 44-20 Serial No. PR183404

Cal. Date 15-May-03 Cal Due Date 15-May-04 Cal. Interval 1 Year Meterface 202-159

Check mark ☒ applies to applicable instr. and/or detector IAW mfg. spec. T. 71 °F RH 46 % Alt 699.8 mm Hg

☐ New Instrument ☐ Instrument Received ☒ Within Toler. $\pm 10\%$ ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☒ Mechanical ck. ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Linearity

☒ F/S Resp. ck. ☒ Reset ck. ☒ Window Operation ☒ Geotropism

☒ Audio ck. ☐ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 5.0 VDC

☒ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments mV Threshold mV
Dial Ratio =

☒ HV Readout (2 points) Ref./Inst. 500 / 499 V Ref./Inst. 2000 / 1998 V

COMMENTS:

Peak settings	Gross Counts	Model 2221 currently set
High Voltage: <u>793V</u>	<u>1100V</u>	for <u>Gross Counts</u>
Threshold dial: <u>642</u>	<u>100 (10mv)</u>	High voltage set with detector
Window dial: <u>40</u>	<u>n/a</u>	connected.
Window Position: <u>"IN"</u>	<u>"OUT"</u>	
Resolution for Cs137: <u>~ 11 %</u>	<u>n/a</u>	Firmware: <u>261027</u>

Calibrated w/ 39" cable

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1000	400 Kcpm	<u>400</u>	<u>400</u>
X 1000	100 Kcpm	<u>100</u>	<u>100</u>
X 100	40 Kcpm	<u>400</u>	<u>400</u>
X 100	10 Kcpm	<u>100</u>	<u>100</u>
X 10	4 Kcpm	<u>400</u>	<u>400</u>
X 10	1 Kcpm	<u>100</u>	<u>100</u>
X 1	400 cpm	<u>400</u>	<u>400</u>
X 1	100 cpm	<u>100</u>	<u>100</u>

*Uncertainty within $\pm 10\%$ C.F. within $\pm 20\%$

ALL Range(s) Calibrated Electronically

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout			Log Scale		
400 K cpm	<u>39912(6)</u>	<u>39912(6)</u>	500 K cpm	<u>450 K</u>	<u>450K</u>
40 K cpm	<u>3985(6)</u>	<u>3985(6)</u>	50 K cpm	<u>50 K</u>	<u>50K</u>
4 K cpm	<u>399(6)</u>	<u>399(6)</u>	5 K cpm	<u>5 K</u>	<u>5K</u>
400 cpm	<u>40(6)</u>	<u>40(6)</u>	500 cpm	<u>500 c/m</u>	<u>500</u>
40 cpm	<u>4(6)</u>	<u>4(6)</u>	50 cpm	<u>55</u>	<u>55</u>

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551

☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☐ Other

☒ m 500 S/N 81084 ☐ Oscilloscope S/N ☒ Multimeter S/N 80040300

Calibrated By: Michael J. Thomas

Date 15-May-03

Reviewed By: WJ Rubie

Date 21 MAY 03

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 04/09/2003

AC Inst. ☐ Passed Dielectric (Hi-Pot) and Continuity Test
Only ☐ Failed:



Designer and Manufacturer
of
Scientific and Industrial
Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 44-20 Serial No. PR 44-20 ¹⁸³⁴⁰⁴

Customer CABRERA SERVICES

Order #. 297073/272297

Counter 2221 Serial No. 174945

Counter Input Sensitivity 10 mV

Count Time 6 sec

Distance Source to Detector Surface

Other _____

High Voltage _____ Background _____ Isotope Am-241 Isotope _____ Isotope _____ Isotope _____
Size 0.77 uCi Size _____ Size _____ Size _____

800 1826 2242

850 2113 8708

900 2238 12570

950 2297 14052

1000 2148 15941

1050 2156 16246

→ 1100 2231 16438

1150 2219 16332

1200 2206 16435

1250 2162 16574

1300 3275 17805

Signature

Michael J Thomas

Date 15-May-03



Designer and Manufacturer
of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.

POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER CABRERA SERVICES

ORDER NO. 213333/280342

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 176941

Mfg. Ludlum Measurements, Inc. Model 44-20 Serial No. PC 172518

Cal. Date 26-Mar-04 Cal Due Date 26-Mar-05 Cal. Interval 1 Year Meterface 202-159

Check mark ☒ applies to applicable instr. and/or detector IAW mfg. spec. T. 75 °F RH 34 % Alt 705.8 mm Hg

☐ New Instrument Instrument Received ☒ Within Toler. +10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☒ Mechanical ck. ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Linearity

☒ F/S Resp. ck. ☒ Reset ck. ☒ Window Operation ☒ Geotropism

☒ Audio ck. ☐ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 4.4 VDC

☒ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set Comm V Input Sens. Comm mV Det. Oper. Comm V at Comm mV Threshold Dial Ratio 100 = 10 mV

☒ HV Readout (2 points) Ref./Inst. 500 1 492 V Ref./Inst. 2000 1 1972 V

COMMENTS:

Peak Settings:
Peak Voltage: 704 V.

Win: 40

Win. Ps. "IN"

Thshld: 642

Resolution for Cs 137 is 990

Gross Settings:

HV: 1000 V.

Win. Ps: "Out"

Thshld 100 (10 mV)

Instrument currently set for Gross Settings.

Calid using 5' c/c Cable.

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-S in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1K	400 Kcpm	400	400
X 1K	100 Kcpm	100	100
X 100	40 Kcpm	400	400
X 100	10 Kcpm	100	100
X 10	4 Kcpm	400	400
X 10	1 Kcpm	100	100
X 1	400 cpm	400	400
X 1	100 cpm	100	100

*Uncertainty within $\pm 10\%$ C.F. within $\pm 20\%$

Range(s) Calibrated Electronically

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400 Kcpm	400.493 Kcpm	500 Kcpm	500 Kcpm	500 Kcpm
	40 Kcpm	400.36 "	50 Kcpm	50 "	50 "
	4 Kcpm	400.3 "	5 Kcpm	5 "	5 "
	400 cpm	400 cpm	500 cpm	500 cpm	500 cpm
	40 cpm	40 "	50 cpm	50 "	50 "

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ 720 ☐ 734 ☐ 1616 ☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☒ Other Am 241 & 0.77 mCi

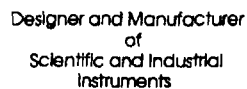
☒ m 500 S/N 54680 ☐ Oscilloscope S/N ☒ Multimeter S/N 69101832

Calibrated By: [Signature] Date 26-Mar-04

Reviewed By: [Signature] Date 27-Mar-04

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 11/26/2003

AC Inst. ☐ Passed Dielectric (Hi-Pot) and Continuity Test
Only ☐ Failed:



LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Detector 44-20 Serial No. Pr 172518

Customer CABRERA SERVICES

Order #. 213333/280342

Counter 2221 Serial No. 176941

Counter Input Sensitivity 10 mV

Count Time 1 min. Source + Background

Distance Source to Detector Surface

Other _____

Signature _____

Date 26-Mar-04



Designer and Manufacturer
of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.

POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER CABRERA SERVICES

ORDER NO. 297073/272297

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 176952

Mfg. Ludlum Measurements, Inc. Model 44-20 Serial No. PR 183465

Cal. Date 20-May-03 Cal Due Date 20-May-04 Cal. Interval 1 Year Meterface 202-159

Check mark ☒ applies to applicable Instr. and/or detector IAW mfg. spec. T. 71 °F RH 46 % Alt 699.8 mm Hg

☐ New Instrument ☐ Instrument Received ☒ Within Toler. +10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☒ Mechanical ck. ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Linearity

☒ F/S Resp. ck. ☒ Reset ck. ☒ Window Operation ☒ Geotropism

☒ Audio ck. ☐ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 5.0 VDC

☒ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments mV Threshold Dial Ratio 100 = 10 mV

☒ HV Readout (2 points) Ref./Inst. 500 / 501 V Ref./Inst. 2000 / V

COMMENTS:

	Peak settings	Gross Counts	Model 2221 currently set
High Voltage:	<u>808v</u>	<u>1150v</u>	for <u>Gross counts</u>
Threshold dial:	<u>642</u>	<u>100 (10mv)</u>	High voltage set with detector
Window dial:	<u>40</u>	<u>n/a</u>	connected.
Window Position:	<u>"IN"</u>	<u>"OUT"</u>	
Resolution for Cs137:	<u>~ 9.4 %</u>	<u>n/a</u>	Firmware: <u>261027</u>

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1000	400 Kcpm	<u>400</u>	<u>400</u>
X 1000	100 Kcpm	<u>100</u>	<u>100</u>
X 100	40 Kcpm	<u>400</u>	<u>400</u>
X 100	10 Kcpm	<u>100</u>	<u>100</u>
X 10	4 Kcpm	<u>400</u>	<u>400</u>
X 10	1 Kcpm	<u>100</u>	<u>100</u>
X 1	400 cpm	<u>400</u>	<u>400</u>
X 1	100 cpm	<u>100</u>	<u>100</u>

*Uncertainty within ± 10% C.F. within ± 20%

ALL Range(s) Calibrated Electronically

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout			Log Scale		
400 K cpm	<u>39842(6)</u>	<u>39842(6)</u>	500 K cpm	<u>450k</u>	<u>450k</u>
40 K cpm	<u>3985(6)</u>	<u>3985(6)</u>	50 K cpm	<u>50k</u>	<u>50k</u>
4 K cpm	<u>398(6)</u>	<u>398(6)</u>	5 K cpm	<u>5k</u>	<u>5k</u>
400 cpm	<u>39(6)</u>	<u>39(6)</u>	500 cpm	<u>500</u>	<u>500</u>
40 cpm	<u>4(6)</u>	<u>4(6)</u>	50 cpm	<u>55</u>	<u>55</u>

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☐ Other ☐ Other

☒ m 500 S/N 81084 ☐ Oscilloscope S/N ☒ Multimeter S/N 80040300

Calibrated By: Michael J. Thomas Date 20-May-03

Reviewed By: W. J. Hulse Date 21 May 03

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FORM C22A 04/09/2003

AC Inst. ☐ Passed Dielectric (Hi-Pot) and Continuity Test
Only ☐ Failed:



LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556 U.S.A.

Detector 44-20 Serial No. PR 183465

Customer CABRERA SERVICES

Order #. 297073/272297

Counter 2221 Serial No. 176952

Counter Input Sensitivity 10 mV

Count Time 6 sec

Distance Source to Detector Surface

Other

Signature

Date 20-May-03

Appendix E

Nal 3 x 3 Daily QC

¹³⁷Cs

Inst.#97841		
QC Daily Source		
Date	Result (cpm)	P/F
6/2/2004	102600	
6/3/2004	101508	
6/4/2004	98130	
6/6/2004	101417	
6/7/2004	102538	
6/8/2004	99,689	
6/9/2004	101618	
6/10/2004	99987	
6/11/2004	101345	
6/14/2004	102129	
6/15/2004	99,870	

Inst.#97841		Source Ser. #	1134
Initial Source Readings		Nuclide	Cs137
Date	Result (cpm)		
6/2/2004	101881		
6/2/2004	105647		
6/2/2004	105033		
6/2/2004	105319		
6/2/2004	103080		
6/2/2004	98471		
6/2/2004	99281		
6/2/2004	101530		
6/2/2004	101991		
6/2/2004	102746		
	Average		
	102498		

Appendix E

Nal 3 x 3 Daily QC
¹³⁷Cs

Inst.#161581		
QC Daily Source		
Date	Result (cpm)	P/F
5/29/2003	52107	
5/29/2003	52218	
5/30/2003	52715	
5/30/2003	52610	
7/14/2003	56432	
7/14/2003	56589	
7/15/2003	56369	
7/15/2003	55989	
7/16/2003	56502	
7/16/2003	56308	
7/17/2003	56183	
7/17/2003	56346	
7/18/2003	56535	
7/18/2003	56134	
7/21/2003	56991	
7/21/2003	56374	
7/22/2003	57173	
7/22/2003	56989	
7/23/2003	56674	
7/23/2003	55758	
7/24/2003	56336	
7/24/2003	56682	
7/29/2003	56888	
7/29/2003	55867	
7/30/2003	56536	
7/30/2003	56124	
7/31/2003	56704	
7/31/2003	55769	
8/7/2003	56569	
8/7/2003	57219	
8/8/2003	55714	
8/8/2003	56421	
8/11/2003	56184	
8/11/2003	56579	
8/12/2003	56701	
8/12/2003	56467	
8/13/2003	56795	
8/13/2003	56352	
8/14/2003	56725	
8/14/2003	55763	

Inst.#161581		Source Ser. #	1127
Initial Source Readings		Nuclide	Cs-137
Date	Result (cpm)		
5/29/2003	51998		
5/29/2003	51972		
5/29/2003	51622		
5/29/2003	51816		
5/29/2003	51914		
5/29/2003	51573		
5/29/2003	51773		
5/29/2003	51565		
5/29/2003	51530		
5/29/2003	52168		
	Average		
	51793		

Appendix E

Nal 3 x 3 Daily QC

⁵⁷Co

Inst.#174945(c)		
QC Daily Source		
Date	Result (cpm)	P/F
8/14/2003	53889	
8/14/2003	53805	
8/15/2003	53683	
8/15/2003	54004	
8/18/2003	54415	
8/18/2003	49909	
8/19/2003	49504	
8/19/2003	51204	
8/20/2003	53895	
8/20/2003	53729	
8/21/2003	53788	
8/21/2003	53896	
8/22/2003	54034	
8/22/2003	53689	
8/25/2003	53367	
8/25/2003	54021	
8/26/2003	53922	
8/26/2003	53749	
8/27/2003	54029	
8/27/2003	53872	

Inst.#174945(c)		Source Ser. #	1127
Initial Source Readings		Nuclide	137Cs
Date	Result (cpm)		
8/14/2003	53257		
8/14/2003	53690		
8/14/2003	53872		
8/14/2003	53483		
8/14/2003	53849		
8/14/2003	53625		
8/14/2003	53771		
8/14/2003	53778		
8/14/2003	54023		
8/14/2003	53714		
	Average		
	53706		

Appendix E

Nal 3 X 3 Daily QC

¹³⁷Cs

Inst.#176941		
QC Daily Source		
Date	Result (cpm)	P/F
6/2/2004	99684	
6/3/2004	99421	
6/4/2004	100200	
6/6/2004	96903	
6/7/2004	98567	
6/8/2004	100195	
6/9/2004	101318	
6/10/2004	96,543	
6/11/2004	99,145	
6/14/2004	100,487	
6/15/2004	101213	

Inst.#176941		Source Ser. #	1134
Initial Source Readings		Nuclide	Cs137
Date	Result (cpm)		
6/2/2004	101072		
6/2/2004	101141		
6/2/2004	100498		
6/2/2004	101092		
6/2/2004	101254		
6/2/2004	103880		
6/2/2004	101204		
6/2/2004	101281		
6/2/2004	101332		
6/2/2004	102313		
	Average		
	101507		

Appendix E

Nal 3 x 3 Daily QC

¹³⁷Cs

Inst.#176952		
QC Daily Source		
Date	Result (cpm)	P/F
5/29/2003	51776	
5/29/2003	52653	
5/30/2003	51893	
5/30/2003	51759	
7/14/2003	55906	
7/14/2003	56387	
7/15/2003	56256	
7/15/2003	56108	
7/16/2003	55958	
7/16/2003	56327	
8/12/2003	57703	
8/12/2003	56289	
8/13/2003	57003	
8/13/2003	57426	
8/14/2003	56102	
8/14/2003	56727	
8/15/2003	56092	
8/15/2003	56847	
8/18/2003	52803	
8/18/2003	52559	
8/19/2003	52554	
8/19/2003	52786	
8/20/2003	55999	
8/20/2003	56358	
8/25/2003	56723	
8/27/2003	52998	
8/27/2003	54784	

Inst.#176952		Source Ser. #	1127
Initial Source Readings		Nuclide	Cs-137
Date	Result (cpm)		
5/29/2003	51994		
5/29/2003	51435		
5/29/2003	52117		
5/29/2003	52172		
5/29/2003	51774		
5/29/2003	51834		
5/29/2003	51587		
5/29/2003	51760		
5/29/2003	51529		
5/29/2003	51909		
	Average		
	51811		

Appendix E

GPS Daily QC

Trimble #0224022532, Antenna # 0220161434, Handset # 0220159474					
QC Daily GPS (Meters)					
Date	AM/PM	Northing (meters)	Easting (meters)	Offset (Meters)	P/F
7/16/2003	AM	197000.7	472402.7	0.34	
7/16/2003	PM	197000.5	472402.5	0.58	
8/13/2003	AM	197001.1	472402.3	0.59	
8/13/2003	PM	197001.4	472402.5	0.57	
8/14/2003	AM	197001.153	472403.009	0.21	
8/14/2003	PM	197000.909	472403.037	0.17	
8/15/2003	AM	197000.771	472402.300	0.63	
8/15/2003	PM	197000.900	472403.100	0.23	
8/18/2003	AM	197000.200	472402.999	0.79	
8/18/2003	PM	197001.609	472403.010	0.64	
8/19/2003	AM	197001.477	472402.686	0.53	
8/19/2003	PM	197000.500	472402.437	0.66	
8/27/2003	AM	197001.790	472402.300	1.00	
8/27/2003	PM	197001.323	472403.156	0.43	

Trimble #0224022532, Antenna # 0220161434, Handset # 0220159474		
Initial GPS Readings (meters)		
Date	Northing	Easting
5/21/2003	197001.2	472402.8
5/21/2003	197001.1	472402.9
5/21/2003	197000.9	472402.9
5/21/2003	197000.8	472402.9
5/21/2003	197000.9	472403.0
5/21/2003	197001.0	472403.0
5/21/2003	197001.1	472403.0
5/21/2003	197001.0	472402.9
5/21/2003	197001.0	472402.8
5/21/2003	197000.9	472402.8
Average		
	197000.985	472402.891

max	197001.2	472403.0
Min	197000.8	472402.8
Delta	0.38900	0.22400
Stdev	0.119791667	0.083658221
Max offset (meters)	0.448884172	

GPS Daily QC

Trimble #0224022532, Handset # 0220207988		
Initial GPS Readings (meters)		
Date	Northing	Easting
5/21/2003	197002.1	472403.1
5/21/2003	197002.1	472403.1
5/21/2003	197001.8	472403.0
5/21/2003	197001.4	472402.9
5/21/2003	197001.6	472403.0
5/21/2003	197001.3	472402.8
5/21/2003	197001.3	472402.8
5/21/2003	197001.2	472403.1
5/21/2003	197001.1	472403.2
5/21/2003	197000.8	472403.2
	Average	
	197001.480	472402.986
max	197002.1	472403.2
Min	197000.8	472402.8
Delta	1.30300	0.39300
Stdev	0.416975797	0.132697561
Max offset (meters)	1.360976855	

Appendix E

GPS Daily QC

Trimble #0224015316 Antenna # 0220161434, Handset # 0220159474					
QC Daily GPS (Meters)					
Date	AM/PM	Northing (meters)	Easting (meters)	Offset (Meters)	P/F
7/16/2003	AM	197000.853	472402.537	0.78	
7/16/2003	PM	197001.385	472402.577	0.44	
7/17/2003	AM	197001.215	472402.557	0.52	
7/17/2003	PM	197000.910	472402.620	0.69	
7/18/2003	AM	197000.610	472402.506	1.00	
7/18/2003	PM	197000.826	472402.753	0.70	
7/21/2003	AM	197001.373	472402.699	0.32	
7/21/2003	PM	197000.546	472402.940	0.94	
7/22/2003	AM	197000.523	472402.961	0.96	
7/24/2003	AM	197001.204	472403.002	0.28	
7/29/2003	AM	197001.375	472402.722	0.30	
7/29/2003	PM	197000.168	472402.657	1.36	
7/29/2003	PM	197001.473	472402.238	0.77	
7/30/2003	AM	197000.324	472402.857	1.16	
7/30/2003	PM	197000.790	472402.567	0.82	
7/31/2003	AM	197000.579	472402.559	1.00	
8/7/2003	AM	197000.602	472402.666	0.94	
8/7/2003	PM	197000.903	472402.876	0.59	
8/8/2003	AM	197000.927	472402.671	0.65	
8/8/2003	PM	197000.889	472402.782	0.63	
8/11/2003	AM	197000.947	472402.904	0.54	
8/11/2003	PM	197001.014	472402.419	0.75	
8/12/2003	AM	197001.042	472402.536	0.64	
8/12/2003	PM	197000.884	472402.880	0.61	
8/13/2003	AM	197000.719	472402.815	0.78	
8/13/2003	PM	197001.229	472402.700	0.39	
8/14/2003	AM	197000.960	472403.193	0.55	
8/14/2003	PM	197000.743	472403.031	0.74	
8/15/2003	AM	197000.882	472402.889	0.61	
8/15/2003	PM	197001.168	472402.657	0.47	
8/18/2003	AM	197001.579	472402.559	0.46	
8/18/2003	PM	197001.014	472402.419	0.75	
8/19/2003	AM	197001.324	472402.857	0.21	
8/19/2003	PM	197000.889	472402.782	0.63	
8/20/2003	AM	197000.764	472402.533	0.86	
8/20/2003	PM	197000.899	472402.561	0.73	
8/25/2003	AM	197001.144	472402.351	0.73	
8/25/2003	PM	197001.719	472402.340	0.71	
8/26/2003	AM	197000.537	472402.809	0.96	
8/26/2003	PM	197001.825	472402.505	0.61	
8/27/2003	AM	197000.724	472403.100	0.76	
8/27/2003	PM	197001.825	472403.000	0.35	

Trimble #0224015316 Antenna # 0220161434, Handset # 0220159474		
Initial GPS Readings (meters)		
Date	Northing	Easting
5/21/2003	197002.1	472403.1
5/21/2003	197002.1	472403.1
5/21/2003	197001.8	472403.0
5/21/2003	197001.4	472402.9
5/21/2003	197001.6	472403.0
5/21/2003	197001.3	472402.8
5/21/2003	197001.3	472402.8
5/21/2003	197001.2	472403.1
5/21/2003	197001.1	472403.2
5/21/2003	197000.8	472403.2
Average		
	197001.480	472403.004

max	197002.1	472403.2
Min	197000.8	472402.8
Delta	1.30300	0.39900
Stdev	0.416975797	0.137207707
Max offset (meters)	1.362721542	

GPS Daily QC

Trimble #0224048724, Antenna # 0220280009, Handset # 0220151861		
Initial GPS Readings (meters)		
Date	Northing	Easting
6/2/2004	197043.000	472450.000
6/2/2004	197043.000	472450.000
6/2/2004	197042.0	472449.0
6/2/2004	197042.0	472450.000
6/2/2004	197042.0	472449.0
6/2/2004	197043.000	472450.000
6/2/2004	197043.000	472450.000
6/2/2004	197042.0	472450.000
6/2/2004	197042.0	472449.0
6/2/2004	197042.0	472449.0
	Average	
	197042.400	472449.600
max	197043.0	472450.0
Min	197042.0	472449.0
Delta	1.00000	1.00000
Stdev	0.516400406	0.516387273
Max offset (meters)	1.414213562	