FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

COMPARABILITY OF IN-SITU GAMMA SPECTROMETRY AND LABORATORY DATA

INFORMATION ONLY

JULY 1997

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

20701-RP-0001
REV. 0

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EXECUTIVE SUMMARY

Two comparability studies (Part A and Part B) were conducted to determine if the use of in-situ gamma spectrometry (hereafter referred to as HPGe) is applicable to soil remediation at the Fernald Environmental Management Project (FEMP). The Part A Comparability Study determined if certification decisions at the certification unit (CU) level based upon HPGe measurements are comparable to certification decisions based upon laboratory analysis of discrete, physical samples. The Part B Comparability Study assessed the comparability of HPGe data with laboratory data generated from the analysis of physical samples and established values, limits, or acceptance criteria for key parameters affecting the quality of HPGe data. In addition, this report incorporates the results of a companion comparability study conducted by DOE's Environmental Measurements Laboratory (EML) within the same time frame as the FEMP Part B Comparability Study.

The Part A study was performed in conjunction with the collection of physical samples taken during the Area 1 Phase I (A1PI) certification process. Twelve HPGe measurements and twelve physical samples were taken at random locations within a given CU. Statistical tests were performed to determine if the upper 95% confidence limit of the mean for each data set (HPGe and physical samples) within a CU exceeded the final remediation level (FRL) for a given analyte. The results of the statistical evaluations for 33 CUs were identical for HPGe and laboratory data for total uranium, cesium-137, and (with the exception of a single CU) radium-226 in that all 33 CUs could be certified as having passed the FRL criteria. The statistical evaluation of data sets also showed that occasionally, some CUs had 95% upper confidence limits exceeding the FRL for thorium-232, based upon laboratory gamma spectrometry, when no such situations occurred based upon HPGe measurements or analysis of samples by laboratory alpha spectrometry data. The issue of laboratory alpha vs. laboratory gamma spectrometry data is addressed in the A1PI Certification Report (Section 4.1.2).

For the Part B study, HPGe measurements and physical samples were taken from ten areas selected based upon the degree of total uranium contamination and upon the estimated heterogeneity of uranium concentrations within each area. The weighted averages (weighted to simulate the probability of gamma rays emitted from a certain volume of soil actually being detected by the HPGe system) of analyte concentrations or activities were compared to the HPGe measurements. Results demonstrated that total uranium, thorium-232, cesium-137, and potassium-40 data generated by HPGe are very

comparable to data generated by laboratory analysis. This conclusion is based upon the overall closeness in agreement of HPGe and laboratory data as well as upon a high degree of linear correlation between HPGe and laboratory data.

Radium-226 activity levels less than 1.0 pCi/g as measured by HPGe are generally close to, but higher than, activities measured by alpha spectrometry for laboratory samples. However, for activities greater than 3.0 pCi/g, HPGe measurements are significantly lower than laboratory alpha spectrometry measurements. Reasons for this are not obvious; they could include radon-222 disequilibrium in surface soils (HPGe measures the gamma rays produced by the decay of radon daughters to quantify radium-226), differences due to instrumental techniques, or a combination of both. A study is underway to investigate reasons for these differences.

The EML Comparability Study results both reinforce and augment those of the FEMP Comparability Study. The good comparability EML demonstrated between laboratory gamma spectrometry and HPGe measurements reinforces the good comparability obtained by the FEMP Part B Comparability Study between laboratory alpha and HPGe measurements. The fact that good agreement was obtained by two different laboratory analytical methods and HPGe strengthens the validity of HPGe methodology. This validity is further demonstrated by good agreement between HPGe measurements made by two different scientific parties, EML and the FEMP. Finally, the laboratory measurements on soil cores made by EML to ascertain depth profiles of certain analytes verifies an assumption made of a uniform source distribution with depth. In this regard, HPGe data based upon the relative attenuation in soil of low energy and high energy gamma photons also indicate a uniform source distribution with depth.

Results from the Part B study have also been used to determine the capability of HPGe to generate data of known quality and usefulness. Quality assurance/quality control (QA/QC) elements and acceptance criteria have been proposed for two data quality levels, Analytical Support Level (ASL) D and ASL B, for HPGe data. The QA/QC elements include accuracy, precision of duplicates, minimum detectable concentration, detector calibration, instrument performance checks, and robustness to environmental conditions. Total uranium, thorium-232, and cesium-137 (potassium-40 is not a contaminant of concern at the FEMP, and thus the data quality level concept is irrelevant to it) meet all acceptance criteria for ASL D and ASL B. Radium-226 currently does not meet the accuracy criterion for either

ASL D or ASL B. The use of control charts in conjunction with repeat measurements at a designated field quality control station is being used to assess the influence of environmental variables or method robustness. To date, data indicate that analytes, except for radium-226, are affected by soil drying and re-moisturization; this effect does not appear to be large. Conversely, radium-226 measurements are significantly influenced by environmental conditions relating to radon emanation from soils.

With respect to implementation, remediation processes requiring ASL D or ASL B data quality levels may utilize HPGe measurements for total uranium, thorium-232, and cesium-137. However, additional data must be acquired to demonstrate comparability of HPGe and laboratory data for total uranium at concentrations near or exceeding 1000 ppm before HPGe can be reliably used for waste acceptance criteria (WAC) activities. This study is underway. HPGe may be used for applications requiring screening data (ASL A) for radium-226, but not for activities requiring radium-226 data at ASL D or ASL B. As stated above, additional method development work is underway for radium-226 in order to understand environmental influences on radium-226 to resolve differences between HPGe and laboratory data. When this work is completed, radium-226 may be used at higher data quality levels in the future. Memorandum reports will be issued as addenda to this report when those studies are concluded.

A report on the applicability of Radiation Tracking System (RTRAK) measurements to soil remediation was also issued in July 1997. The RTRAK is a mobile, in-situ, gamma ray measuring instrument employing sodium iodide detectors. The RTRAK and HPGe systems complement each other. The RTRAK is able to provide 100% coverage of an area. Its precision and detection limits are sufficient to determine the degree of homogeneity and heterogeneity of a given area with respect to total uranium, thorium-232 and radium-226. Its data output is amenable to mapping. These features make the RTRAK ideal as a front-end survey tool to help focus and guide the use of HPGe.

The strengths of the HPGe are its ability to accurately quantify a variety of isotopes, its high degree of energy resolution (which makes interferences less likely), and its ability to average data over either large or small areas, thereby minimizing sample error and maximizing data representativeness. These characteristics dictate the HPGe's use in providing high-quality data for certification/verification activities relative to remediation of soils for hot spots, WAC exceedances, and FRLs. Additionally,

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LIST OF ACRONYMS AND ABBREVIATIONS

ARAR	applicable or relevant and appropriate requirement
ASL	analytical support level
ASTM	American Society of Testing and Materials
CLP	Contract Laboratory Program
COC	constituent of concern
Cs	cesium
CU	certification unit
DOE	US Department of Energy
DQO	data quality objective
EML	Environmental Measurements Laboratory
EPA	US Environmental Protection Agency
eV	electron volt
FCS	field quality control station
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
FRL	final remediation level
FS	feasibility study
ft	feet
FWHM	full width half maximum
GPS	global positioning system
HPGe	in-situ gamma spectrometry
K	potassium
keV	kiloelectron volt
m	meter
MDA	minimum detectable activity
MDC	minimum detectable concentration
NaI	sodium iodide
OSDF	on-site disposal facility
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
ppm	parts per million
QA/QC	quality assurance/quality control
Ra	radium
RAWP	remedial action work plan
RI	remedial investigation
ROD	record of decision
RPD	relative percent difference or deviation
RTRAK	Radiation Tracking System
SCQ	Sitewide CERCLA Quality Assurance Project Plan
SD	standard deviation
SED	Sitewide Environmental Database
SOW	statement of work
Th	thorium
U	uranium
UCL	upper confidence level
UMTRA	Uranium Mill Tailings Remedial Action Project

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USID	Uranium in Soils Integrated Demonstration
WAC	waste acceptance criteria

1.0 INTRODUCTION, BACKGROUND AND OBJECTIVES

1.1 INTRODUCTION

The Fernald Environmental Management Project (FEMP) is currently conducting remediation of site soils that are radiologically and chemically contaminated. Soil contamination originated from airborne dispersion of both fugitive and stack emissions throughout the production period (1952-1989), as well as from direct releases due to spills and site disposal practices. While a number of chemicals and radionuclides contribute to site risk, contaminated soil volume, and areal extent of contamination, only five species contribute large cumulative percentages. These five species, called "primary contaminants of concern" (COCs) in this report, include total uranium, thorium-232, thorium-228, radium-226 and radium-228.

A number of factors support the use of field-deployable instruments to detect activities of these five COCs in a "real-time" mode, as opposed to traditional sampling and laboratory analysis protocols. These include:

- The ability to rapidly determine the presence or absence of contaminants above Final Remediation Levels (FRLs) in soils to better control the quantity of material to be excavated;
- Attainment of analytical data in "real-time" to avoid potential delays in construction activities;
- Rapid determination of whether or not excavated soil volumes meet waste acceptance criteria (WAC);
- Rapid identification and confirmation of areas of elevated contamination and potential "hot spots;" and
- Use of techniques which can allow rapid determination of radiological COCs for final certification.

This report sets the stage for the utilization of a field-deployable analytical technique: in-situ gamma spectrometry (HPGe), to be used routinely in soil excavation and certification activities. The report describes the results of two studies, Comparability Studies Parts A and B, completed to ensure that data generated by HPGe are comparable to laboratory data, are of known quality, and that the decisions made based upon HPGe data are the same as those based upon established laboratory methods.

Additionally, this report incorporates the results of a companion comparability study conducted by DOE's Environmental Measurements Laboratory (EML) during the same time span as the FEMP Part B Comparability Study. Finally, this report relates utilization of the HPGe in soil remediation to utilization of the Radiation Tracking System (RTRAK), a mobile in-situ gamma ray measurement system based upon sodium iodide detectors (RTRAK Applicability Study, DOE 1997).

1.2 IN-SITU GAMMA INVESTIGATIONS AT THE FEMP

In-situ gamma ray spectrometry for measuring activities of gamma-emitting radionuclides in the environment is well established. Several recent publications (for example, the International Commission on Radiation Units and Measurements report entitled "Gamma Ray Spectrometry in the Environment," 1993; the US Nuclear Regulatory Commission report entitled "Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria, Nureg-1506, 1995; and a publication by Fong and Alverez, 1997, entitled "Data Quality Objectives for Surface Soil Cleanup Operation Using In-Situ Gamma Spectrometry for Concentration Measurements") provide overviews of various aspects of in-situ gamma spectrometry.

The application of in-situ gamma spectrometry to solve remediation problems has received increased attention at DOE environmental restoration projects. Accordingly, Miller, et. al. (1994), described the application of in-situ gamma spectrometry to the measurement of uranium in FEMP soils, and found good agreement between in-situ gamma spectrometry measurements and laboratory measurements of uranium-238.

At approximately the same time as the Miller study, a series of tests was conducted by Sandia Laboratories and Fluor Daniel Fernald (FDF) Technology Programs at the FEMP. These tests, called the Uranium in Soils Integrated Demonstration (USID), examined in detail the potential applicability of using non-intrusive detector systems to determine the levels of uranium contamination in FEMP soils. These tests indicated that several gamma ray detector systems, in particular those using high-purity germanium (HPGe) and sodium iodide (NaI) detectors, warranted additional, site-specific testing. The USID concluded that these two detector systems showed results that were spatially similar and generally comparable to those obtained through standard laboratory analysis. For additional details about the USID Program, refer to the Fernald Field Characterization Demonstration Program Data Report (Rautman, et. al., 1994).

Results of the Miller study and the USID program led to further evaluation at the FEMP of a field-deployable HPGe system by FDF personnel in the summer of 1995. This evaluation demonstrated the potential usefulness of the HPGe detector in providing accurate, quantitative assessments of gamma-emitting radiological COCs in soil. More specifically, results indicated that total uranium data generated by HPGe measurements showed good comparability with total uranium data generated by laboratory measurements. Thorium-232 and radium-226 data generated by HPGe showed acceptable comparability to data generated by laboratory methods. These encouraging results led DOE to propose the comparability studies described in this report.

A more detailed description of the HPGe system used at the FEMP is provided in Appendix E. That description provides an overview of the measurement theory and high-purity germanium detector characterization for in-situ gamma ray spectrometry.

1.3 OBJECTIVES

This comparability study builds and expands upon the 1994 USID and 1995 FDF studies in order to demonstrate the HPGe system's capability in generating "real-time" data of known quality and usefulness. In this regard, the following are the major objectives of the report:

1. Determine comparability of analytical data generated by HPGe with data generated through laboratory analysis of discrete samples for site-specific radiological contaminants (emphasizing primary radiological COCs as applicable);

2. Determine whether a series of HPGe measurements for a given area will yield results equivalent to discrete soil sampling over the same area, and will result in the same certification decision;

3. Verify the assumption of a uniform distribution with depth of radionuclide analytes in Fernald soils;

4. Identify and define key parameters that affect the known data quality for the HPGe system;

5. Establish values, limits, or acceptance criteria, as applicable, for these parameters based upon data collected in field operations;

6. Recommend the role that HPGe field-deployable systems should have in future sitewide soil excavation operations; and

7. Recommend, as applicable, what additional method development research is needed to further improve system capabilities.

1.4 REPORT FORMAT

Section 1 introduces, provides background, delineates objectives, and provides an overview of this comparability study report. Section 2 outlines the design and methodologies for the studies described in this report. Section 3 evaluates the data generated for the Part B comparability study (Objective 1). Section 4 presents the results of the EML comparability study (Objectives 1 and 3). Section 5 identifies and quantifies key quality evaluation parameters and discusses their significance with respect to data quality levels (Objectives 4 and 5). Section 6 determines equivalency of certification decisions for the Part A Comparability Study based upon HPGe measurements and laboratory analysis of physical samples (Objective 2). Section 7 discusses the future role of in-situ gamma spectrometry relative to soil excavation and characterization activities (Objectives 6 and 7). All supporting data, technical details, calculations, and technical operating descriptions appear in Appendices A through E and in Appendix G. The EML comparability study, in the form of two memoranda, is provided in Appendix F.

Results of the Part B Comparability Study (Sections 3, 4, and 5) are discussed before those of the Part A Comparability Study (Section 6), because it is more logical to discuss the comparability of data first and then the comparability of decisions based upon that data.

2.0 COMPARABILITY STUDY DESIGN AND METHODS

2.1 PURPOSE

The purpose of the Comparability Study is to establish if in-situ gamma spectrometry can generate data which can be used for making decisions purposes during soil restoration activities. This section of the report describes the study design, sampling methods, and the field analytical methods used to acquire data for the comparability studies described below. This section does not include a discussion of sampling design or methodology for the EML comparability study; these are provided, as applicable, in Appendix F.

2.2 SUBCOMPONENTS OF STUDY

Two comparability studies (Part A and Part B) were conducted to determine if the use of in-situ gamma spectrometry detector systems is applicable to soil remediation activities at the FEMP. The Part A Comparability Study was conducted to determine if certification decisions at the Certification Unit (CU) level, based upon HPGe measurements, are comparable to certification decisions based upon laboratory analyses of discrete physical samples. The Part B Comparability Study was conducted to assess the comparability of in situ HPGe data with laboratory data generated through the analysis of discrete samples, and to establish values, limits or acceptance criteria for key parameters affecting the quality of data collected in field analytical operations. Laboratory analytical procedures that were used in these studies are briefly discussed in Appendix E of this report.

2.2.1 Part A

This study was performed in conjunction with the collection of physical samples obtained during the Area 1, Phase I certification process. The Area 1, Phase I remediation area was divided into CUs which were sampled to demonstrate that residual COC soil concentrations are lower than the soil final remediation levels (FRLs). Data collection for the Part A Comparability Study involved using the HPGe detector at one randomly selected location within each of the subunits in each CU from which certification samples were collected for laboratory analysis. Certification physical sampling entailed collecting one randomly located physical sample within each of the 12 subunits in each selected CU for primary COCs, and 9 randomly located physical samples per selected CU for secondary COCs for laboratory analysis. Figure 2-1 shows an example of physical sample and HPGe measurement locations in a CU. Surface moisture-density gauge measurements or physical soil samples for

laboratory moisture analysis were taken adjacent to all HPGe measurement areas to allow HPGe data to be calculated on a dry weight basis for comparison with FRLs.

The HPGe detector system was placed directly above the randomly-selected locations. Two sets of measurements were collected at each location. Measurement heights were at 31 centimeters (1 foot) and 1 meter (3.28 feet). Data collection took 15 minutes for each measurement. This allowed the HPGe detector to achieve minimum detectable concentrations (MDCs) near or below average background concentrations of primary radiological COCs. Each sample location was surveyed using either Geodimeter survey instrumentation or the global positioning system (GPS) as conditions required.

The field technicians removed all surface vegetation, if present, within a six-inch radius of the sample point. They used a clean, stainless steel trowel, and minimized the removal of any soil. Samples were collected using a 1 to 3-inch butyrate or stainless steel liner with or without a split or solid barrel sampler, as soil conditions required, to collect a soil core to a depth of four inches. The core diameter depended on the volume of soil required for analysis. Technicians followed FDF Procedure SMPL-01, *Solid Sampling*. The liner served as the sample container and was capped at both ends immediately following sample collection.

Laboratories used analytical procedures in accordance with the Sitewide CERCLA Quality Assurance Project Plan (SCQ, DOE 1994). All laboratories analyzing the physical samples met the following guidelines for radiological analysis sample preparation:

1. All sample material was removed from the liner, weighed, and recorded. The analyst performing this step recorded the sample appearance.

2. All sample material was dried at 105° to 112° C for a minimum of 8 hours to a constant weight.

3. The percent moisture content of the sample was calculated and recorded.

4. The entire sample was ground until all the material passed through a one-millimeter sieve.

5. The sample was then mixed by hand or machine to homogenize it.

6. The necessary aliquot was removed for analysis and the remaining sample material was archived.

Certification samples were sent to commercial laboratories for analysis at Analytical Support Level (ASL) D for all primary radiological and secondary radiological COCs. (Refer to the SCQ for additional information on ASLs.) Measurements were performed using both alpha and gamma spectrometry. HPGe data were analyzed in order to determine activities (dry weight basis) for total uranium, thorium-232, radium-226, cesium-137, and potassium-40.

2.2.2 Part B

Part B of the comparability study entails determining the similarity between data generated by HPGe measurements and data generated by laboratory analysis of physical samples. Part B also delineates key quality control elements and data quality elements.

Five radiological species were measured by HPGe and by laboratory methods: total uranium, thorium-232, radium-226, cesium-137, and potassium-40. Total uranium (in ppm) has been calculated from HPGe activity measurements of uranium-238 and uranium-235 using the following formula:

$$\text{Total U (ppm)} = \text{U-238 (pCi/g)}/0.3363 + \text{U-235 (pCi/g)}/2.163 + \text{U-238 (pCi/g)}/6248$$

Laboratory total uranium data have been calculated from uranium-238, uranium-235, and uranium-234:

$$\text{Total U (ppm)} = \text{U-238 (pCi/g)}/0.3363 + \text{U-235 (pCi/g)}/2.163 + \text{U-234 (pCi/g)}/6248$$

Of the thorium isotopes, only thorium-232 HPGe data are presented in this report because thorium-230 cannot be measured by gamma spectrometry systems, and because determination of thorium-228 entails detecting and measuring the same gamma rays as for the determination of thorium-232. Neither thorium-228 nor thorium-232 emit gamma rays that can be used to quantify them directly; both are quantified by detecting and measuring gamma rays of the same daughter products. Assuming secular equilibrium, thorium-228 and thorium-232 will have the same activity.

Similarly, of the radium isotopes, only radium-226 is analyzed by HPGe and laboratory methods in this report. Radium-228, like thorium-228 and thorium-232, is quantified by detecting and measuring the same gamma photons emitted by the same daughter products. Assuming secular equilibrium, radium-228 and thorium-232 will have the same activities. Cesium-137 and potassium-40 are included to extend the number of analytes in the study. Because these two radionuclides are easy to measure by gamma spectroscopy, and because they should be uniformly distributed in FEMP surface soils, they can indicate when HPGe detector systems drift.

2.2.2.1 Layout and HPGe Measurements

Data collection areas (Table 2-1) were selected based on the concentration and estimated heterogeneity of total uranium. Data collection was conducted in ten selected areas having the dimensions of 33 x 33 ft (10 x 10 m) areas. Each area was mowed and raked prior to the start of field activities. Area locations are illustrated in Figure 2-1. Five distinct activities occurred at each of the ten selected areas:

- HPGe measurements
- Soil and air temperature measurements
- Physical soil sampling
- Surface moisture-density gauge measurements and physical samples for surface soil moistures
- Surveying

Field personnel used Geodimeter surveying instruments to survey the coordinates and elevations of each sample location.

Operation of the HPGe detector followed the requirements contained within FDF Procedure EQT-23, *Operation of ADCAM Series Analyzers with Gamma Sensitive Detectors*. HPGe measurements were obtained from both 31 cm (1 foot) and 1 meter (3.28 ft) heights above a fixed point on the ground surface. At a height of 31 cm, the HPGe effectively measures a circle that is 5 meters in diameter, which corresponds to an approximately 20 m^2 total area. At a height of 1 meter, the HPGe will effectively measure a circle that is 10-12 meters in diameter, which corresponds to an area that is approximately 80-120 m^2. Data collection took 15 minutes for each measurement. Two 15-minute measurements were taken at each sample location for each detector height to obtain information on precision of duplicates. Surface moisture was measured adjacent to each HPGe location as necessary to provide environmental information to interpret HPGe data.

2.2.2.2 Temperature Measurements

A single air and soil temperature measurement was recorded on the Field Activity Log for each surface moisture-density gauge measurement taken. Measurements were recorded to the nearest 0.1°C. Two thermometers were used to obtain temperature measurements. The first thermometer was used to measure air temperature and was suspended in the air by means of a string attached to a stake or similar apparatus. The stake or similar apparatus was located inside the 33 x 33 ft (10 x 10 m) test area. The center of the thermometer was placed 3.28 ft (1 m) above the ground surface and was protected from the influences of direct sunlight and wind. The air thermometer was set up before physical soil samples were collected.

The second thermometer, designed to be inserted into the ground without requiring a pilot hole, was used to measure in-situ soil temperatures. The thermometer base was inserted four inches below the surface and was capable of obtaining an accurate soil temperature. The soil thermometer was inserted adjacent to the physical sampling location. The soil temperature was measured before physical soil samples were collected.

2.2.2.3 Physical Soil Sampling

Immediately after in-situ HPGe measurements were taken, 6 to 15 physical soil samples were collected for a given area for isotopic analysis of radiological constituents. One duplicate sample was also collected for each area. The location and number of physical samples collected relative to the HPGe location for each of the ten areas depended upon the degree/heterogeneity of uranium contamination (based upon historical data) and upon the theory of in-situ gamma spectrometry. Based upon statistical considerations, collection of six physical samples was expected to be representative of low contaminated, homogeneous areas (Areas 1, 8, and 9). The collection of ten physical samples was expected to be representative of moderately contaminated, homogeneous areas (Areas 2, 4, 5, and 6). Collection of fifteen samples was expected to be representative of either highly contaminated or highly contaminated and potentially heterogeneous areas (Areas 3, 7, and 10).

Samples were collected in a "bullseye" pattern to mimic the averaging done by the field HPGe detector. That is, the area from which physical samples were taken can be envisioned as a circle, with the HPGe detector located in the center. The HPGe detector receives gamma ray photons from every point

within the circle; however, it receives more gamma rays from soil closer to the detector than from soil further from the detector. If the circle is divided into concentric bands, the relative weighting factor for each band can be calculated based upon the percentage fluence of gamma photons at the detector which originates from a given band of soil, assuming a uniform source distribution with depth and a 1 MeV photon energy (see, for example, Figure 6.1 in NRC Report NUREG-1506, 1995). The relative weighting factor is the relative importance of each band with respect to the probability of gamma rays emitted from within that band being detected by the HPGe. In this regard, Figure 6.1 of NUREG-1506 shows that, for an HPGe detector 1 m off the ground, 10% of the gamma photon fluence comes from soil within 0.5 m of the detector, while 36% of the fluence comes from soil 0.5 to 1.5 meters from the detector. A 1 m distance is a good approximation of a midpoint to represent this fluence in that 50% of the fluence comes from between 0.5 and 1.0 m and 50% comes from between 1.0 and 1.5 m. Finally, approximately 54% of the gamma photon fluence originates from 1.5 to 10 m from the detector. A 3.0 m distance is a good approximation of a midpoint in that 50% of the fluence within this band occurs between 1.5 and 3.0 m and 50% occurs between 3.0 and 10.0 m. Tables 2-2 through 2-4 show the results of weighting calculations based on fluences. For example, in Table 2-2, a band of soil 1 meter from the detector would have a weighting factor at 0.33 for a detector height of 31 cm, and a weighting factor of 0.36 for a detector height 1 meter above the ground. Similarly, a band of soil 3 meters from the detector would have weighting factors of 0.18 for a 31 cm detector height and 0.54 for a 1 meter detector height.

The number of samples per band is divided into the weighting factor per band to give a weighting factor per sample. For example, Table 2-3 shows that six samples were taken on a band three meters from the detector. For a one meter detector height, that band has a weighting factor of 0.54. Therefore, the weighting factor per sample is 0.09 (0.54/6). These weighting factors have been used to calculate weighted statistical data in Section 3.

Figures 2-3 through 2-5 show the locations of physical samples relative to a central point (HPGe locations) for areas of low, medium, and high uranium contamination. The sample location distribution is based upon geometrical considerations and the total number of samples. For areas with six physical samples, one sample is taken directly beneath the detector, two on a circle one meter from the detector, and three on a circle three meters from the detector. Samples collected at the one- and three-meter radii are assumed to represent areas extending inward, as well as outward, from one- and three-meter

sample points, respectively, as discussed in the paragraph on fluence weighting. Thus, the sample distribution is assumed to represent an area substantially larger than a circle with a radius of three meters. Based on this assumption, the sample location design is consistent with the HPGe field of view, in which approximately 90% of the gamma photons originate within ten meters of the detector.

Each of the ten areas was identified as a low, medium, high, or heterogeneous uranium contamination area, based on historical information, and was assigned an arbitrary identification number from one to ten. Table 2-1 summarizes the area designations. The designations were used to determine both the number of physical samples to be collected from each area and the sample layout that was followed in the field to identify each physical sample location.

Physical samples were collected and submitted for on-site laboratory analysis. Data collection began in low contamination areas and concluded in high contamination areas to avoid cross-contamination. For all areas, the first sample was taken directly below the HPGe setup location. Sampling then proceeded radially outward in one of three patterns. For designated low contamination areas, the sampling pattern shown in Figure 2-3 was followed. For designated medium contamination areas, the sampling pattern shown in Figure 2-4 was followed. For designated high or heterogeneous contamination areas, the sampling pattern shown in Figure 2-5 was followed.

2.2.2.4 Physical Sample Collection

Each sample location and sample material was field-screened using a pancake Geiger-Mueller detector, and results were recorded on the Sample Collection Log and Field Activity Log. The sample label was completed with sample collection information, and the technicians completed a Field Activity Log, Sample Collection Log, and Chain of Custody/Request for Analysis form.

Technicians used a clean polybutyrate liner with or without a split barrel sampler, as conditions required, to collect a 0 to 4-inch deep by 3-inch diameter core of soil. The liner served as the sample container and was capped at both ends, using pre-fitted plastic caps, after filling. Liners 12 inches in length could be used to collect a 0 to 4-inch deep sample without cutting to a 4-inch length. Technicians ensured accurate depth by measuring and recording the depth at which the liner (or split barrel sampler) is inserted into the soil. The minimum sample volume was 200 cm^3.

A geologist described the soil adjacent to each sample location on the Field Activity Log. The description included the sample color and percent organic material, clay, sand, and gravel per *Draft DRL-04, Classification of Soils and Completion of Lithologic Log* (American Society of Testing and Materials [ASTM] D 2488-84, Standard Practice for Description Identification of Soils). Each physical soil sampling location was staked for survey purposes. The sample identification number was inscribed on each stake.

2.2.2.5 Sample Identification

All samples collected by field technicians were assigned a unique sample number supplied by the Field Sampling Lead. This unique sample number appeared on the Chain of Custody form and was used to identify the sample during analysis, data entry, and data management. A prefix was added to each sample number to identify why and where the sample was collected. The prefix began with the project and area identification number followed by the sample location number as shown on the Physical Sampling Patterns. Sample numbers began with a "PBC" (Part B Comparability) followed by the area number (1 through 10), followed by a sample location number. For example: PBC-3-12 is the sample number for Part B Comparability, Area 3, Sample Number 12.

2.2.2.6 Area Preparation for Physical Samples

Technicians noted the condition of the sampling area, including disturbances due to excavation, vehicle traffic, etc., in the Field Activity Log. Using a clean stainless steel trowel and other tools as directed by the Field Sampling Lead, a technician removed all vegetative, loose, and disturbed material, and removed additional material as necessary to reach the top of the soil surface to be tested/sampled. Technicians took care not to remove any soil if the surface vegetation was removed.

A horizontal area of sufficient size to accommodate the surface Troxler moisture-density gauge was prepared. The area was planed smooth to obtain maximum contact between the soil and the instrument. The maximum void beneath the instrument that could be tolerated did not exceed 0.125 in (3 mm), per ASTM procedures for void definition and tolerances. Native fines of similar water content immediately adjacent to the Troxler reading area were used as needed to fill existing voids. The total area filled in did not exceed ten percent of the bottom area of the instrument. Several trial seatings were required to achieve these conditions. Preparation activities were recorded in the Field Activity Log.

2.2.2.7 Surface Moisture and Surface Density Measurements

The Troxler Model 3440 Nuclear Gauge is an instrument used to analyze soil moisture and density conditions. Surface moisture and density measurements were obtained within each study area for the Part B Comparability Study, and also at each HPGe measurement point for Part A. Surface moisture measurements were conducted in accordance with ASTM procedure D 3017-88, and surface density measurements followed ASTM procedure D 2922-91. Physical soil moisture samples were collected in place of moisture-density gauge readings when environmental conditions were unfavorable for gauge measurements. Unfavorable environmental conditions include periods of extended cold, causing surface soil to freeze into an irregular topography unsuitable for proper gauge-soil coupling, and periods of extreme rain, rendering the surface soil, especially clays, too muddy to safely operate the tool.

Table 2-5 shows a comparison of moisture values calculated from Troxler measurements vs. those calculated from laboratory measurements based upon weight loss after drying. Moisture data are presented on an "as is" basis, i.e., as weight moisture per wet weight sample, rather than on a geotechnical basis, i.e., weight moisture per dry weight sample. The Troxler, on average, yields moisture readings about 3% higher (absolute basis) than laboratory measurements. This difference is not significant with respect to adjusting data to either a wet weight basis or dry weight basis.

TABLE 2-1
AREA DESIGNATIONS

Area Designation	Contamination Level	Areas by Identification Number
Low	0 - 80 ppm Total Uranium	1, 8, 9
Medium	80 - 200 ppm Total Uranium	2, 4, 5, 6
High and potentially Heterogeneous	> 200 ppm Total Uranium	3, 7, 10

TABLE 2-2
WEIGHTED AVERAGE 6-SAMPLE SCHEME, LOW RANGE (0-80 ppm U)

No. of Samples	Horizontal Distance from Point Under Detector (m)	Detector Height = 31 cm		Detector Height = 1 m	
		Weight (per sample)	Weight (per circle)	Weight (per sample)	Weight (per circle)
1	0	0.49	0.49	0.1	0.1
2	1	0.165	0.33	0.18	0.36
3	3	0.06	0.18	0.18	0.54
Total = 6			Total = 1.00		Total = 1.00

TABLE 2-3
WEIGHTED AVERAGE 10-SAMPLE SCHEME, MEDIUM RANGE (80-200 ppm U)

No. of Samples	Horizontal Distance from Point Under Detector (m)	Detector Height = 31 cm		Detector Height = 1 m	
		Weight (per sample)	Weight (per circle)	Weight (per sample)	Weight (per circle)
1	0	0.49	0.49	0.1	0.1
3	1	0.11	0.33	0.12	0.36
6	3	0.03	0.18	0.09	0.54
Total = 10			Total = 1.00		Total = 1.00

TABLE 2-4
WEIGHTED AVERAGE 15-SAMPLE SCHEME, HIGH RANGE (> 200 ppm U)

No. of Samples	Horizontal Distance from Point Under Detector (m)	Detector Height = 31 cm		Detector Height = 1 m	
		Weight (per sample)	Weight (per circle)	Weight (per sample)	Weight (per circle)
1	0	0.49	0.49	0.1	0.1
4	1	0.083	0.33	0.09	0.36
10	3	0.018	0.18	0.054	0.54
Total = 15			Total = 1.00		Total = 1.00

TABLE 2-5
COMPARISON OF SOIL MOISTURES[a]
BASED UPON TROXLER AND LABORATORY MEASUREMENTS

Sample	Troxler (% Moisture)	Laboratory (% Moisture)
PBC-6-1	31.6	26.7
PBC-6-5	27.0	24.7
PBC-4-1	29.0	27.3
PBC-4-5	29.2	23.1
PBC-5-1	24.5	21.8
PBC-5-5	27.2	18.8
PBC-10-1	22.1	20.8
PBC-7-1	32.5	28.4
PBC-7-9	29.6	28.7
PBC-2-5	30.8	24.3
PBC-2-1	25.3	21.9
PBC-3-1	28.0	21.2
PBC-3-8	26.4	24.1
PBC-8-1	30.8	29.9
PBC-8-4	35.5	30.9
PBC-9-3	28.5	29.3
PBC-9-1	27.5	26.3
PBC-1-1	24.6	24.1
PBC-1-4	23.7	20.4
	mean = 27.8	mean = 24.6

[a] Moistures calculated on a wet weight basis (i.e., weight moisture per wet weight sample)

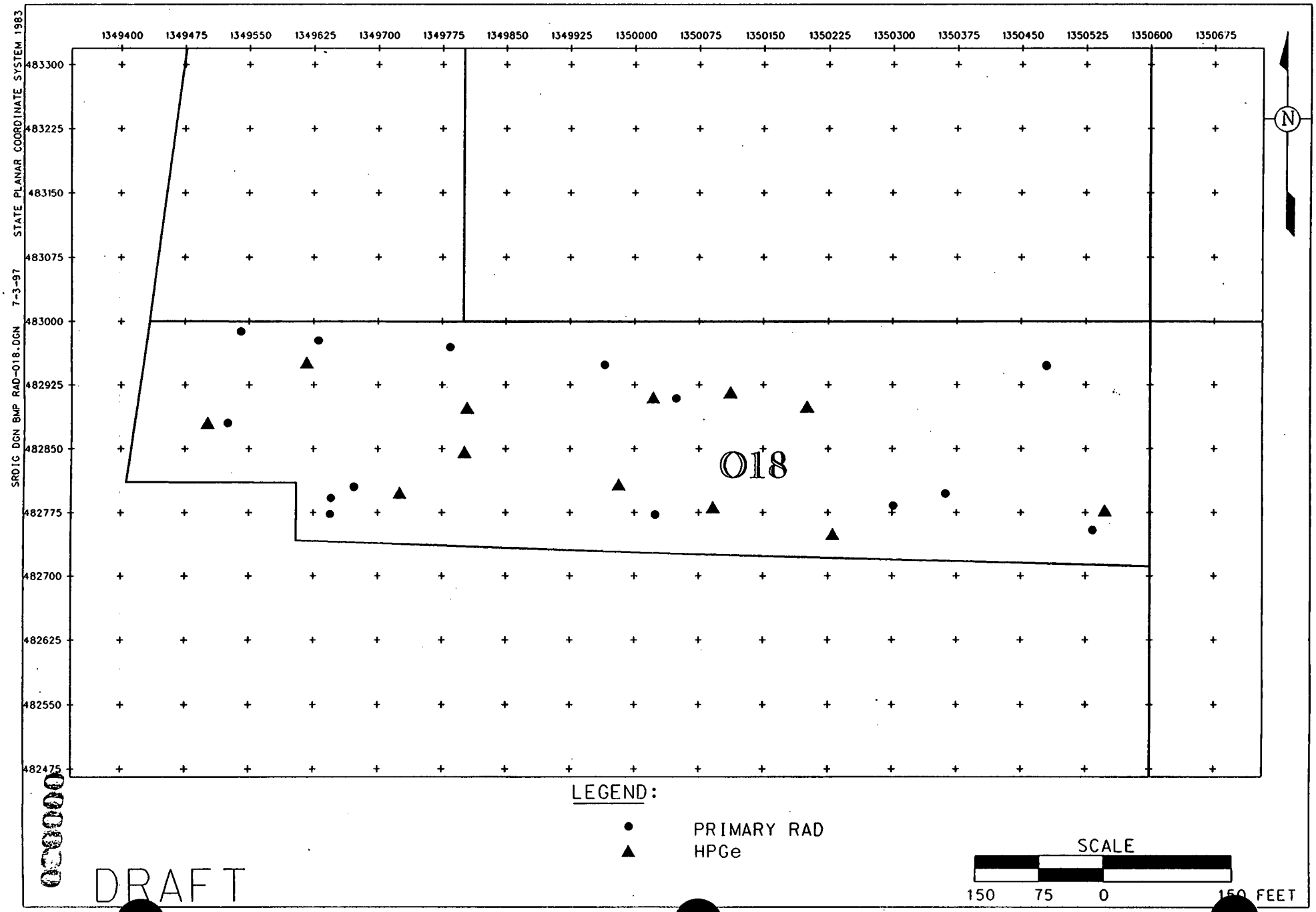
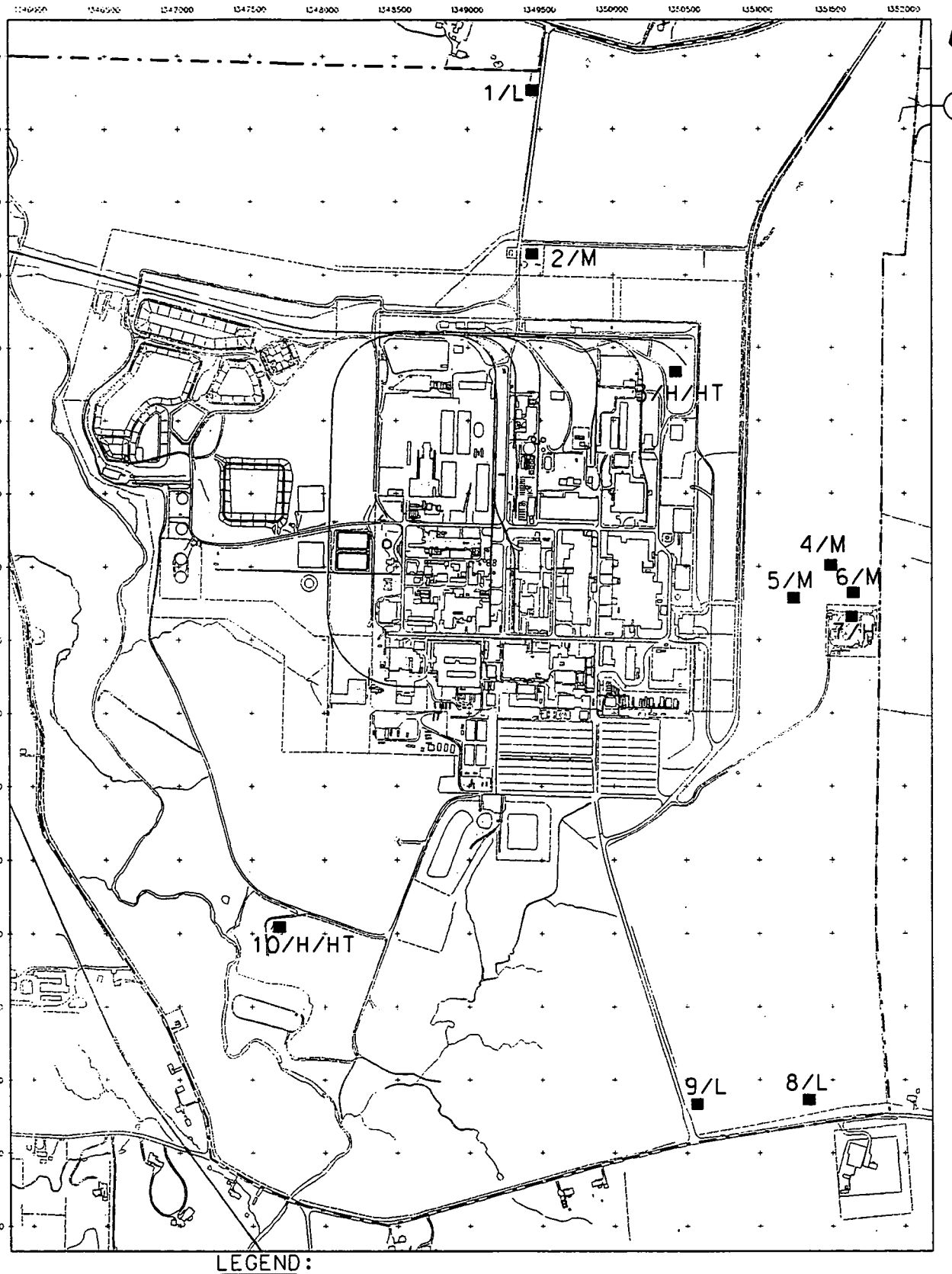


FIGURE 2-1. SAMPLE LOCATIONS OF PRIMARY RADIOLOGICAL SAMPLES AND HPGe MEASUREMENT LOCATIONS

/SRDIC/DGN/MAP/HOR/DPTH/SL83_080.DGN FER 4/17/97 STATE PLANAR COORDINATE SYSTEM 1983



LEGEND:

FEMP BOUNDARY

L LOW
M MEDIUM
H HIGH
HT HETEREOGENEOUS

SCALE

350 175 0 350 FEET

FIGURE 2-2. PART (B) COMPARABILITY STUDY TEST LOCATIONS

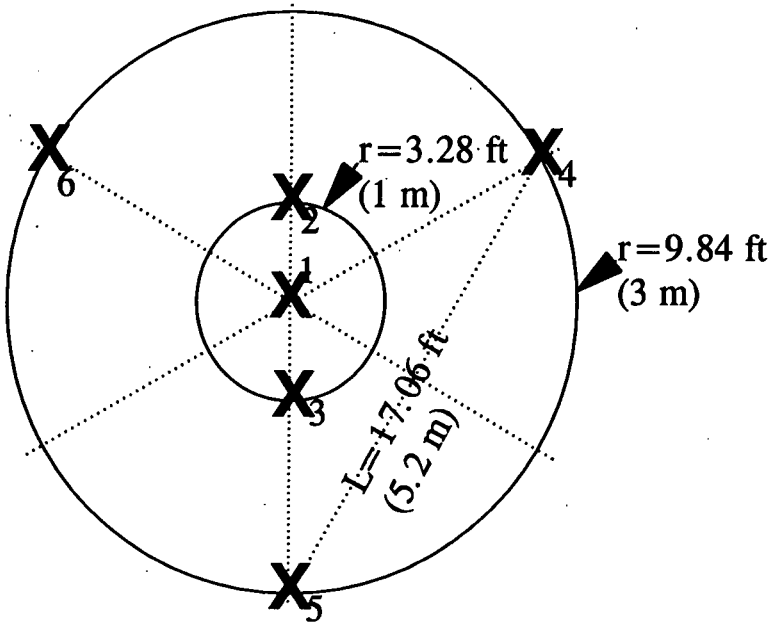


FIGURE 2-3
Low Designation (6-Point) Sampling Pattern
For Areas 1, 8, and 9

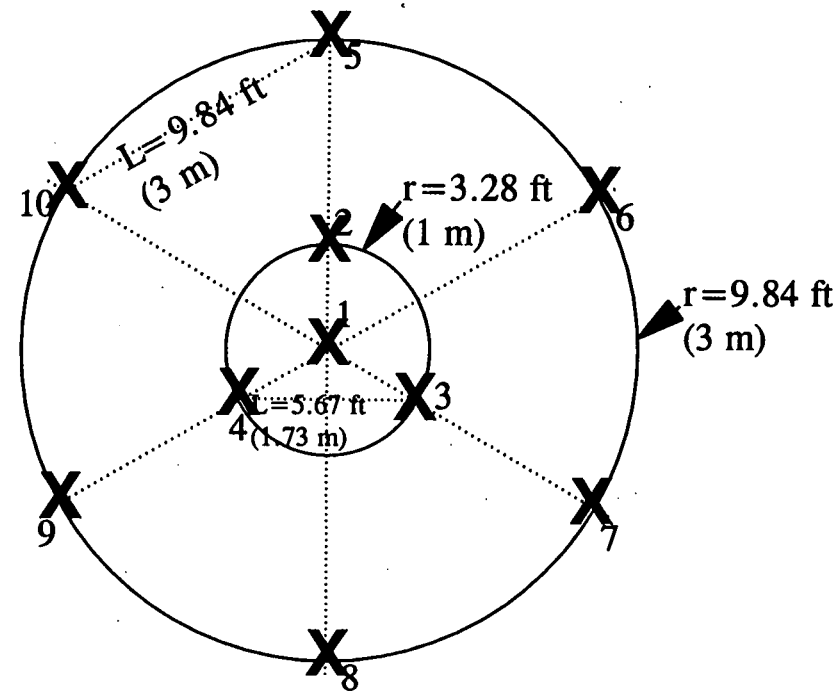


FIGURE 2-4
Medium Designation (10-Point) Sampling Pattern
For Areas 2, 4, 5, and 6

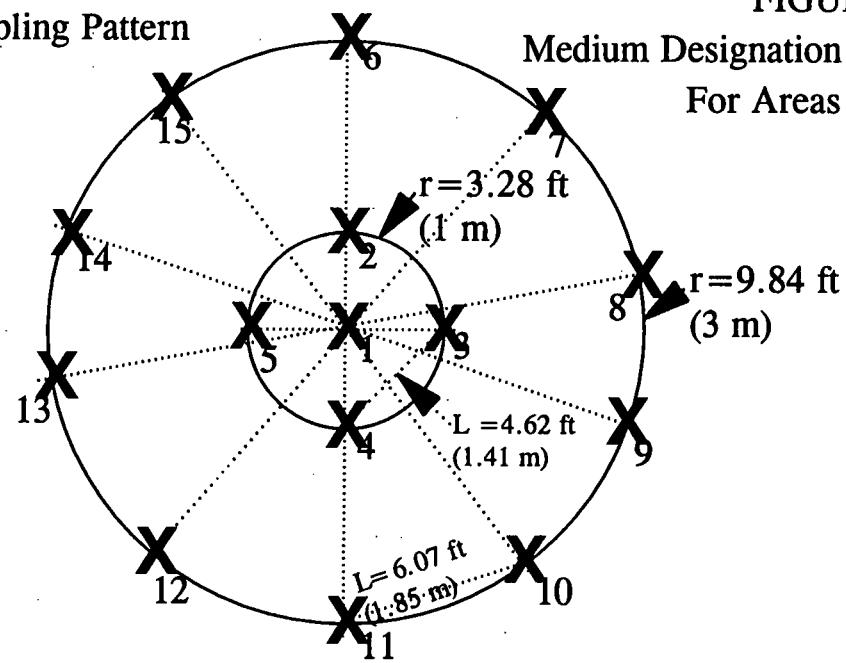


FIGURE 2-5
High and Heterogeneous Designations (15-Point) Sampling Pattern
For Areas 3, 7, and 10

X Sampling Point

1 meter = 3.28 feet
1 foot = [illegible]5 meters

000022

3.0 RESULTS AND ANALYSIS - PART B COMPARABILITY STUDY

3.1 COMPARABILITY

Comparability refers to one of five elements identified by the US Environmental Protection Agency (EPA) to describe data quality. It is an expression of the confidence with which one data set can be compared to another. Analytical data for the same analyte generated by the same analytical procedure (whether by the same laboratory at different times or by different laboratories) are comparable provided that specified acceptance criteria for quality control parameters such as detection limits, accuracy, precision, matrix spikes, etc. are met or exceeded. Data for the same analytes generated by different analytical procedures are also comparable provided that specified acceptance criteria for quality control elements such as those listed above are met or exceeded (Sutton et al., 1994).

This definition implies that similarly accurate and precise data are comparable; inaccurate and imprecise data are not comparable. Comparability also implies that comparable data are correlative. Section 3 reports the similarity, or degree of closeness, between HPGe data and laboratory data as well as the degree of correlation between HPGe data and laboratory data.

3.1.1 Laboratory Comparability vs. Laboratory/Field Comparability

An overview of how data comparability is determined between new and established laboratory analytical methods is helpful prior to the presentation of HPGe and laboratory data comparability. In the laboratory, typically, a certified standard or reference material, if it is a soil, is used by itself, spiked onto a homogeneous soil, or spiked into distilled water. In each instance, the samples to be analyzed are extremely homogenous and the concentration of the analyte in the spiked soil or certified reference material is known with certainty. The new analytical method and the established method are then used to analyze a number of replicates of the sample at selected analyte concentrations. Comparability involves comparing the difference between the analyzed and true values for both the new and established laboratory methods.

The situation is different when comparing in-situ field data generated by the HPGe to laboratory data generated from discrete sample analysis. In this case, certified standards cannot be used and the comparison of data must be based on the actual sample analytical results. Because the HPGe detects gamma rays over a wide areal extent, the HPGe measures an "average" concentration for that area. Conversely, laboratory data are analyses of samples collected at discrete points. If an analyte is

distributed very evenly across that areal extent, the degree of heterogeneity is small, and HPGe and laboratory data should agree closely. However, if the analyte is very unevenly distributed across the areal extent, the heterogeneity is large. In this case, HPGe and laboratory data may or may not agree closely, depending on the representativeness of the discrete samples. A potential further heterogeneity also exists but on the range of sample or subsample scales. Laboratory alpha spectrometry measurements typically use sample sizes on the order of grams. Laboratory gamma spectrometry measurements typically use sample sizes on the order of several hundred grams. Thus, unless care is taken to completely homogenize the samples, laboratory-scale heterogeneity in data could also affect comparability with HPGe data. Thus, comparability of HPGe field data with data from physical samples taken for a given areal extent depends upon the degree of analyte heterogeneity within the area, the number of physical samples collected, and instrumental and detector factors.

The sampling strategy outlined in Section 2, combined with the weighting factors for samples, attempts to minimize the effect of analyte heterogeneity. Where successful, data differences should only reflect instrumental and/or detector differences. Where unsuccessful, data differences will also reflect a component of analyte heterogeneity.

There are several possible scenarios for analyte heterogeneity and data comparability. First, sometimes laboratory data will be randomly higher or lower than HPGe data for a homogenous area when the analytical methods are not systematically biased relative to one another. Second, HPGe data may be biased higher or lower than laboratory data, or may appear to be so due to heterogeneity of the analyte distribution in a large area or due to analyte heterogeneity within the sample collected for analysis. Thus, where laboratory data are significantly higher than HPGe data, laboratory samples may contain higher soil concentrations of an analyte than does the average soil in the area analyzed by HPGe, e.g., a localized, elevated contamination zone; or a systematic bias could exist between the methods. Alternatively, laboratory data may be significantly lower for a given area than HPGe data when the area detected by the HPGe contains high concentration pockets not present in the physical samples, or it could represent a systematic bias between the methods.

3.1.2 Moisture Conventions

The following moisture conventions are used:

- When HPGe data are compared to laboratory data or when HPGe data are control charted, the data are presented on an "as is" or "wet weight" basis.
- When HPGe data are compared to FRLs, the data are presented on a dry weight basis.

3.2 COMPARISON OF HPGe AND LABORATORY ANALYTICAL DATA

3.2.1 Analytical Methods

Alpha spectrometry was the FEMP laboratory method chosen for comparing to HPGe data for total uranium, thorium-232, and radium-226 because FEMP personnel have considerable analytical experience using this technique. Additionally, alpha spectrometry is an established laboratory method that is routinely used by radioanalytical laboratories across the country to generate high quality data for alpha-emitting radionuclides. However, gamma spectrometry was the laboratory method for comparing HPGe data for cesium-137 and potassium-40, as these radionuclides do not emit alpha particles. Details of the instrumental methods used to generate the data are provided in Appendix E.

3.2.2 Analytical Data

Appendix A contains alpha spectrometry, gamma spectrometry, HPGe and soil moisture data for the ten areas. The moisture data were used to calculate laboratory results on a wet weight basis. HPGe data are shown on a wet weight, or "as is," basis. Tables 3-1 through 3-5 summarize the data in Appendix A. For the sample location in each area from which duplicate samples were collected, the average of the data for the duplicates was used in the following calculations. Using the weighting factors described in Section 2 (the sum of the weighting factors equals 1.0, $\Sigma w_{ij} = 1$), the weighted mean and weighted standard deviation for laboratory samples are calculated using the following equations:

$$\bar{X}_i = \sum_{j=1}^{n_i} w_{ij} X_{ij}$$

$$s_i^2 = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} w_{ij} \, (x_{ij} - \bar{x}_i)^2$$

$$s_i = \sqrt{s_i^2}$$

where:

x_{ij} is the value of the jth sample in the ith sample area

$\bar{x}_i$ is the weighted mean of the ith sample area (PBC)

w_{ij} is the weight of the jth sample in the ith sample area

n_i is the number of samples in the ith sample area

s_i^2 is the weighted variance of the sampling distribution of the ith sample area

s_i is the weighted standard deviation of the ith sampling area

Two 15-minute HPGe readings were taken at the center of each sampling area (each PBC area)at each detector height. The mean and standard deviations for HPGe in Tables 3-1 through 3-5 are the means and standard deviations for these two readings. It is important to emphasize that, for Tables 3-1 through 3-5, only one set of laboratory data was taken for each PBC area. However, as explained above and as shown in Tables 2-1 through 2-4, different weighting factors are used for laboratory data depending upon whether the data are compared to HPGe measurements at 31 cm detector height or at 1 m detector height.

Using the above equations, a weighted "average" value for each PBC area can be calculated against which to compare HPGe data. Assessment of similarity involves assessing the degree of closeness between alpha and gamma spectrometry weighted means results and HPGe data for each study area.

Tables 3-6 through 3-10 summarize the closeness of laboratory data weighted means and HPGe data. The closeness of weighted means is expressed as the % relative deviation:

$$\%\,RelativeDeviation = [(|\bar{x}_1 - \bar{x}_2|)/\bar{\bar{x}}] \times 100$$

where:

$\bar{x}_1$ is the weighted mean of the laboratory data corresponding to simulate HPGe measurements at a given detector height

$\bar{x}_2$ is the mean of duplicates for HPGe measurement at a given detector height

$\bar{\bar{x}}$ is the average of the two means

| | is the absolute value symbol

Contract Laboratory Program (CLP) statements of work (SOW) and SW-846 guidelines for relative precision requirements for metals state that data are considered acceptable when the percent relative difference between duplicates is less than 20% for data the are greater than five times the MDC. For data less than five times the MDC, the precision requirements are ± the MDC. When relative precision is greater than 20%, the analyses are either flagged with qualifiers or reanalyzed. However, US EPA CLP National Functional Guidelines for Inorganic Data Review specifies that the relative precision criterion for metals soils be 35% before data are flagged. Adopting these criteria to interpret data in Tables 3-6 through 3-12, when the relative deviation between HPGe and laboratory data is less than 20%, the data are defined as being very similar; when the relative deviation is greater than 20% but less than 35%, the data are defined as having acceptable similarity. When the relative deviation is greater than 35%, the data are defined as dissimilar.

Based upon the above guidelines, all of the thorium-232 data are very similar (Table 3-7). All of the uranium data except for areas PBC-03 and PCB-10 are very similar (Table 3-6). One sample in PBC-03 (PBC-03-01) was unexpectedly found to contain a very radioactive piece of cement, thereby skewing the weighted average of the entire PBC-03 area toward the high concentrations of uranium relative to HPGe. This is an example of analyte distribution heterogeneity causing a difference in data variability rather than detector methods. When PBC-03-01 is excluded, the weighted average of the laboratory measurement and HPGe readings are virtually identical. Conversely, in Area PBC-10, HPGe measurements of total uranium were higher than the weighted average for laboratory measurements. This could represent a case where physical samples did not contain, on average, as high a concentration of uranium as detected by the HPGe. Alternatively, it could represent either HPGe data readings biased high or laboratory data biased low. However, area PBC-06 had HPGe readings very similar to area PBC-10. In area PBC-10, almost all individual laboratory data values are less than the HPGe measurements; the converse is true for area PBC-06. In other words, the data sets

for PBC-06 and PBC-10 argue against bias in either the laboratory or HPGe measurements. Thus, the difference between laboratory and HPGe data in area PBC-10 should result from analyte heterogeneity.

A majority of relative deviations for radium exceed 20%, and about half of the relative deviations exceed 35%. Thus, about half the radium data appear to be of acceptable similarity and about half appear to be dissimilar based upon the relative deviation criterion. Whether this is due to analyte heterogeneity, a bias in alpha spectrometry data, a bias in HPGe data, or environmental factors cannot be readily ascertained from the data. Radium data are further discussed in the correlation section of this report (Section 2.3) and in Section 5.7 on robustness of data with respect to environmental conditions.

In order to help resolve the use of inconsistent similarity between HPGe and laboratory radium-226 data, a small subset of the original samples will be reanalyzed by two independent laboratories. One laboratory will use the alpha spectrometry technique for these reanalyses, while the other will use a radon emanation technique to determine whether these different laboratory methods agree with the original analyses. One of the labs will also test an alternative soil digestion procedure to determine if this influences the results. With regard to HPGe measurements in the field, the degree of radon-222 (radon daughters are measured to quantify radium-226 by gamma spectrometry) emanation from soils is being investigated to provide disequilibrium factors for radium-226 progeny.

Tables 3-9 and 3-10 shows the relative deviation of means between weighted laboratory gamma spectrometry data and HPGe data for cesium-137 and potassium-40. In general, most of the relative deviations are less than 20%, but several are between 20% and 35%, suggesting that overall, the data are very similar for both cesium-137 and potassium-40. Examination of Tables 3-4 and 3-5 indicates that the weighted means of laboratory gamma spectrometry data are consistently higher than HPGe data by about 15% for both cesium-137 and potassium-40. Whether the laboratory data are biased high, the HPGe data are biased low or a combination of both cannot be determined from these data.

3.3 CORRELATION OF HPGe AND LABORATORY DATA

Figures 3-1 through 3-10 show both of the individual HPGe measurements (two measurements were taken at each height, except for PBC-06 in which six measurements were taken) for a given area plotted against the weighted averages of laboratory measurements for that area. Error bars for the HPGe

measurements are not derived from the standard deviations in Tables 3-1 and 3-5, but represent the 1.96 σ counting errors listed for each HPGe measurement in Appendix A. Also shown in Figures 3-1 through 3-10 are lines with slopes of 1.0 intersecting the origin. These lines are not regression lines, but are intended to indicate how well or how poorly the data compare to perfect correlations.

A number of points are immediately obvious from inspection of these figures. First, the individual HPGe measurements are close together, indicating good precision of duplicates. Second, the counting errors associated with the measurements are generally small. Third, uranium and thorium display a very good degree of correlation, encompassing the entire range of data. All data points fall near the line with a slope of 1.0. Fourth, radium data less than 1.0 pCi/g appear to be consistently slightly higher for HPGe measurements than for laboratory alpha spectrometry measurements. Conversely, for activities greater than 3.0 pCi/g, HPGe measurements appear considerably lower than for laboratory alpha spectrometry measurements. Fifth, as noted in the preceding section, laboratory gamma spectrometry data for Cs-137 and K-40 are consistently higher than HPGe data. The following paragraphs highlight and emphasize these observations.

Appendix D contains the regression analysis of HPGe and laboratory data prepared using from a commercial statistics program. The significance of the statistical parameters is explained in Appendix D. To demonstrate good comparability of data from linear correlation analysis, three criteria must be met: a high correlation coefficient, an intercept of the regression line near zero, and a slope of the regression line near 1.0. A low value of the intercept as a percentage of the FRL is important. The intercept could be interpreted as a measure of inherent bias of one technique relative to another. Therefore, by measuring the ratio of the intercept to the FRL, an estimate of how important this potential bias is can be made. Acceptable similarity, based upon linear correlation, is defined as a high value of the correlation coefficient and a low value of the intercept as a percentage of the FRL. Table 3-11 summarizes these three parameters for the 12 linear regressions listed below. Linear regressions have been performed for:

- HPGe vs. alpha spectrometry total uranium data, including and excluding one sample (PBC-03-01) in Area PBC-03 that contained a piece of very radioactive cement,
- HPGe vs. alpha spectrometry thorium-232 data,
- HPGe vs. alpha spectrometry radium-226 data,
- HPGe vs. gamma spectrometry cesium-137 data, and

- HPGe vs. gamma spectrometry potassium-40 data.

Regressions have been performed for HPGe data obtained at 1 m and 31 cm. heights.

As shown in Table 3-11, the correlation coefficients are high for all regression analyses. The slopes are near 1, and the intercepts as a percentage of FRLs are small for the regression analyses for uranium (PCB-03-1 excluded) and thorium. For cesium-137, the percentage of the intercept relative to the FRL is small and the slope of the line is moderately close to 1.0. However, for radium-226, the slope of the regression line is very different from 1.0 (0.27), and the percentage of the intercept relative to the FRL is approximately 35%. Correlation analysis of potassium-40 also displays a regression line slope close to 1.0. Potsssium-40 does not have an FRL. Thus, based upon the criteria outlined above, uranium, thorium-232, cesium-137, and potassium-40 analyses for HPGe are very comparable to those of laboratory measurements, while radium-226 analyses by HPGe do not appear comparable to those of alpha spectrometry using the data in this study. As stated in Section 3.2.2, a study is underway to investigate the reasons for differences between HPGe and laboratory data for radium-226.

Graphic displays of the regression analyses are included in Appendix D. The best fit line in these figures is shown as a solid line, while the two dashed lines correspond to 95% confidence limits. The two solid lines bounding the best fit line correspond to the 95% prediction limits.

The conclusions from the correlation analysis support those based upon relative deviations. Uranium, thorium-232, cesium-137, and potassium-40 data appear comparable between HPGe and laboratory analyses, both at 31 cm and 1.0 m HPGe detector heights. Conversely, radium-226 data generated by laboratory analyses do not appear comparable to HPGe data. Reasons for this are not known, but are currently being investigated.

3.3.1 31 cm vs. 1.0 m HPGe Data

Inspection of Tables 3-1 through 3-5 shows that only small differences exist between HPGe measurements at 31 cm and 1.0 m for total uranium, thorium-232, radium-226, cesium-137 and potassium-40, provided there is no extreme heterogeneity in analyte distribution; e.g., PBC-03-01. The overall similarity of 31 cm and 1.0 m HPGe data is reinforced by the overall closeness of linear

correlation parameters (Table 3-11); i.e., correlation coefficient, slope of regression line, intercept of regression line for 31 cm and 1.0 m correlations of HPGe data to weighted laboratory data. Lastly, Figure 3-11 displays a plot of the measured HPGe concentrations of total uranium, radium-226, thorium-232, cesium-137 and potassium-40 at 31 cm height vs. the same parameters at 1.0 m height. All of the analytes are displayed on the same log/log plot to demonstrate the close agreement of data over nearly four orders of magnitude. The slope of the regression line (0.9987) combined with a very high R^2 coefficient (0.9983) indicate a one-to-one correspondence of 31 cm data and 1.0 m data.

In light of the high degree of correlation between 31 cm (approximately effective 20-meter square measuring area) HPGe data and 1.0 m (approximately 100-meter square measuring area) HPGe data, future measurements need not be taken at both heights. Therefore, the practice will be to collect only routine measurements at 1.0 m height in order to obtain larger areal coverage, unless measurements at 31 cm are required for special purposes; e.g., for hot spot delineation or when there is extreme analyte heterogeneity. Also, for radionuclides that deliver some of their dose via an external radiation pathway, the measurement at a 1.0 m detector height best represents the dose at the receptor height.

3.4 CONCLUSIONS

Results of the Part B comparability study conducted by FEMP personnel demonstrate that total uranium, thorium-232, cesium-137, and potassium-40 data generated by HPGe measurements are very comparable to those generated by laboratory alpha spectrometry and gamma spectrometry measurements. This conclusion is based upon the overall closeness of HPGe and alpha spectrometry data, with small relative deviations of less than 20%, as well as upon a high degree of linear correlation.

Radium activities less than 1.0 pCi/g as measured by HPGe are generally close to those measured by alpha spectrometry. However, for activities greater than 3.0 pCi/g, HPGe measurements are much lower than alpha spectrometry measurements. Reasons for this are not obvious; they could include extreme heterogeneity of radium-226, differences due to instrumental techniques, or differences resulting from environmental factors. A study is currently underway to investigate reasons for the differences.

TABLE 3-1
COMPARISON OF ALPHA SPECTROMETRY AND HPGe TOTAL URANIUM DATA

HPGe Setting	Area	Alpha Spectrometry		HPGe	
		Weighted Mean (ppm)	Weighted Std. Dev. (ppm)	Mean (ppm)	Std. Dev. (ppm)
31 cm (1 ft)	PBC-01	7.5	0.32	9.0	0.63
	PBC-02	29.6	1.3	31.3	1.9
	PBC-03	1099	222	291	10.4
	PBC-03*	288	15.6	291	10.4
	PBC-04	57.4	1.8	56.5	1.5
	PBC-05	36.1	3.8	42.2	0.86
	PBC-06	84.3	2.2	76.7	1.3
	PBC-07	162	8.3	141	1.2
	PBC-08	5.0	0.5	5.8	0.26
	PBC-09	5.9	0.2	6.5	1.2
	PBC-10	64.4	3.1	80.9	0.4
1.0 m (3.28 ft)	PBC-01	7.4	0.40	8.0	**
	PBC-02	26.2	1.4	26.0	2.8
	PBC-03	451	128	287	7.9
	PBC-03*	285	17.7	287	7.9
	PBC-04	55.9	3.0	58.6	1.9
	PBC-05	45.3	5.3	47.9	1.7
	PBC-06	87.2	3.3	75.9	2.9
	PBC-07	174	13.2	140	2.1
	PBC-08	4.9	0.66	5.3	0.28
	PBC-09	6.2	0.2	6.9	0.51
	PBC-10	55.0	3.5	74.0	0.46

* Sample PBC-03-01 excluded from data set
** Only one HPGe reading. Second measurement did not detect any gamma rays used to quantify uranium and was excluded as a valid measurement

TABLE 3-2
COMPARISON OF ALPHA SPECTROMETRY AND HPGe THORIUM-232 DATA

HPGe Setting	Area	Alpha Spectrometry		HPGe	
		Weighted Mean (pCi/g)	Weighted Std. Dev. (pCi/g)	Mean (pCi/g)	Std. Dev. (pCi/g)
31 cm (1 ft)	PBC-01	0.50	0.02	0.52	0.03
	PBC-02	0.55	0.08	0.64	0.02
	PBC-03	2.0	0.06	2.2	0.02
	PBC-04	0.77	0.01	0.80	0.01
	PBC-05	0.76	0.02	0.79	0.01
	PBC-06	0.76	0.01	0.81	0.03
	PBC-07	0.99	0.02	0.99	0.01
	PBC-08	0.53	0.02	0.55	0.004
	PBC-09	0.53	0.01	0.63	0.02
	PBC-10	6.0	0.87	5.8	0.01
1.0 m (3.28 ft)	PBC-01	0.50	0.02	0.51	0.003
	PBC-02	0.55	0.08	0.63	0.02
	PBC-03	2.1	0.10	2.5	0.02
	PBC-04	0.74	0.01	0.78	0.005
	PBC-05	0.79	0.04	0.79	0.02
	PBC-06	0.79	0.01	0.80	0.02
	PBC-07	1.02	0.03	0.97	0.06
	PBC-08	0.50	0.02	0.53	0.04
	PBC-09	0.52	0.01	0.58	0.01
	PBC-10	7.3	1.4	6.9	0.04

TABLE 3-3
COMPARISON OF ALPHA SPECTROMETRY AND HPGe RADIUM-226 DATA

HPGe Setting	Area	Alpha Spectrometry		HPGe	
		Weighted Mean (pCi/g)	Weighted Std. Dev. (pCi/g)	Mean (pCi/g)	Std. Dev. (pCi/g)
31 cm (1 ft)	PBC-01	0.50	0.03	0.64	0.01
	PBC-02	0.63	0.02	0.66	0.01
	PBC-03	13.6	1.3	4.2	0.15
	PBC-04	0.54	0.03	0.82	0.03
	PBC-05	0.58	0.02	0.72	0.04
	PBC-06	0.62	0.02	0.80	0.01
	PBC-07	0.74	0.03	0.80	0.01
	PBC-08	0.43	0.02	0.65	0.01
	PBC-09	0.40	0.01	0.73	0.03
	PBC-10	3.4	0.34	1.9	0.04
1.0 m (3.28 ft)	PBC-01	0.52	0.05	0.60	0.01
	PBC-02	0.60	0.02	0.68	0.02
	PBC-03	13.6	1.7	4.3	0.05
	PBC-04	0.58	0.03	0.80	0.02
	PBC-05	0.55	0.02	0.73	0.01
	PBC-06	0.66	0.02	0.80	0.01
	PBC-07	0.77	0.05	1.03	0.08
	PBC-08	0.42	0.03	0.61	0.02
	PBC-09	0.42	0.01	0.69	0.002
	PBC-10	3.2	0.42	1.7	0.01

TABLE 3-4
COMPARISON OF GAMMA SPECTROMETRY AND HPGe CESIUM-137 DATA

HPGe Setting	Area	Gamma Spectrometry		HPGe	
		Weighted Mean (pCi/g)	Weighted Std. Dev. (pCi/g)	Mean (pCi/g)	Std. Dev. (pCi/g)
31 cm (1 ft)	PBC-01	0.38	0.03	0.43	0.016
	PBC-02	0.73	0.05	0.60	0.003
	PBC-03	0.68	0.05	0.51	0.040
	PBC-04	0.39	0.01	0.35	0.004
	PBC-05	0.38	0.02	0.34	0.001
	PBC-06	0.37	0.02	0.32	0.011
	PBC-07	0.33	0.01	0.29	0.004
	PBC-08	0.10	0.02	0.11	0.004
	PBC-09	0.28	0.02	0.27	0.011
	PBC-10	0.37	0.02	0.28	0.007
1.0 m (3.28 ft)	PBC-01	0.41.	0.04	0.38	0.004
	PBC-02	0.62	0.04	0.50	0.018
	PBC-03	0.57	0.06	0.46	0.001
	PBC-04	0.37	0.02	0.33	0.001
	PBC-05	0.40	0.02	0.35	0.011
	PBC-06	0.41	0.02	0.32	0.016
	PBC-07	0.35	0.02	0.28	0.013
	PBC-08	0.13	0.01	0.12	0.001
	PBC-09	0.31	0.02	0.26	0.007
	PBC-10	0.33	0.03	0.30	0.008

TABLE 3-5
COMPARISON OF GAMMA SPECTROMETRY AND HPGe POTASSIUM-40 DATA

HPGe Setting	Area	Gamma Spectrometry		HPGe	
		Weighted Mean (pCi/g)	Weighted Std. Dev. (pCi/g)	Mean (pCi/g)	Std. Dev. (pCi/g)
31 cm (1 ft)	PBC-01	12.2	0.57	11.4	0.21
	PBC-02	8.6	0.43	7.8	0.01
	PBC-03	12.0	0.36	11.1	0.56
	PBC-04	10.9	0.33	9.4	0.13
	PBC-05	13.0	0.38	11.0	0.07
	PBC-06	11.1	0.26	9.1	0.13
	PBC-07	10.4	0.18	9.0	0.17
	PBC-08	10.8	0.16	8.7	0.01
	PBC-09	10.8	0.15	9.2	0.04
	PBC-10	11.8	0.21	10.5	0
1.0 m (3.28 ft)	PBC-01	12.5	0.83	10.7	0
	PBC-02	8.7	0.58	7.7	0.14
	PBC-03	12.8	0.30	11.1	0.14
	PBC-04	11.4	0.30	9.1	0.01
	PBC-05	12.4	0.36	10.4	0.07
	PBC-06	11.1	0.37	8.8	0.09
	PBC-07	10.8	0.26	9.1	0.04
	PBC-08	10.6	0.24	8.9	0.35
	PBC-09	10.7	0.22	8.8	0.20
	PBC-10	11.5	0.24	10.0	0.22

TABLE 3-6
CLOSENESS OF TOTAL URANIUM DATA

Area	% Relative Deviation of Means (31 cm, 1 ft)*	% Relative Deviation of Means (1 m, 3.28 ft)*
PBC-01	(-)18.2	(-)7.8
PBC-02	(-)5.6	(+)0.76
PBC-03	(+)116.2	(+)44.4
PBC-03**	(-)1.0	(-)0.7
PBC-04	(+)1.6	(-)4.7
PBC-05	(-)15.6	(-)5.6
PBC-06	(+)9.4	(+)13.8
PBC-07	(+)13.9	(+)21.6
PBC-08	(-)14.8	(-)7.8
PBC-09	(-)9.7	(-)10.7
PBC-10	(-)22.7	(-)29.4

* negative signs indicate laboratory data are less than HPGe data; positive signs indicate laboratory data are greater than HPGe data. Signs are not taken into account in computation of averages.
** sample PBC-03-01 excluded from data set

Average (using PBC-03) = 22.8% Average (using PBC-03) = 14.6%

Average (using PBC-03*) =11.2% Average (using PBC-03*) =10.3%

TABLE 3-7
CLOSENESS OF THORIUM-232 DATA

Area	% Relative Deviation of Means (31 cm, 1 ft)*	% Relative Deviation of Means (1 m, 3.28 ft)
PBC-01	(-)3.9	(-)2.0
PBC-02	(-)15.1	(-)13.6
PBC-03	(-)9.5	(-)17.4
PBC-04	(-)3.8	(-)5.3
PBC-05	(-)3.9	0
PBC-06	(-)6.4	(-)1.2
PBC-07	0	(+)5.0
PBC-08	(-)3.7	(-)5.8
PBC-09	(-)17.2	(-)10.9
PBC-10	(+)3.4	(+)5.6

* negative signs indicate laboratory data are less than HPGe data; positive signs indicate laboratory data are greater than HPGe data. Signs are not taken into account in computation of averages.

Average = 6.7% Average = 6.7%

TABLE 3-8
CLOSENESS OF RADIUM-226 DATA

Area	% Relative Deviation of Means (31 cm, 1 ft)*	% Relative Deviation of Means (1 m, 3.28 ft)*
PBC-01	(-)24.5	(-)14.3
PBC-02	(-)4.6	(-)12.5
PBC-03	(+)105.6	(+)103.9
PBC-04	(-)41.2	(-)31.9
PBC-05	(-)21.5	(-)28.1
PBC-06	(-)25.4	(-)19.2
PBC-07	(-)7.8	(-)28.9
PBC-08	(-)40.7	(-)36.9
PBC-09	(-)58.4	(-)48.6
PBC-10	(+)56.6	(+)61.2

* negative signs indicate laboratory data are less than HPGe data; positive signs indicate laboratory data are greater than HPGe data. Signs are not taken into account in computation of averages.

Average = 35.0% Average = 38.6%

Average excluding PBC-03 = 27.1% Average excluding PBC-03 = 31.3%

TABLE 3-9
CLOSENESS OF CESIUM-137 DATA

Area	% Relative Deviation of Means (31 cm, 1 ft)*	% Relative Deviation of Means (1 m, 3.28 ft)*
PBC-01	(-)12.3	(+)7.6
PBC-02	(+)19.5	(+)21.4
PBC-03	(+)28.6	(+)21.4
PBC-04	(+)10.8	(+)11.4
PBC-05	(+)11.1	(+)13.3
PBC-06	(+)14.5	(+)24.6
PBC-07	(+)12.9	(+)22.2
PBC-08	(-)9.5	(+)8.0
PBC-09	(+)3.6	(+)17.5
PBC-10	(+)27.7	(+)9.5

* negative signs indicate laboratory data are less than HPGe data; positive signs indicate laboratory data are greater than HPGe data. Signs are not taken into account in computation of averages.

Average = 15.0% Average = 15.6%

TABLE 3-10
CLOSENESS OF POTASSIUM-40 DATA

Area	% Relative Deviation of Means (31 cm, 1 ft)*	% Relative Deviation of Means (1 m, 3.28 ft)*
PBC-01	(+)6.8	(+)15.5
PBC-02	(+)9.8	(+)12.2
PBC-03	(+)7.8	(+)14.2
PBC-04	(+)14.8	(+)22.4
PBC-05	(+)16.7	(+)17.5
PBC-06	(+)19.8	(+)23.1
PBC-07	(+)14.4	(+)17.1
PBC-08	(+)21.5	(+)17.4
PBC-09	(+)16.0	(+)19.5
PBC-10	(+)11.6	(+)14.0

* negative signs indicate laboratory data are less than HPGe data; positive signs indicate laboratory data are greater than HPGe data. Signs are not taken into account in computation of averages.

Average = 13.9% Average = 17.3%

TABLE 3-11
LINEAR CORRELATION PARAMETERS

Analyte	HPGe Height	Correlation Coefficient	Slope of Regression Line	Intercept of Regression Line	Intercept as Percent of FRL
Uranium including PBC-03-01	31 cm	0.934	0.242	36.5	44.5
	1 m	0.987	0.624	15.5	18.9
Uranium excluding PBC-03-01	31 cm	0.994	0.969	2.20	2.68
	1 m	0.989	0.949	1.52	1.85
Thorium-232	31 cm	0.999	0.950	0.090	6.00
	1 m	0.997	0.940	0.106	7.07
Radium-226	31 cm	0.992	0.268	0.615	36.2
	1 m	0.994	0.274	0.605	35.6
Cesium-137	31 cm	0.958	0.716	0.061	4.36
	1 m	0.982	0.774	0.027	1.93
Potassium-40	31 cm	0.909	0.914	- 0.471	NA
	1 m	0.943	0.821	0.222	NA

Figure 3-1
Correlation Between 31 cm HPGe and Laboratory Data for Total Uranium (w/o PBC-03-01)

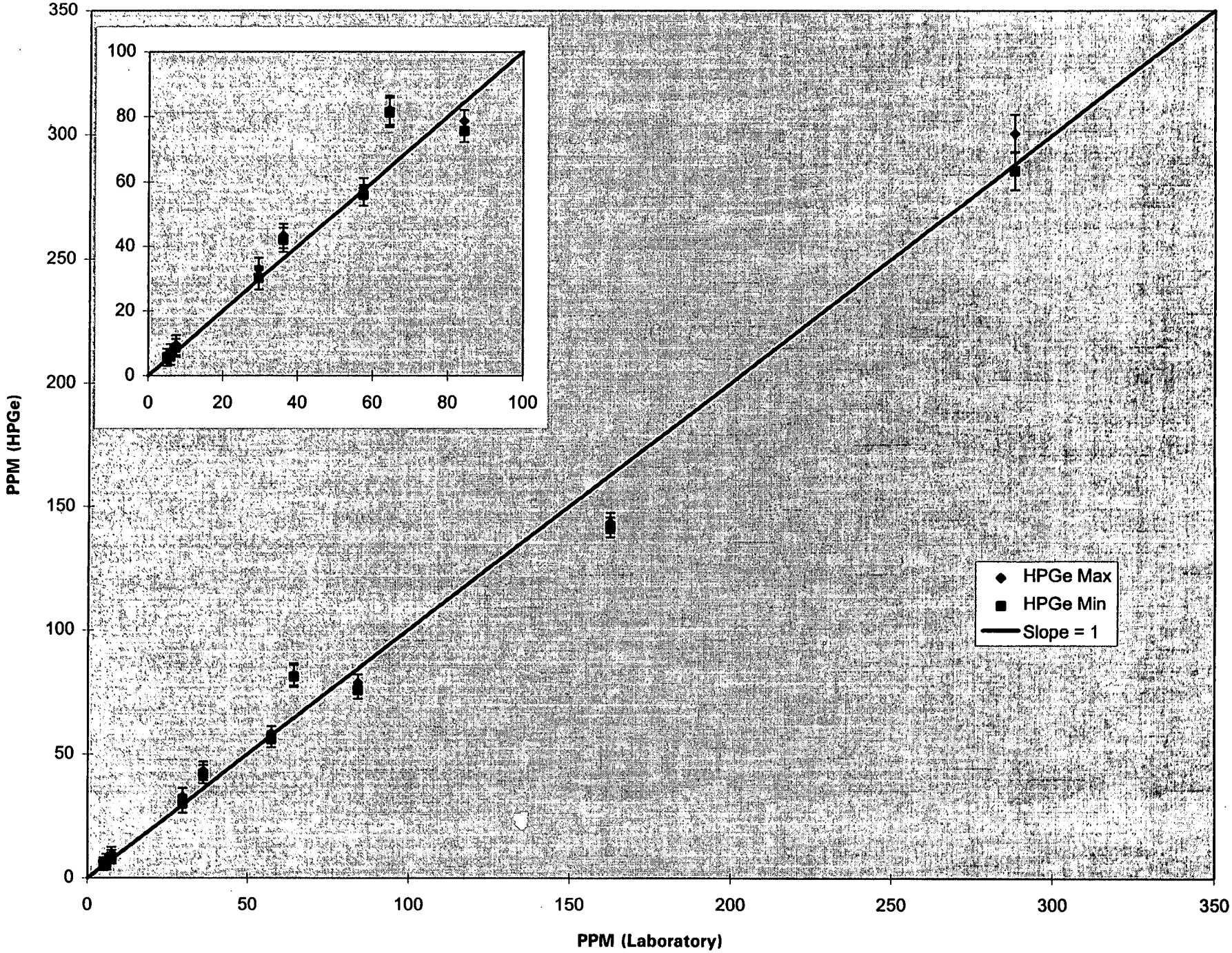


Figure 3-2

Correlation Between 100 cm HPGe and Laboratory Data for Total Uranium (w/o PBC-03-01)

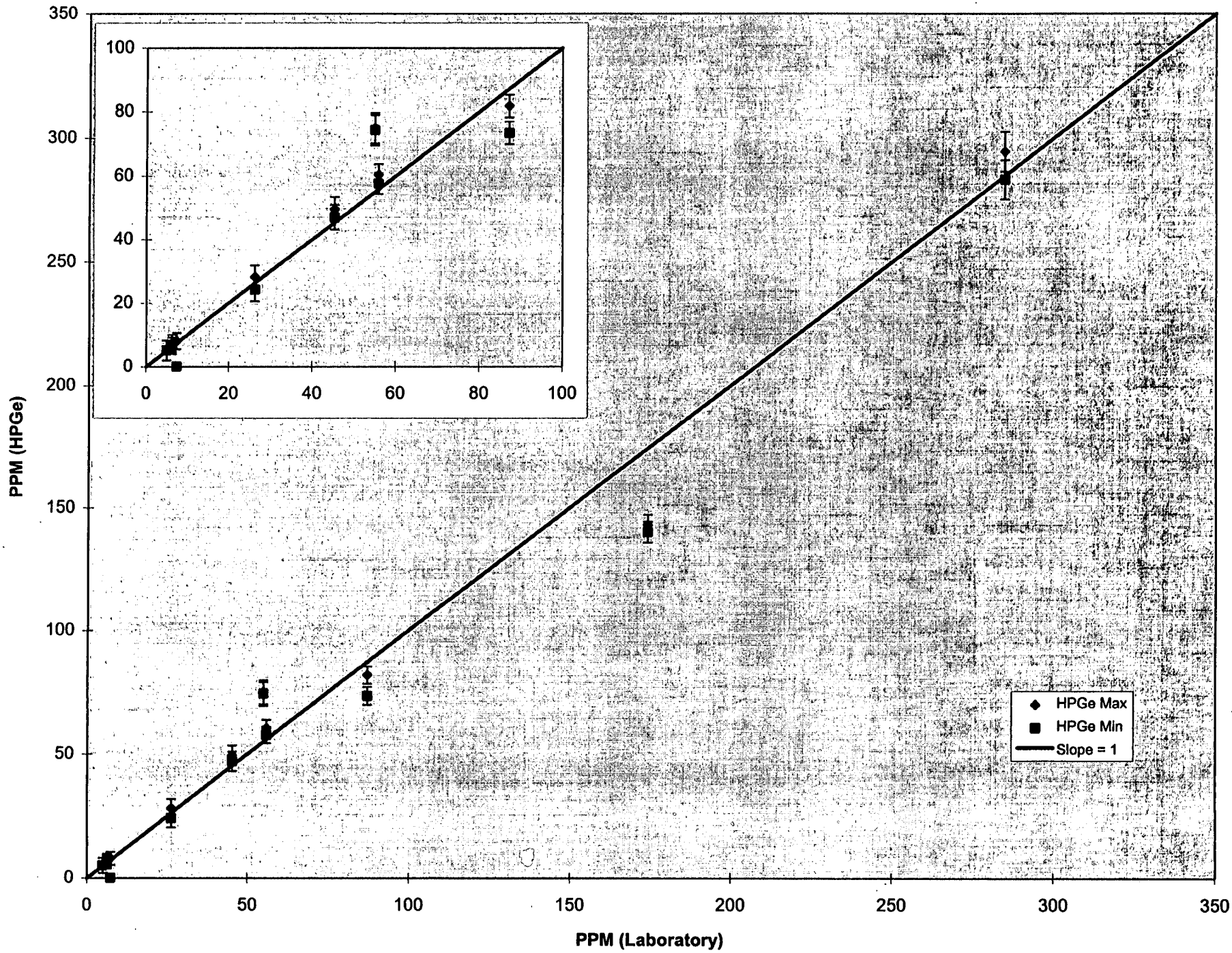


Figure 3-3
Correlation Between 31 cm HPGe and Laboratory Data for Thorium-232

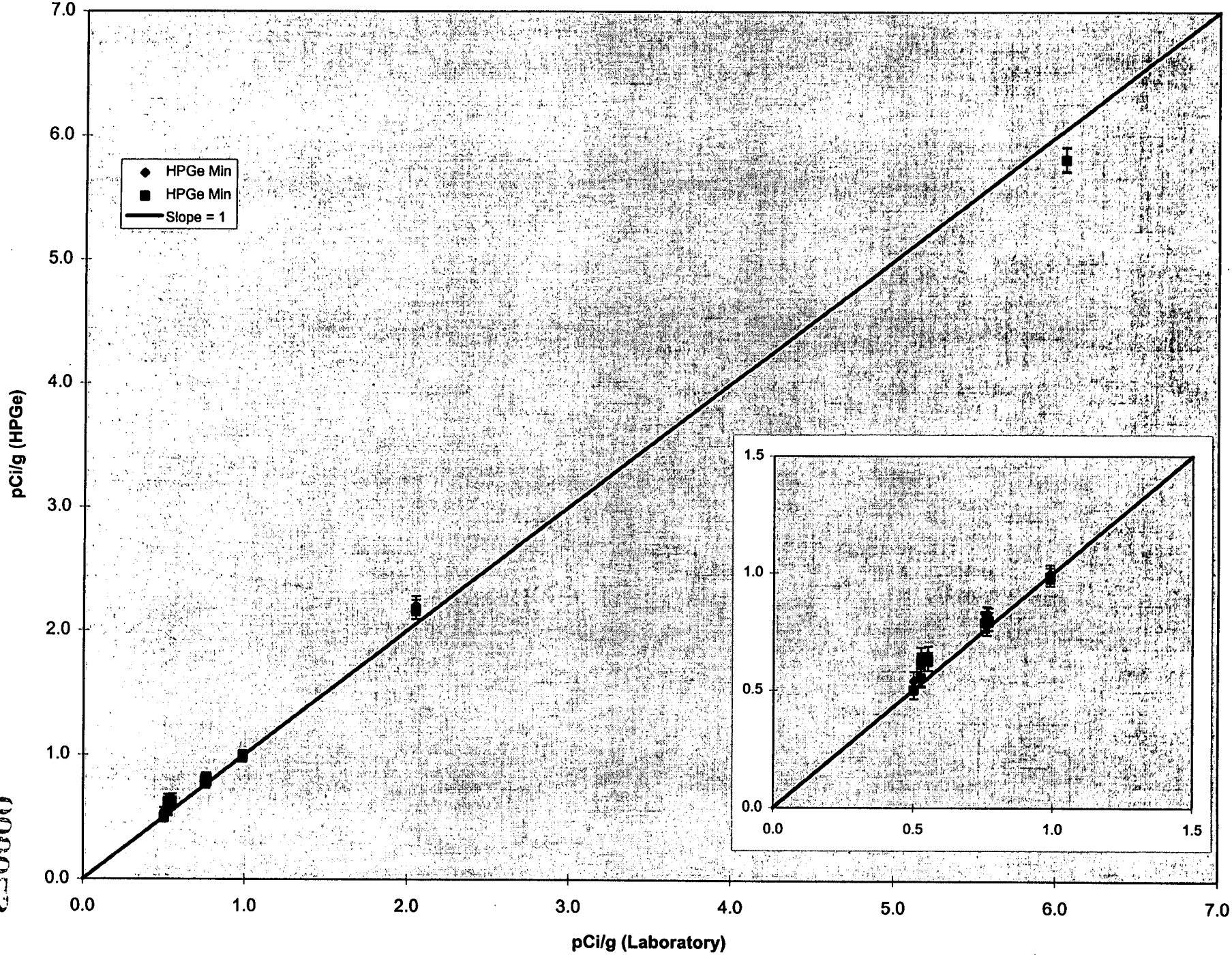


Figure 3-4
Correlation Between 100 cm HPGe and Laboratory Data for Thorium-232

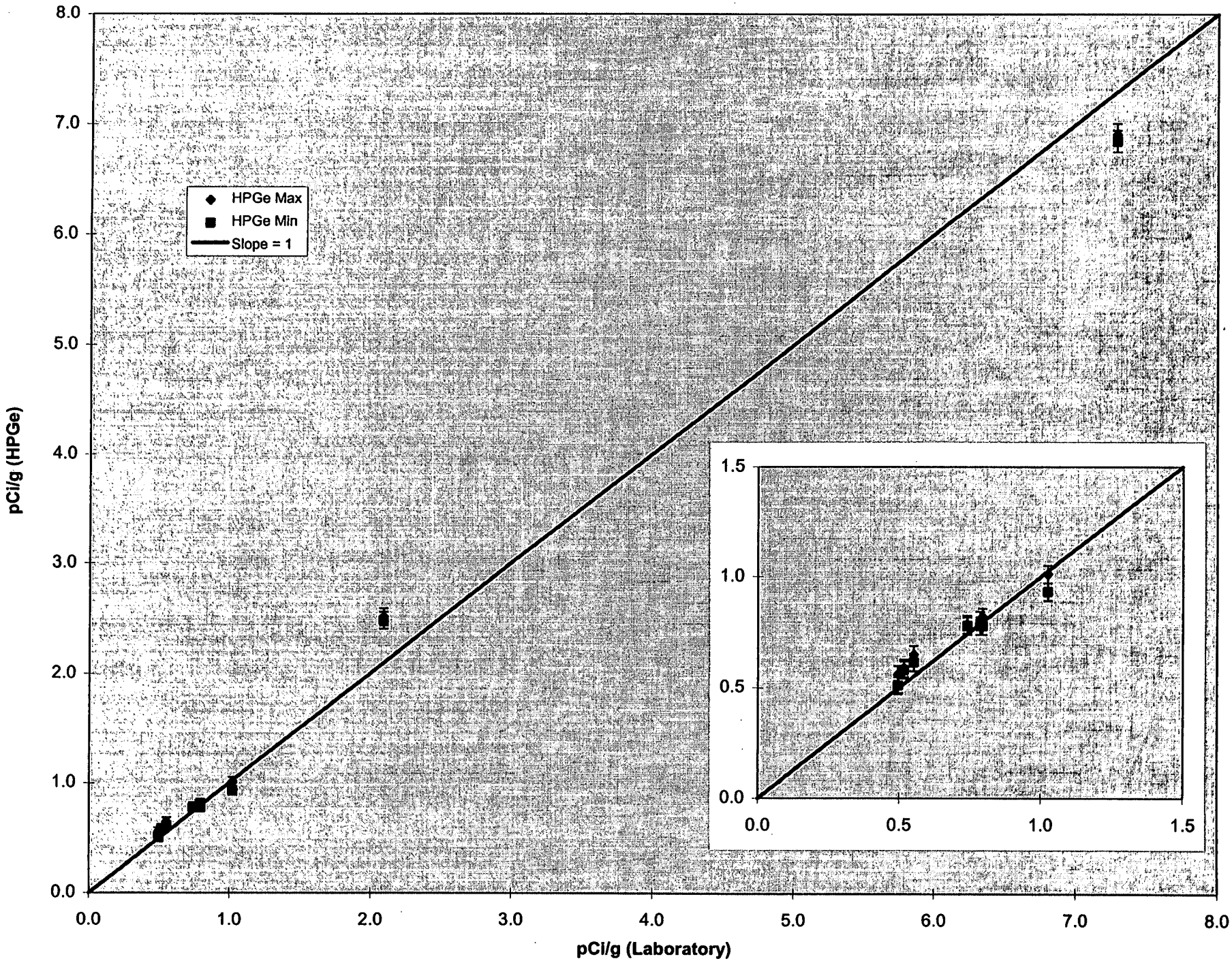


Figure 3-5
Correlation Between 31 cm HPGe and Laboratory Data for Radium-226

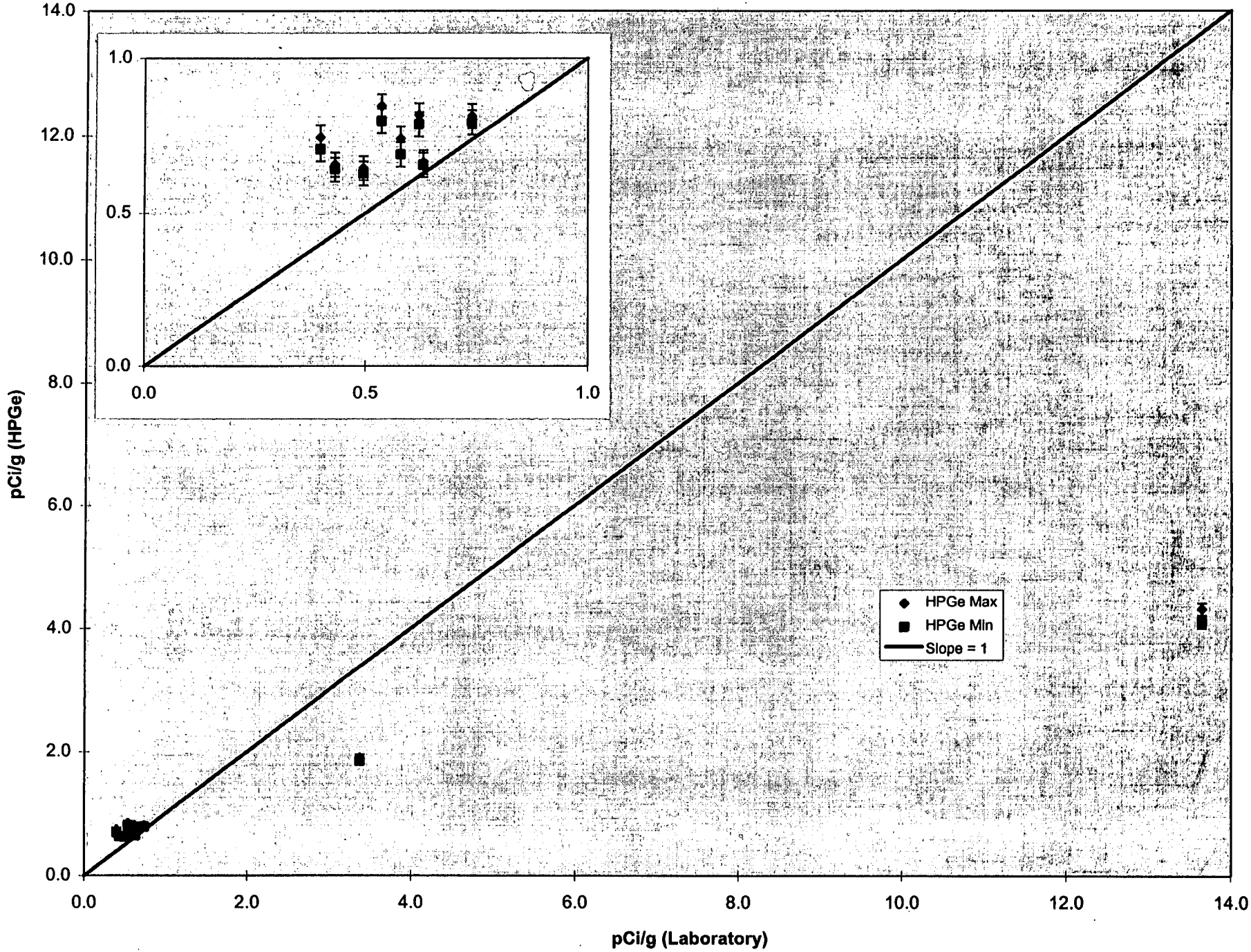


Figure 3-6
Correlation Between 100 cm HPGe and Laboratory Data for Radium-226

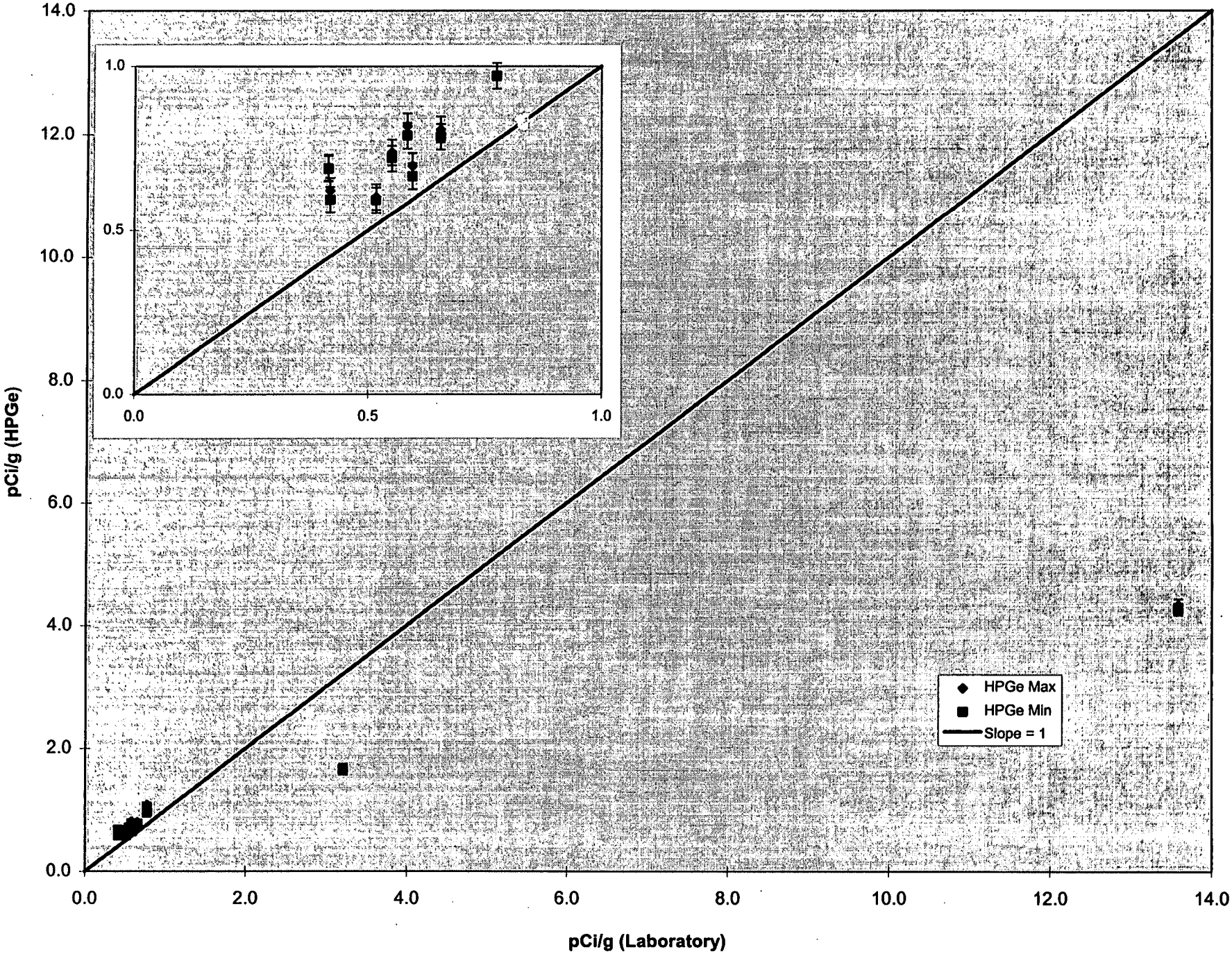


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Figure 3-7
Correlation Between 31 cm HPGe and Laboratory Data for Potassium-40

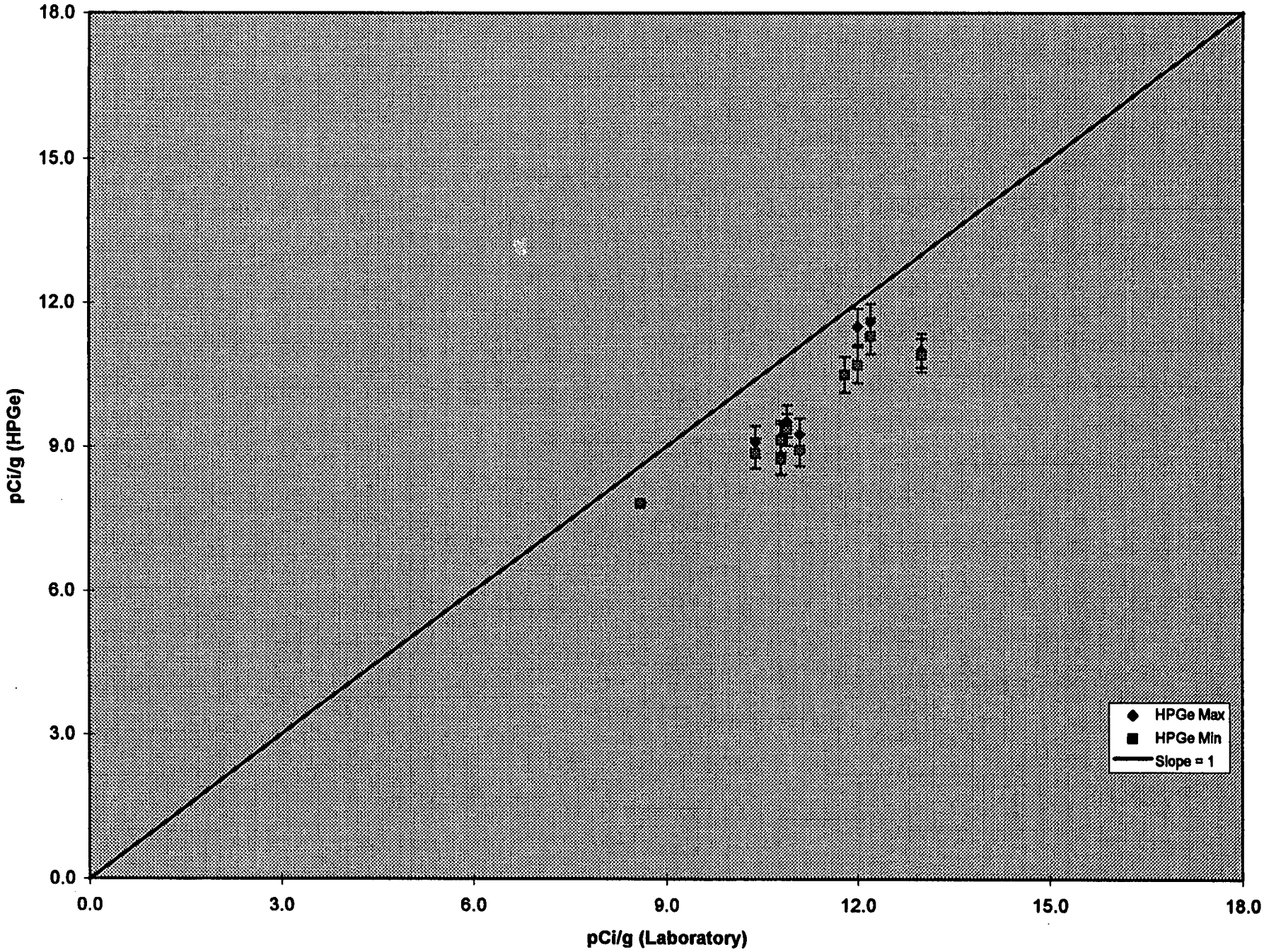


Figure 3-8
Correlation Between 100 cm HPGe and Laboratory Data for Potassium-40

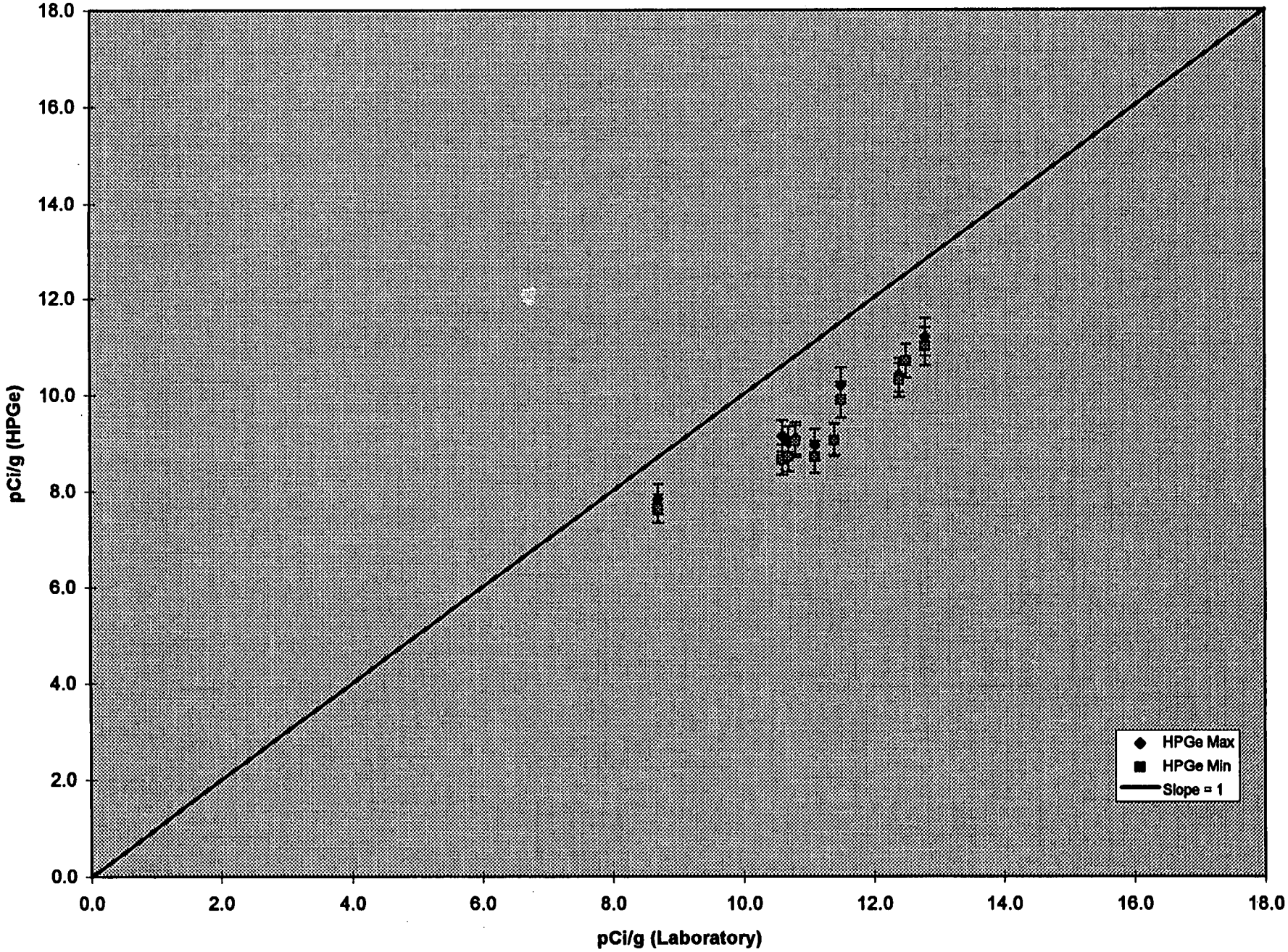


Figure 3-9
Correlation Between 31cm HPGe and Laboratory Data for Cesium-137

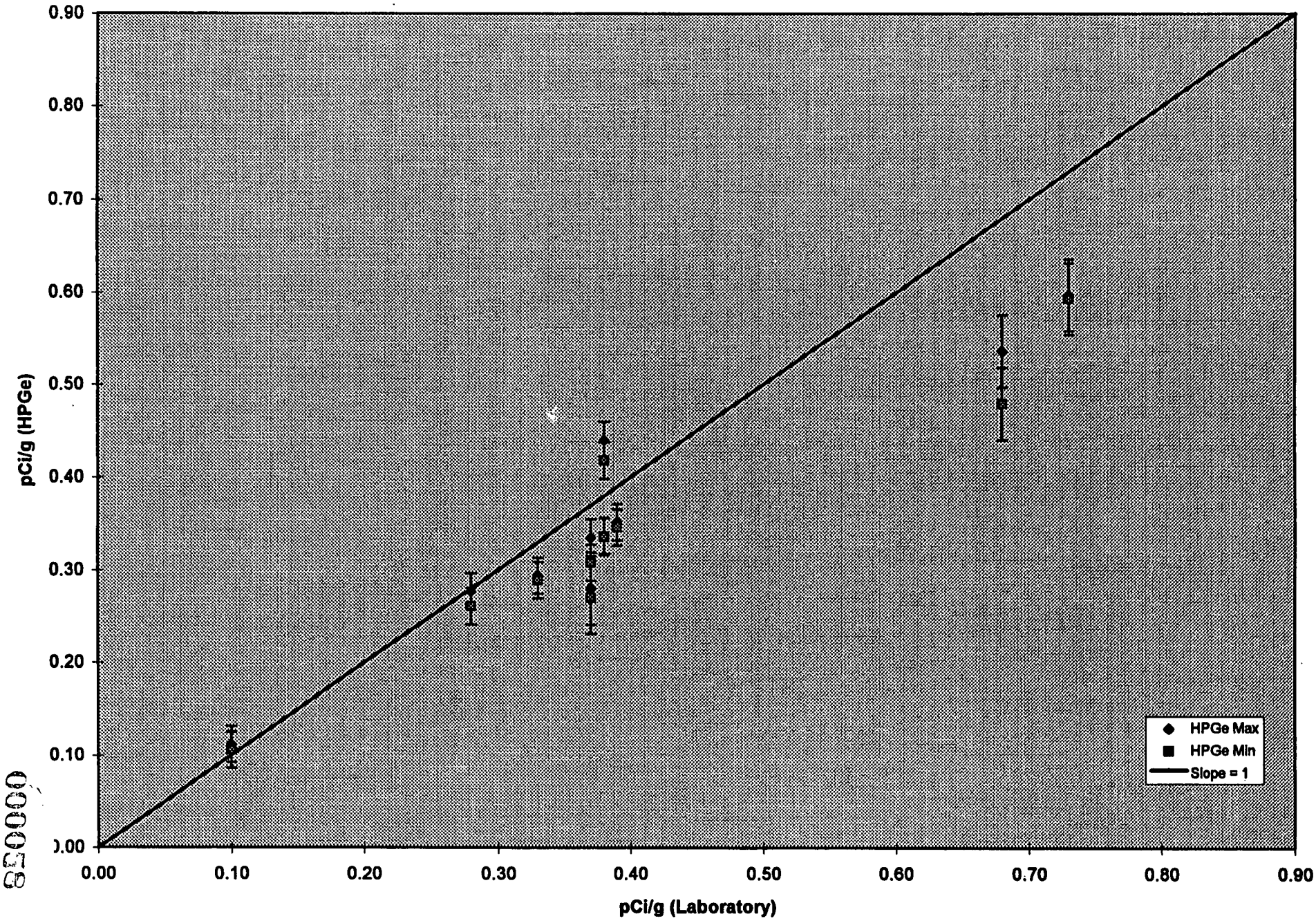


Figure 3-10
Correlation Between 100cm HPGe and Laboratory Data for Cesium-137

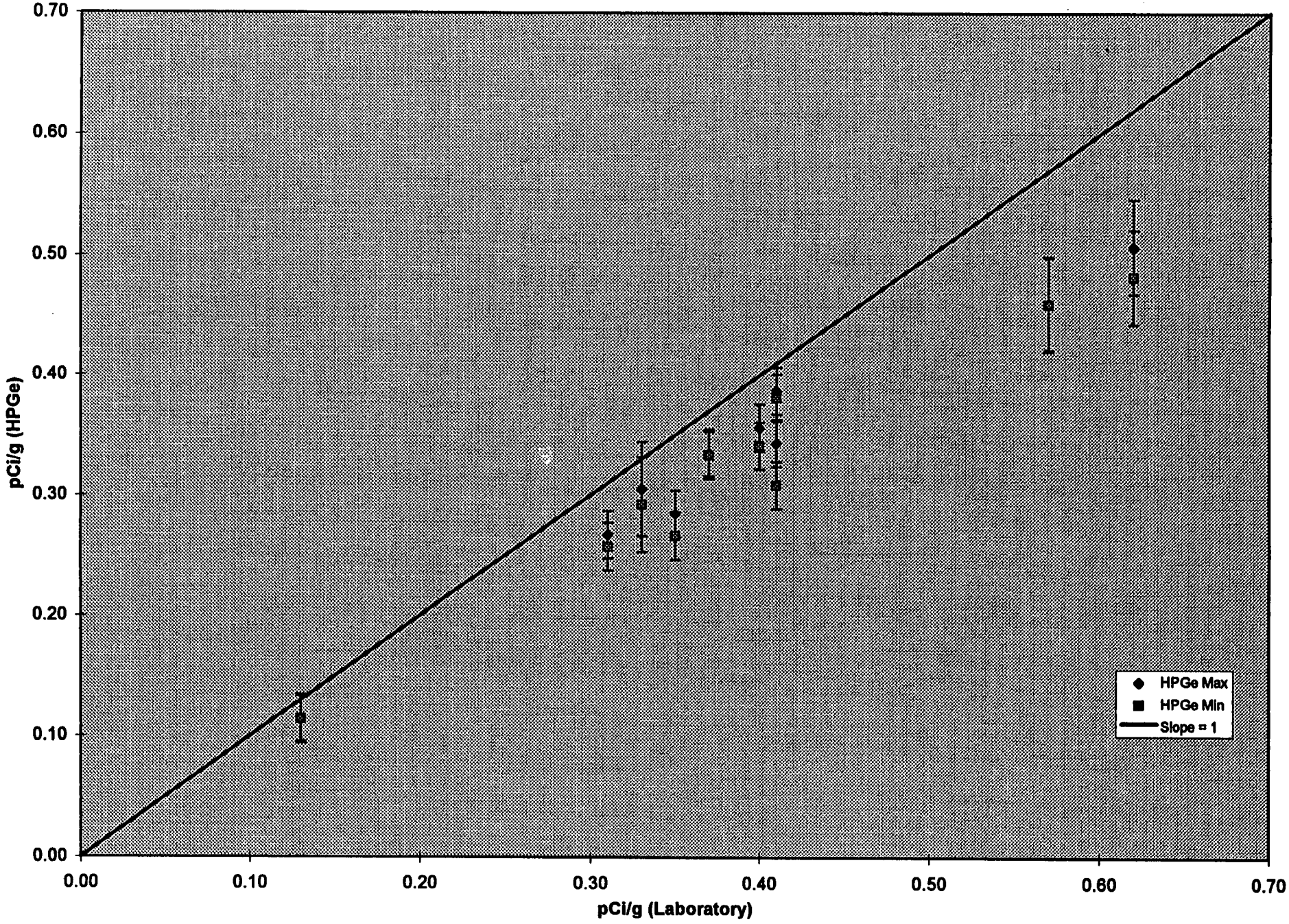
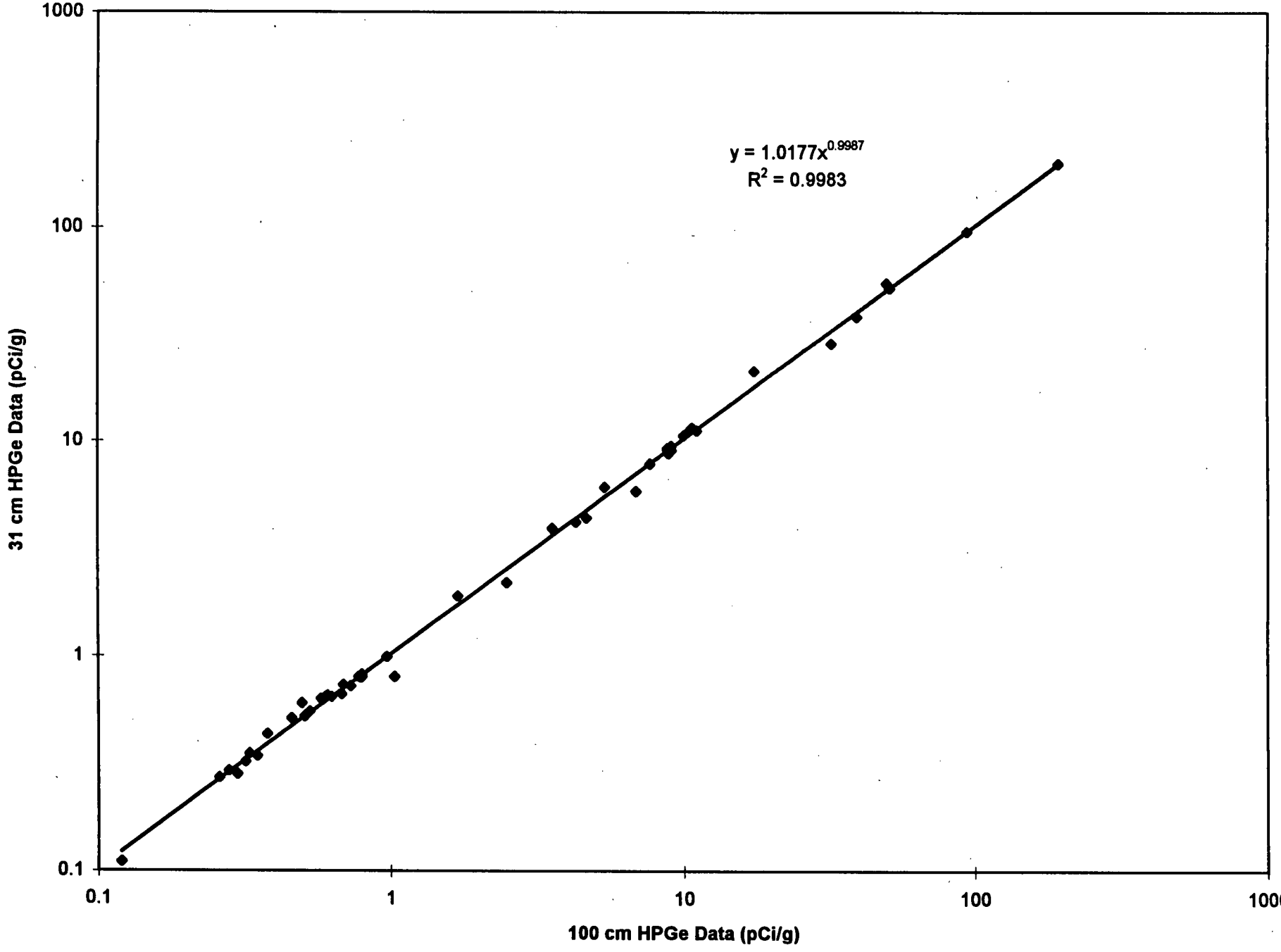


Figure 3-11
Correlation of HPGe 31cm vs 100cm Data
(Includes Total Uranium, Th-232, Ra-226, K-40, and Cs-137)



4.0 DOE ENVIRONMENTAL MEASUREMENTS LABORATORY COMPARABILITY STUDY

4.1 INTRODUCTION

In tandem with the FEMP HPGe measurement and sample collection study described in Section 2, scientists from DOE's Environmental Measurements Laboratory (EML) performed HPGe measurements and collected samples from the same areas as collected by FEMP scientists. The EML study served an independent quality assurance role with respect to sampling, applicability of theory, HPGe field measurements and laboratory analyses. While EML compared laboratory analysis results to HPGe measurements, the EML study also had a focus that was, to a certain extent, different from the focus of the FEMP study. The FEMP study emphasized sample collection in areal, "bullseye" patterns designed to mimic the averaging done by the HPGe field detector. In contrast, the EML study stressed the analysis of soil samples as a function of depth in a given area to ascertain the effects, if any, of vertical source distribution on measured results. This focus by EML was to help validate the applicability of in-situ gamma spectrometry theory at the FEMP.

This section uses data and conclusions from the EML study to complement and reinforce data and conclusions from the FEMP study, which were presented in Section 3. In particular, the EML study is used to demonstrate:

- Comparability of HPGe and laboratory data;
- Comparability of HPGe data collected by two different groups (EML and the FEMP) with two different instruments; and
- Validity of a uniform, vertical source distribution in FEMP soils.

The EML comparability study is presented in Appendix F in the form of two memoranda. The first, dated April 9, 1997, contains all data and data interpretations. The second, dated April 25, 1997, addresses HPGe data usage in soil remediation.

4.2 COMPARABILITY OF EML LABORATORY AND HPGe DATA

The figures contained in the EML reports (Appendix F) present graphs of laboratory measurements vs. HPGe measurements. The dark, solid lines in the graphs represent perfect agreement between laboratory and HPGe data in that they are straight lines through the origin with a slope of 1.0. Using

the 20% relative percent difference (RPD) criterion between laboratory and HPGe measurements as a measure of good comparability (Section 3.2.2), bounding lines representing ±20 percent difference from the perfect agreement line have been drawn in the graphs to represent zones of good comparability.

A majority of the EML data fall well within the perfect agreement ±20% zone for the analytes measured: uranium-238, total uranium, potassium-40, radium-226, and thorium-232. The observed agreement between concentrations inferred from soil sample analysis and in-situ measurements is consistent with similar studies performed by EML over the past 30 years.

It is particularly significant that EML laboratory measurements for total uranium, thorium-232 and radium-226 were obtained using gamma spectrometry, while FEMP laboratory measurements were obtained using alpha spectrometry. Despite the differences between methods, both EML and the FEMP have demonstrated good correlation between laboratory and HPGe measurements for total uranium and thorium-232. EML has also demonstrated good correlation between laboratory and HPGe measurements for radium. Thus, the EML and the FEMP data taken together demonstrate that comparability of HPGe and laboratory data is not dependent on specific laboratory methods.

4.3 COMPARABILITY OF HPGe DATA

Both EML and the FEMP performed HPGe measurements at the same locations with different instruments and crews. Tables 4-1 and 4-2 compare HPGe measurements made by EML and FEMP crews for total uranium, thorium-232, potassium-40, and radium-226. The degree of closeness between the data is expressed by the relative precent deviation, as defined in Section 3.2.2, and as given at the bottom of each table.

All the pairs of measurements fall well within the 20 percent criterion for good comparability except for a few pairs of uranium measurements (PBC-01, PBC-08, and PBC-09) in which uranium concentrations are near the minimum detectable concentration of the HPGe. Because measurements become less accurate and precise near detection limits, larger relative precent deviations are not surprising for these data.

Examination of the data in Tables 4-1 and 4-2 reveals no apparent consistent bias between the two HPGe systems for total uranium and radium-226. Thus, there are approximately equal numbers of results where FEMP data are either high or low relative to the EML data, and the average RPDs taking signs into account are close to zero for total uranium and radium-226. However, the FEMP HPGe consistently measured low relative to the EML HPGe for thorium-232 and potassium-40. Nonetheless, these data still represent good comparability.

Bias between FEMP and EML HPGe data was also examined using the Wilcoxon Signed Ranks Test. This test is nonparametric in that population distributions are not assumed to be normal. The procedure for performing the Wilcoxon Signed Ranks Test is taken from the National Bureau of Standards Handbook 1991 (Natrella 1963) and is briefly outlined in Appendix G. Results of these statistical tests (Table G-1) support the conclusions made based upon examination of Tables 4-1 and 4-2: there appears to be no bias between the two HPGe systems for total uranium and radium-226, while there does appear to be bias between the two systems for thorium-232 and potassium-40. Reasons for the bias between the two systems will be investigated.

4.4 CONFIRMATION OF A UNIFORM, VERTICAL SOURCE DISTRIBUTION

As explained in Appendices E and F, the algorithms used by EML to calculate concentrations (pCi/g) assume a uniform horizontal and vertical source distribution. A vertical source distribution may or may not be consistent with the actual contamination patterns. Data from the EML and FEMP studies demonstrate that the assumption of a uniform vertical source distribution is valid in that observed deviations of analyte concentrations from non-uniformity are minor and do not introduce significant errors in the calculation of concentrations.

The analyte concentration vs. depth profiles presented in Figures 4-1 through 4-4 are based upon EML study data. The concentrations of analytes in the 5-10 and 10-15 cm sections are displayed as ratios relative to the concentration of the same analytes in the 0-5 cm depth section. The data for Areas 4, 5, and 6 displayed in the figures are averages of multiple cores that were taken from each area. For example, in Area 5, three different core samples were taken for laboratory analysis of the 0-5, 5-10, and 10-15 cm core intervals.

As shown in Figures 4-1 through 4-4, Area 4 has essentially uniform distributions with depth for all of the analytes. Areas 5 and 6 show a decrease in total uranium in the 10-15 cm section, and a slight increase in thorium-232, potassium-40, and radium-226 concentrations in the 5-15 cm depth range. In practice, because most of the gamma rays detected by the HPGe originate from the top 10 cm of soil, the depth profiles shown can be considered uniform with respect to source distribution, and thus should not introduce significant errors in calculated concentrations.

This assertion can be verified through examination of HPGe measurements for uranium-238 based upon gamma photons having three different energies (63.2 keV, 92.6 keV, and 1001.1 keV). High energy gamma photons such as the 1001.1 keV photon are less attenuated by soil than low energy photons and can, in effect, "see" further into the soil. As a result, the calculated concentration of uranium-238 from the 1001.1 keV photon, relative to those from the 63.2 and 92.6 keV photons, can provide information pertaining to vertical source distribution (Miller, et. al, 1994). Where the concentration of uranium-238 calculated for the 1001.1 keV photon is substantially greater than uranium-238 calculated from the 63.2 and 92.6 keV gamma photons, a source distribution that increases with depth is indicated. Conversely, where the concentration of uranium-238 calculated from the 1001.1 keV photon is significantly less than those calculated from the lower energy photons, a source distribution that falls off with depth is indicated.

Tables 4-3 and 4-4 show uranium-238 concentrations calculated for each of the three energy gamma photons. Areas 1, 8, and 9 are not included because uranium-238 activities were too low for one or more of the three photons to be consistently detected above instrument background for those areas. Tables 4-3 and 4-4 include the 1.96 σ total propagated counting errors. Figures 4-5 through 4-8 are cross plots of uranium-238 based upon the 1001.1 keV gamma photons vs. uranium-238 based upon either the 63.2 or 92.6 keV gamma photons. A line of perfect correlation, i.e. a slope of 1.0 and y-intercept of 0.0, is shown for reference. A large majority of the points lie near the line and are not significantly different from it based upon overlap of the 1.96 σ error bars, so the data do not indicate significant deviations from the assumption of a uniform, vertical source distribution. Therefore, HPGe soil attenuation data are consistent with depth profiles based upon laboratory data.

4.5 SUMMARY

The results of the EML Comparability Study both reinforce and augment those of the FEMP Comparability Study. The good comparability EML demonstrated between laboratory gamma spectrometry and HPGe measurements reinforces the good comparability obtained by the FEMP between laboratory alpha and HPGe measurements. The fact that good agreement was obtained by two different laboratory analytical methods and HPGe strengthens the validity of HPGe methodology. This validity is further demonstrated by good agreement between HPGe measurements made by two different instruments operated by two different scientific parties. Finally, the laboratory measurements on soil cores made by EML to ascertain depth profiles of certain analytes verifies the assumption of a uniform source distribution with depth. Soil analytical data are consistent with HPGe data based upon the relative attenuation in soil of low energy and high energy gamma photons.

TABLE 4-1
COMPARISON OF EML AND FEMP HPGe DATA (31 cm)

Area[a]	Total Uranium			Thorium-232			Radium-226			Potassium-40		
	FEMP (ppm)	EML (ppm)	RPD[b] (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)
PBC-01	9.0	10	(-)10.5	0.52	0.62	(-)17.5	0.64	0.58	(+)9.8	11.4	12.1	(-)6.0
PBC-02	31.3	32	(-)2.2	0.64	0.75	(-)15.8	0.66	0.60	(+)9.5	7.8	8.1	(-)3.8
PBC-04	56.5	55	(+)2.7	0.80	0.86	(-)7.2	0.82	0.87	(-)5.9	9.4	10.0	(-)6.2
PBC-05	42.2	38	(+)10.5	0.79	0.86	(-)8.4	0.72	0.68	(+)5.7	11.0	11.7	(-)6.2
PBC-06	76.7	75	(+)2.2	0.81	0.91	(-)11.6	0.80	0.88	(-)9.5	9.1	9.8	(-)7.41
PBC-07	141	153	(-)8.2	0.99	1.11	(-)11.4	0.80	0.78	(+)2.5	9.0	9.6	(-)6.4
PBC-08	5.8	3	(+)63.6	0.55	0.62	(-)12.0	0.65	0.71	(-)8.8	8.7	9.7	(-)10.9
PBC-09	6.5	7	(-)7.4	0.63	0.67	(-)6.2	0.73	0.82	(-)11.6	9.2	9.9	(-)7.3
PBC-10	80.9	80	(+)1.1	5.8	6.26	(-)7.6	1.9	1.77	(+)7.1	10.5	10.7	(-)1.9
		Mean RPD = 12.0			Mean RPD = 10.8			Mean RPD = 7.8			Mean RPD = 6.2	
		Mean RPD* = +5.8			Mean RPD* = -10.8			Mean RPD* = -0.13			Mean RPD* = -6.2	

[a] Area PBC-03 not measured by EML

[b] $RPD = \frac{|FEMP - EML|}{Average}$

$$Average = \frac{FEMP + EML}{2}$$

* mean RPD taking into account the sign (+ or -) of the relative deviation in order to reflect bias.

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TABLE 4-2
COMPARISON OF EML AND FEMP HPGe DATA (100 cm)

Area[a]	Total Uranium			Thorium-232			Radium-226			Potassium-40		
	FEMP (ppm)	EML (ppm)	RPD* (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)	FEMP (pCi/g)	EML (pCi/g)	RPD (%)
PBC-01	8.0	14	(-)54.5	0.51	0.60	(-)16.2	0.60	0.56	(+)6.9	10.7	12.0	(-)11.4
PBC-02	26.0	24	(+)8.0	0.63	0.75	(-)17.4	0.68	0.75	(-)9.8	7.7	8.1	(-)5.1
PBC-04	58.6	56	(+)4.5	0.78	0.85	(-)8.6	0.80	0.81	(-)1.2	9.1	9.9	(-)8.4
PBC-05	47.9	50	(-)4.3	0.79	0.92	(-)15.2	0.73	0.68	(+)7.1	10.4	11.0	(-)5.6
PBC-06	75.9	77	(-)1.4	0.80	0.88	(-)9.5	0.80	0.82	(-)2.5	8.8	9.6	(-)8.7
PBC-07	140	152	(-)8.2	0.97	1.05	(-)7.9	1.03	0.80	(+)25.1	9.1	9.9	(-)8.4
PBC-08	5.3	4	(+)27.9	0.53	0.61	(-)14.0	0.61	0.67	(-)9.4	8.9	9.8	(-)9.6
PBC-09	6.9	4.5	(+)42.1	0.58	0.66	(-)12.9	0.69	0.80	(-)14.8	8.8	9.8	(-)10.8
PBC-10	74.0	73.1	(+)1.2	6.9	7.64	(-)10.2	1.7	1.73	(-)1.7	10.0	10.7	(-)6.8
		Mean RPD = 16.8			Mean RPD = 12.4			Mean RPD = 8.7			Mean RPD = 8.3	
		Mean RPD* = +1.7			Mean RPD* = -12.4			Mean RPD* = -0.03			Mean RPD* = -8.3	

[a] Area PBC-03 not measured by EML

[b] $RPD = \frac{|FEMP - EML|}{Average}$

$$Average = \frac{FEMP + EML}{2}$$

* mean RPD taking into account the sign (+ or -) of the relative deviation in order to reflect bias

TABLE 4-3
GAMMA PHOTONS USED TO QUANTIFY U-238 AT 31 cm HPGe DETECTOR HEIGHT*

Area[a]	63.2 keV				92.6 keV				1001.1 keV			
	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)
PBC-02	11	1.76	12	2.48	11	0.99	11	1.30	9.2	0.92	9.6	1.25
	14	1.82			11	0.88			9.9	0.89		
PBC-03	110	3.30	110	4.57	99	1.98	96	2.65	96	1.92	93	2.63
	110	3.30			92	1.84			94	1.88		
PBC-04	21	1.26	21	1.89	19	0.76	18	1.02	18	1.08	18	1.50
	21	1.47			18	0.72			18	1.08		
PBC-05	16	1.92	16	2.63	13	0.91	13	1.26	15	1.05	14	1.50
	17	1.87			13	0.91			14	1.12		
PBC-06	27	1.35	27	1.87	26	0.78	26	1.08	26	1.04	25	1.55
	27	1.35			26	0.78			24	1.20		
PBC-07	50	1.50	51	2.12	46	0.92	46	1.28	49	1.47	48	1.98
	52	1.56			46	0.92			46	1.38		
PBC-10	29	1.74	29	2.41	29	1.16	28	1.58	22	1.54	22	2.02
	29	1.74			28	1.12			23	1.38		

[a] Areas exclude PBC-01, PBC-08, and PBC-09 because one or more of the 63.2, 92.6, and 1001.1 keV photons not detected.
[b] 1.0 σ counting error
[c] 1.96 σ propagated counting error

* Data were collected using FEMP HPGe

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TABLE 4-4
GAMMA PHOTONS USED TO QUANTIFY U-238 AT 1.0 m HPGe DETECTOR HEIGHT*

Area[a]	63.2 keV				92.6 keV				1001.1 keV			
	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)	U-238 (pCi/g)	σ [b] (pCi/g)	Ave (pCi/g)	TPU[c] (pCi/g)
PBC-02	11	1.98	11	2.66	8.0	0.96	8.9	1.34	7.4	0.89	7.9	1.25
	11	1.87			9.8	0.98			8.4	0.92		
PBC-03	100	4.00	100	5.55	98	1.96	96	2.65	95	1.90	94	2.60
	100	4.00			93	1.86			93	1.86		
PBC-04	22	1.54	22	2.09	20	0.80	20	1.08	19	1.14	19	1.58
	21	1.47			19	0.76			19	1.14		
PBC-05	17	1.87	18	2.61	15	0.90	14	1.30	16	1.12	17	1.52
	19	1.90			14	0.98			18	1.08		
PBC-06	26	1.56	28	2.09	24	0.72	26	1.06	25	1.25	26	1.77
	29	1.45			27	0.81			26	1.30		
PBC-07	52	1.56	50	2.10	46	0.92	46	1.28	46	1.38	46	1.91
	49	1.47			46	0.92			46	1.38		
PBC-10	24	1.92	24	2.60	27	1.08	27	1.50	22	1.54	22	2.13
	23	1.84			27	1.08			22	1.54		

[a] Areas exclude PBC-01, PBC-08, and PBC-09 because one or more of the 63.2, 92.6, and 1001.1 keV photons not detected.
[b] 1.0 σ counting error
[c] 1.96 σ propagated counting error

* Data were calculated using FEMP HPGe

Figure 4-1
TOTAL URANIUM DEPTH PROFILES

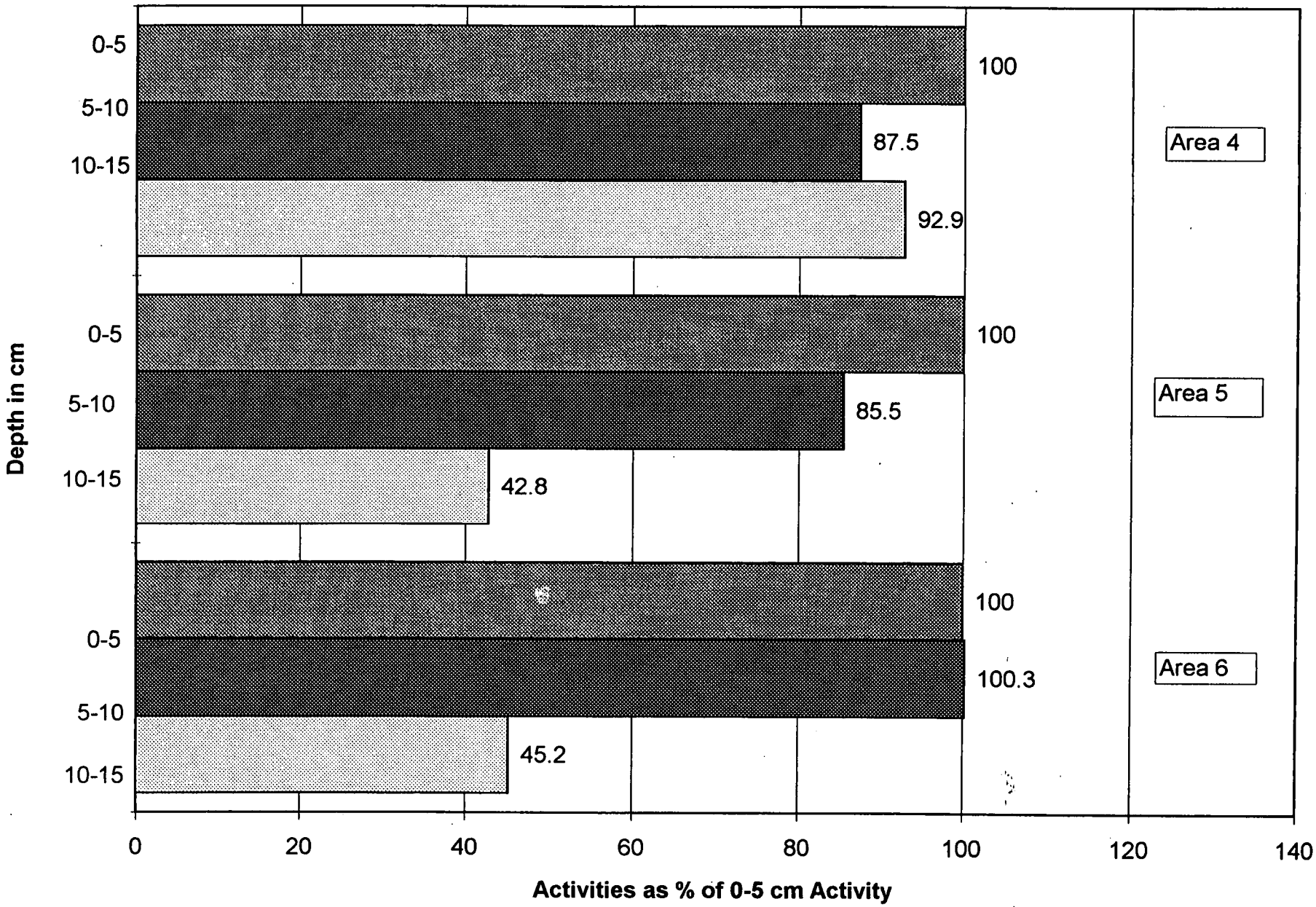


Figure 4-2
THORIUM-232 DEPTH PROFILES

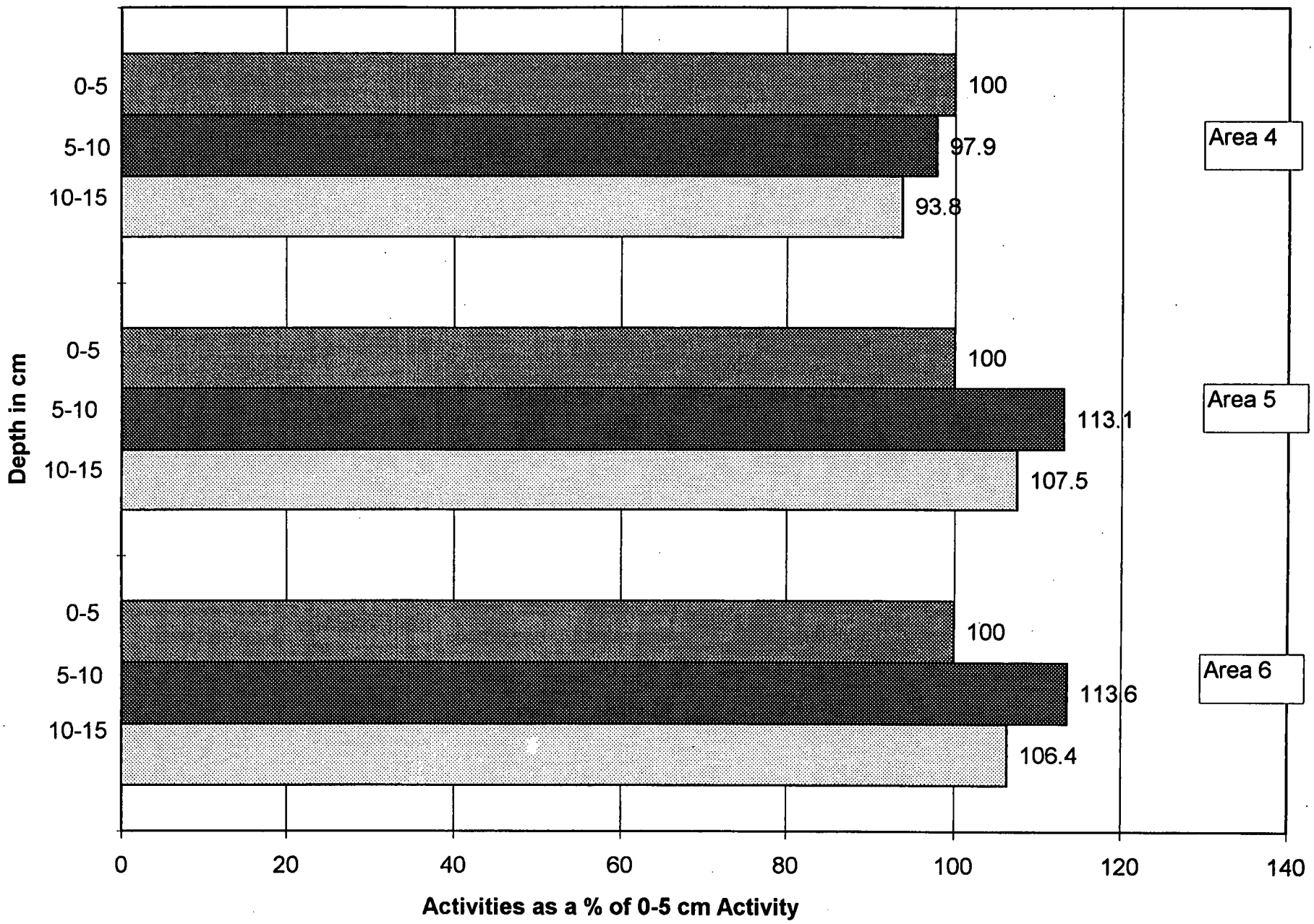


Figure 4-3
RADIUM-226 DEPTH PROFILES

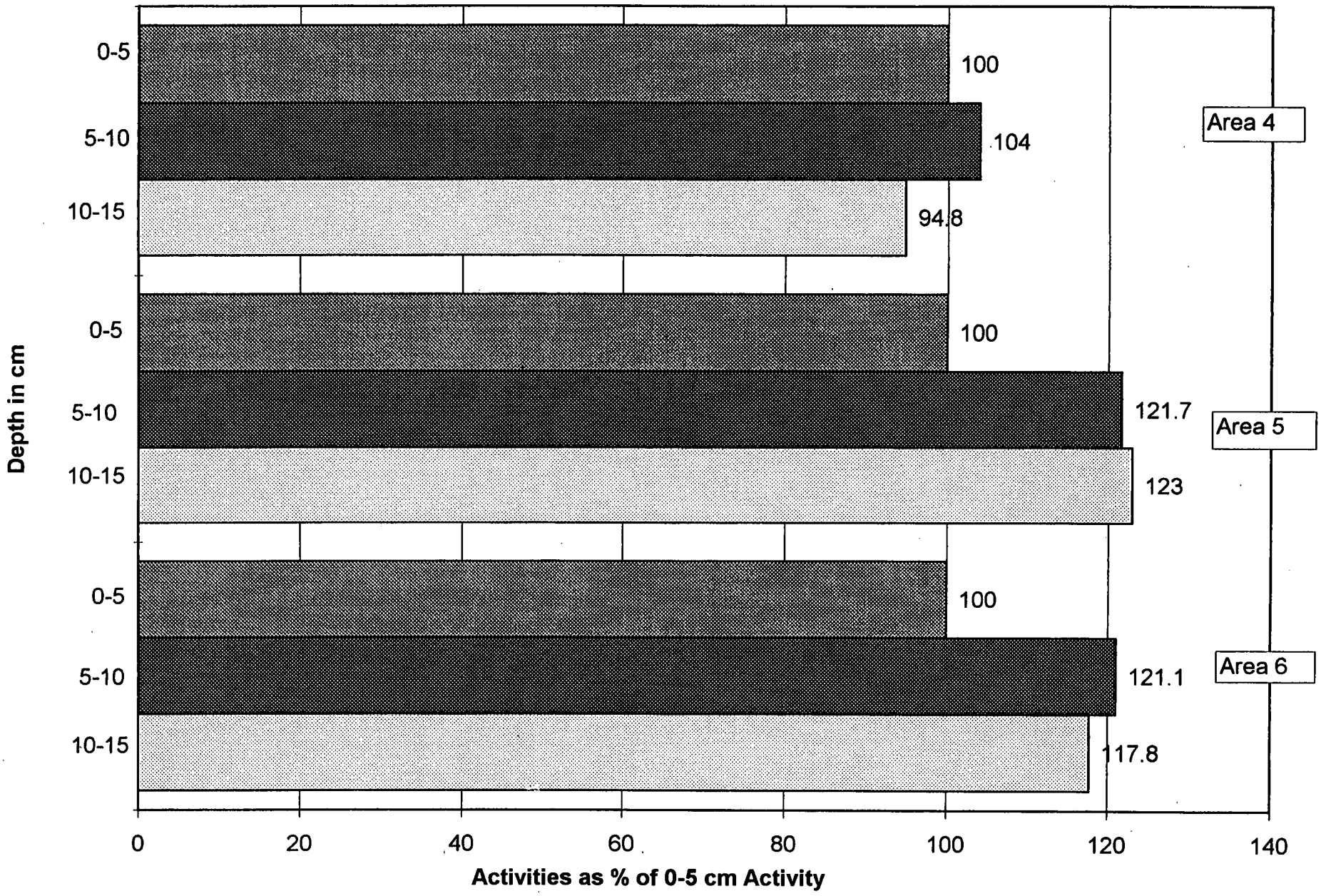


Figure 4-4
POTASSIUM-40 DEPTH PROFILES

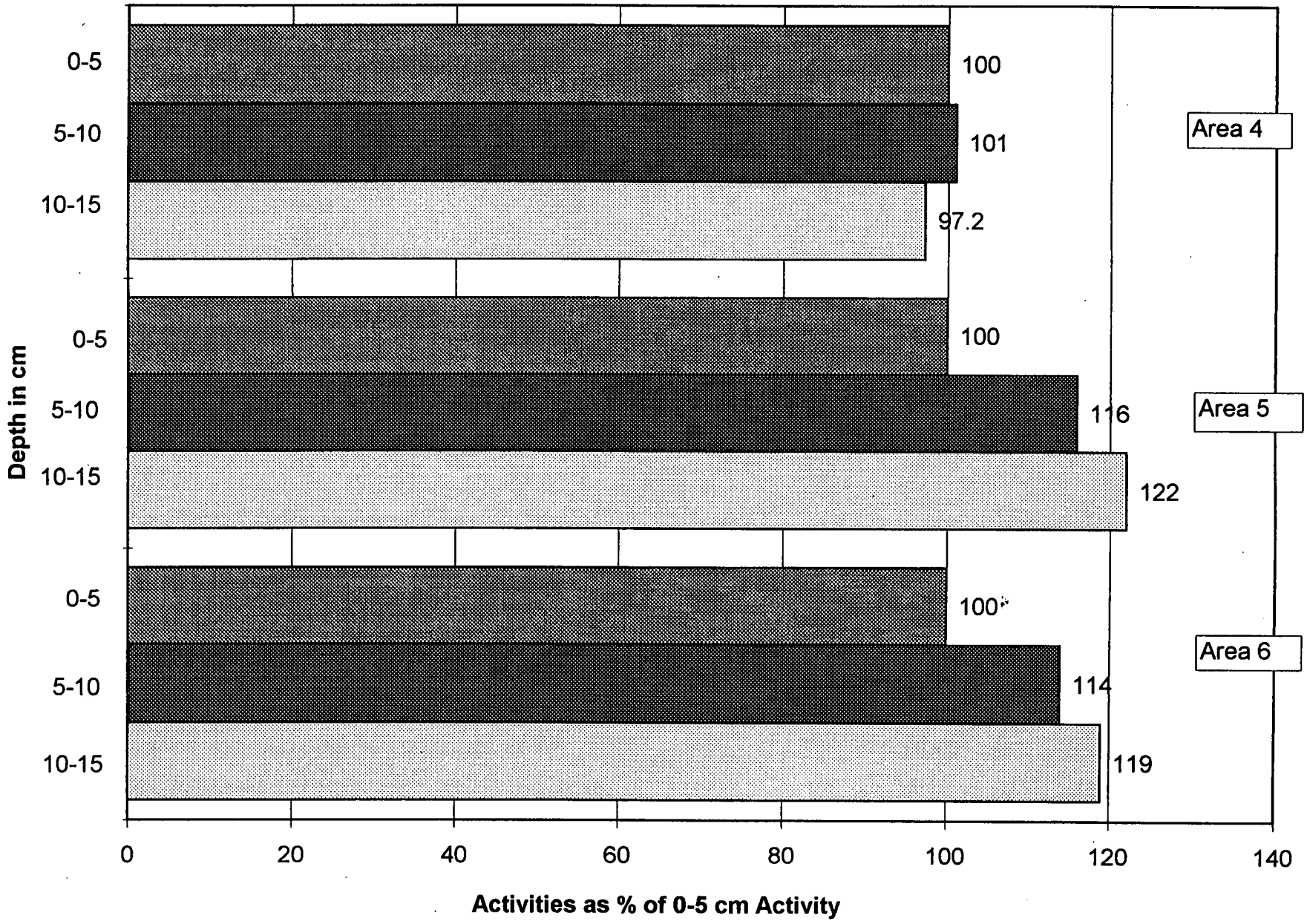


Figure 4-5
Concentration of U-238 based upon 63.2 and 1001.1 keV Gamma Photons at a 31 cm HPGe Detector Height

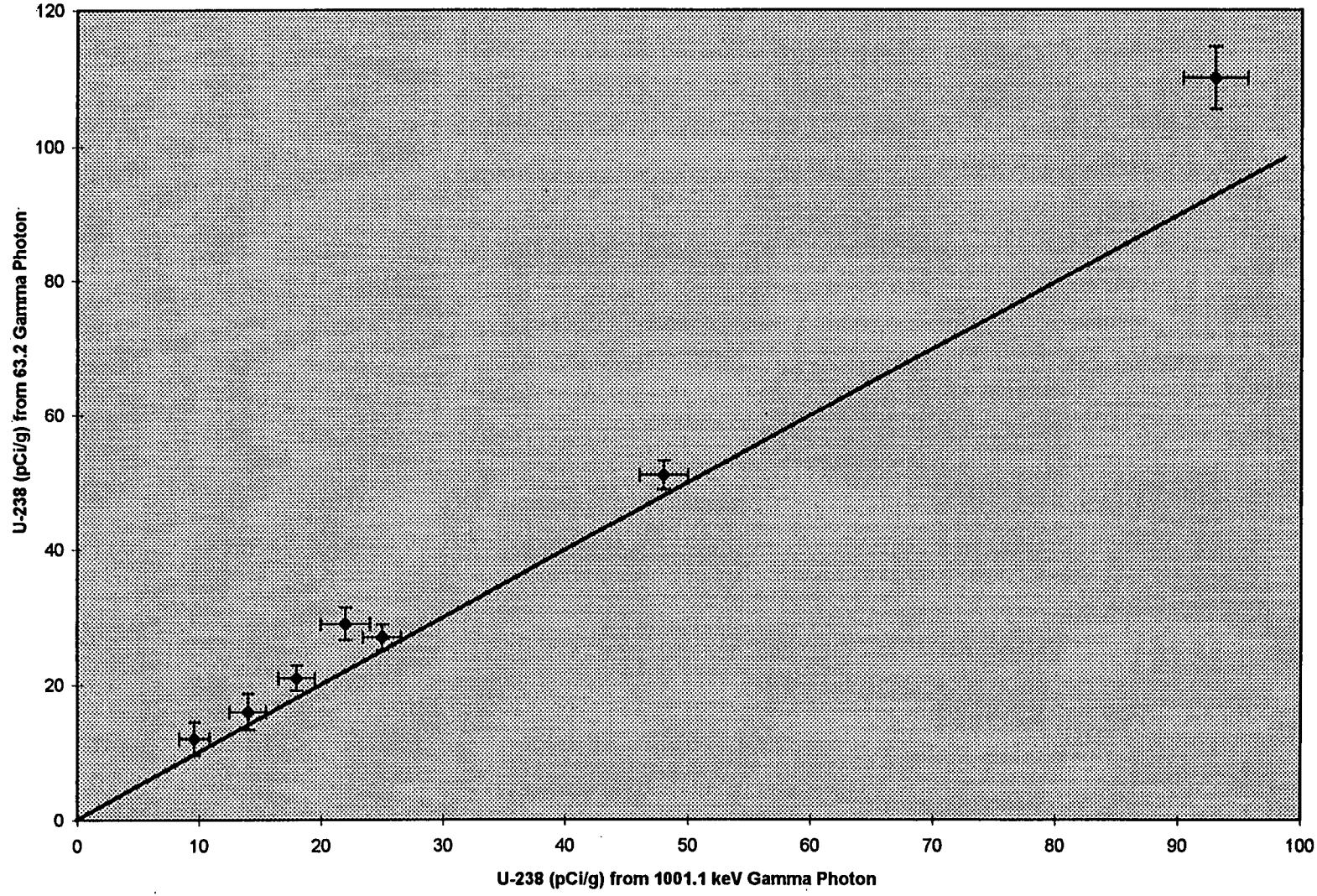


Figure 4-6
Concentration of U-238 based upon 92.6 and 1001.1 keV Gamma Photons at a 31 cm HPGe Detector Height

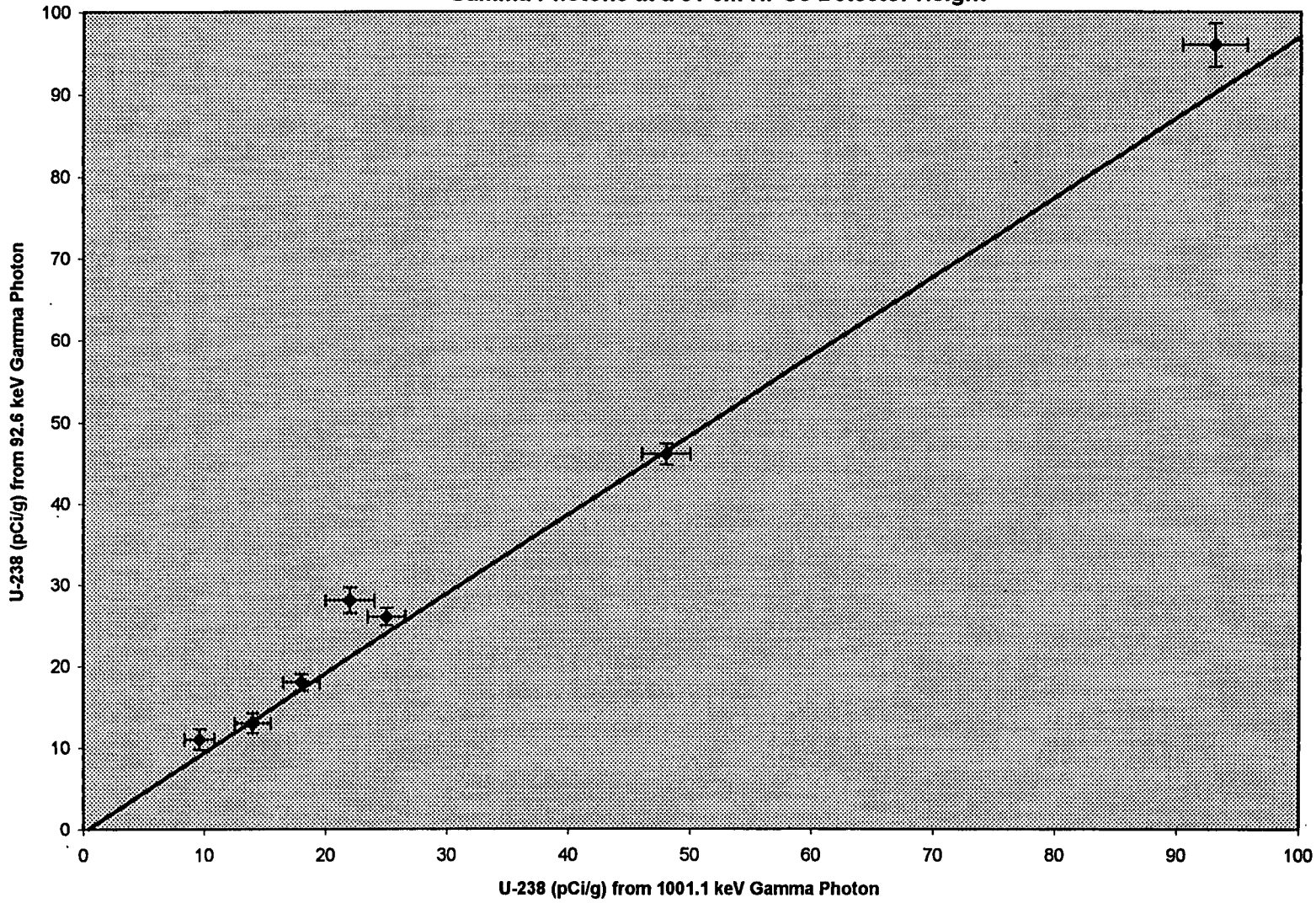


Figure 4-7
Concentration of U-238 based upon 63.2 and 1001.1 keV Gamma Photons at a 1.0 m HPGe Detector Height

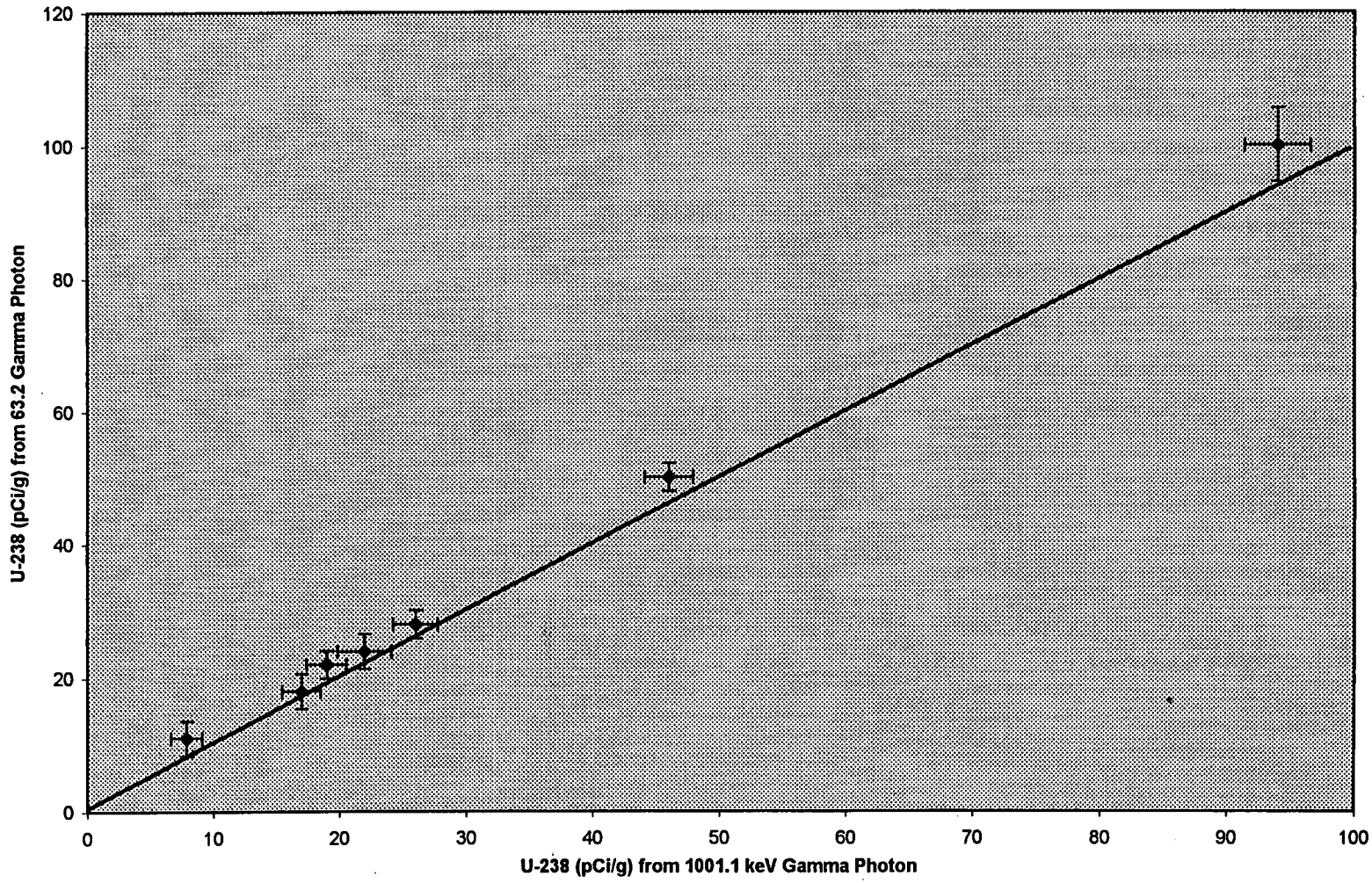
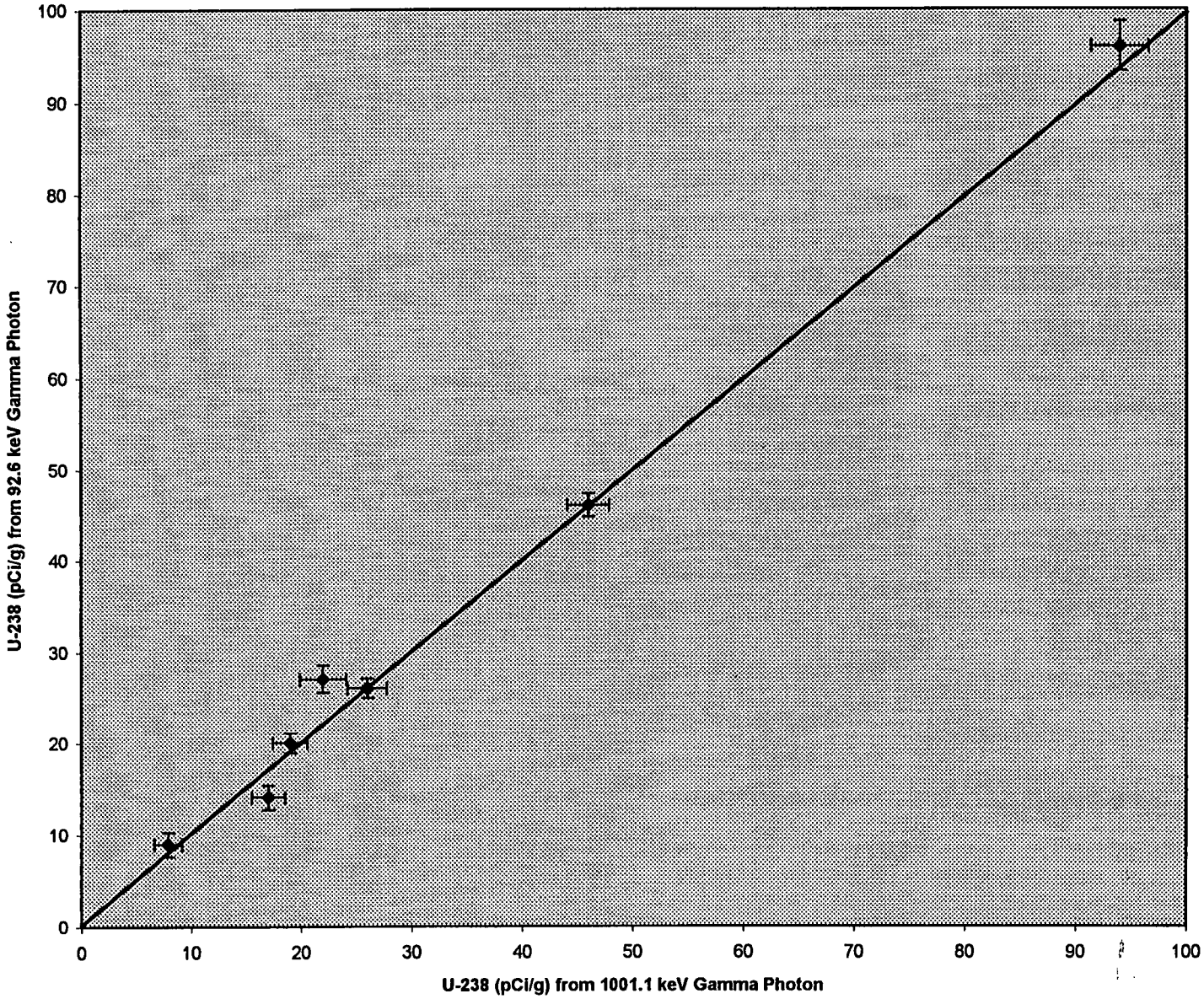


Figure 4-8
Concentrations of U-238 based upon 92.6 and 1001.1 keV Gamma Photons at a 1.0 m HPGe Detector Height



5.0 DATA QUALITY ELEMENTS

5.1 DATA QUALITY ELEMENTS

As the objectives in Section 1.3 indicate, results from the comparability study will be used to determine the capabilities of the HPGe for generating data of known quality and usefulness. The results must be sufficiently detailed and specific to facilitate decision-making on the applicability of HPGe to meet data quality objectives (DQOs) for radiological COCs relative to WAC attainment, certification of clean closure, delineation of areas with elevated soil contamination, and delineation of soil volumes containing contamination above and below FRLs. As Objectives 4 and 5 (Section 1.3) specify, a major emphasis of the comparability study is to delineate key data quality elements and to establish values, limits, or acceptance criteria for them. Such parameters can then be compared directly to FRLs or to DQOs.

The principal DQOs and/or quality control elements of significance are:

- Accuracy and bias;
- Precision;
- MDC;
- Calibration;
- Linearity; and
- Robustness.

5.1.1 Data Categories

In September 1993, the US Environmental Protection Agency (EPA) issued the interim final guidance document for the data quality objectives process for Superfund projects (EPA 1993). The document defines two categories of data: 1) screening data with definitive confirmation; and 2) definitive data. Screening data with definitive confirmation are defined as data generated by rapid, less precise methods of analysis. The data provide identification and quantification, although the data may be relatively imprecise. Definitive data are defined as data generated using rigorous analytical methods, such as approved EPA reference methods. Methods produce tangible raw data such as spectra in the form of paper printouts or computer-generated electronic files. For the data to be definitive, either analytical or total measurement errors must be determined. The quality assurance/quality control (QA/QC) elements defined for these two data categories match the requirements of the SCQ for ASLs B and D, respectively. ASL B corresponds to screening data with definitive confirmation and ASL D

corresponds to definitive data. Because the HPGe is envisioned as definitive for certification use as well as for less regulated uses such as excavation control, for which screening data are required, this section of the Comparability Study Report delineates QC elements and the acceptance criteria needed for ASL B and ASL D analyses.

5.2 ACCURACY AND BIAS

Accuracy of a measurement is the closeness of a measurement to its accepted true value. Bias is the systematic error of a measurement relative to its accepted value. HPGe detects and measures gamma rays from an approximately 100 m^2 area when positioned one meter above the ground. Thus, it measures an average value for the area. To approximate the average value for this same 100 m^2 area by laboratory measurements, a series of physical samples were collected throughout the area, and the data were weighted and averaged as described in Section 3. Assessing accuracy and bias, then, for the HPGe depends on a comparison of HPGe measurements with the average of weighted discrete samples analyzed in the laboratory by alpha or gamma spectrometry. The closeness of HPGe and laboratory measurements will be considered a measure of accuracy, and systematic differences between HPGe and laboratory measurements will indicate a bias. Because of the nature of the experiments as explained in Section 3.1.1, an absolute bias cannot be definitively assigned to either HPGe or laboratory measurements without independent evidence.

In the following sections, quality control acceptance criteria are proposed for HPGe accuracy and precision. Guidance for acceptance limits can be adopted from laboratory acceptance criteria. Currently, four quality control parameters are used by laboratories to provide information on accuracy and precision. These are: relative percent deviation (RPD) of duplicates, matrix spikes, matrix spike duplicates, and laboratory control standards. Table 5-1 contains current acceptance limits based upon CLP-SOW for inorganics and SW-846 methods for metals. Information in Table 5-1 is taken from the "Guide to Environmental Analytical Methods" (Wagner 1996) and "Environmental Laboratory Data Evaluation" (Berger, et. al., 1996).

5.2.1 Accuracy

As discussed in Section 3.2, when the relative deviation between HPGe and the average weighted laboratory data is less than 20%, the data are defined as very similar. When the relative deviation between HPGe and the average of weighted laboratory data is greater than 20% but less than 35%, the

data are defined as acceptably similar. When the relative deviation between HPGe data and the average of weighted laboratory data is greater than 35%, the data are defined as dissimilar. Examination of the data in Table 5-1 suggests these above guidelines are very reasonable and can be used as acceptance criteria as discussed below.

Accuracy is defined for both ASL D and ASL B quality levels: when the relative deviation between HPGe and the average of laboratory data is less than 20%, HPGe data are considered accurate for ASL D data quality levels. When the relative deviation between HPGe and the average of laboratory data is greater than 20% but less than 35%, HPGe data are considered accurate for ASL B purposes. These definitions implicitly assume that the weighted average of laboratory data from discrete samples represent the "true" value. In reality, as discussed in Section 3.1.1, this may not be the case. Therefore, the mean of HPGe data and laboratory data is used in the denominator of the relative precision calculation.

Using these definitions of accuracy, total uranium, thorium-232, cesium-137, and potassium-40 measurements by HPGe are considered accurate for ASL D purposes (Tables 3-6, 3-7, 3-9, and 3-10). Conversely, HPGe measurements for radium-226 cannot currently be used for either ASL D or ASL B investigations, based upon FEMP data. Based upon EML data (Appendix F), radium-226 appears to meet ASL B criteria. However, the EML soil measurements were not made at areas PBC-3 and PBC-10, which had the highest radium concentrations and the largest differences between HPGe and laboratory data. As discussed in Section 5.7, environmental factors influence HPGe radium measurements, and until these influences are resolved, it is premature to state that radium-226 can be used for either ASL D or ASL B irrespective of FEMP or EML results. A major step toward understanding environmental influences on radium-226 HPGe measurements is a better understanding of radon-222 disequilibrium. EML is carrying out studies toward that end.

Accuracy of HPGe data vs. laboratory data will be addressed annually for both ASL D and ASL B work. Physical samples will be collected from the field quality control station (see Section 5.7), as described in Section 2.2.2.3 of this report, once a year. HPGe measurements must fall within ± 20% of the weighted average of the physical samples collected to meet ASL D requirements defined in this section. HPGe measurements must fall within ± 35% of the weighted average of the physical samples to meet the requirements for ASL B as defined in this section.

5.2.2 Bias

Systematic differences between HPGe and weighted laboratory data indicate biases. Table 5-2, reporting only 1.0 meter HPGe data for illustrative purposes, indicates that some such systematic differences do exist (the method of calculating biases is explained at the bottom of Table 5-2). For total uranium and thorium-232, HPGe, on average, appears to yield slightly higher results than weighted, laboratory alpha spectrometry data. For radium-226, the results are more complicated. HPGe measurements are consistently higher (27.6%) than alpha spectrometry data for radium-226 activities less than 1.0 pCi/g. However, HPGe measurements are significantly lower than alpha spectrometry measurements for radium-226 activities greater than 2 or 3 pCi/g. An investigation is currently being conducted to explore this finding. Finally, data in Table 5-2 indicate that laboratory gamma spectrometry data are consistently higher than HPGe data by 15% for both cesium-137 and potassium-40. Wilcoxon Signed Ranks Tests (discussed in Section 4.3) were performed on laboratory vs. HPGe measurements to assess bias. Test results are provided in Appendix G, Table G-2. These tests suggest that, based upon laboratory and HPGe methods, measurements of total uranium and radium-226 do not exhibit consistent bias. Conversely, measurements of cesium-137 and potassium-40 do exhibit bias between laboratory and HPGe methods. The statistical tests differ for thorium-232 depending on whether 31 cm or 100 cm data are used.

QC acceptance criteria for bias are incorporated into the acceptance criteria for accuracy, specified in Section 5.2.1. That is, bias is acceptable as long as the bias does not lead to errors such that the accuracy acceptance criteria are exceeded.

5.3 PRECISION OF DUPLICATE HPGe MEASUREMENTS

Precision is the measure of the closeness of replicate measurements in this study. Two HPGe readings were performed at each detector height above the ground. Precision and acceptance criteria can be determined from these data. Figures 5-1 and 5-2 show the high positive correlation between duplicates for all duplicate measurements.

Precision of duplicates is a standard quality control parameter for environmental analytical chemistry (Table 5-1). Standard practice is to accept data when the percent relative difference between duplicates is less than 20% for data greater than five times MDC. For data less than five times MDC, the precision requirements are ± MDC. Tables 5-3 and 5-4 show the percent relative precision between

duplicates of HPGe measurements for all analytes for measurements at 31 cm and 1.0 m height, respectively.

Percent relative precision is defined by the equation in Section 3.2. Of the 100 relative precision measurements for 31 cm and 1.0 m heights, only one exceeds 25% (total uranium, Point #9, 31 cm) and only seven exceed 10%. The remaining 92 duplicates have relative precisions less than 10%.

Current laboratory conventions for precision of duplicates will be adapted for both ASL D and ASL B HPGe data. The data will be accepted when relative precision of duplicates is less than 20%. The field measurements will be repeated where precision of duplicates are greater than 20%. The recommended frequency for duplicates is similar to that specified in the PSP for OSDF Support Areas Certification Sampling, i.e., one HPGe duplicate measurement per CU. The 20% acceptance criteria holds for data where the values are greater than five times the MDC (see Section 5.4). For data less than five times the MDC, the criterion for duplicates is ± MDC (on a % RPD basis). Precision of duplicate data in Tables 5-3 and 5-4 demonstrate that HPGe measurements can meet the criterion for precision. As explained in Section 3.2.2, data validation requirements for inorganic analytes are 35% relative percent precision for soil matrices. However, because of the tightness of data displayed here, a more stringent 20% criterion is proposed.

5.4 MINIMUM DETECTABLE CONCENTRATION

MDC refers to the statistically determined quantity of a radionuclide that can be measured at a preselected confidence level. The magnitude of the MDC is a function of instrument parameters, radiological background levels, and the procedure used to make the measurement. While any confidence level could be chosen to calculate the MDC, it is traditionally defined as the activity level above which there is less than 5% probability that activity will be reported as present when it is really absent (Type I error, or false detection) or reported as absent when it is really present (Type II error, or false non-detection). This confidence level has been adopted for the purposes of this study.

The concept of using the MDC for measurements of radionuclides was first proposed by L. Currie in 1968. It is intended to be an *a priori* estimate of the activity level that a system or technique can reliably measure under a given set of conditions. The MDC is not intended to be used *a posteriori* to evaluate individual measurements.

The MDC indicates the ability of a detection system to differentiate between the activity of a radionuclide being analyzed and the background activitiy. It is given by the expression:

$$MDC\ (pCi/g) = K(2.71 + 4.65s_b)$$

where:

K = constants relating the instrument response (in counts) to an activity concentration
s_b = the standard deviation of the number of background counts detected during a measurement period. For measurements of radioactivity, this is typically assumed to be equivalent to the square root of the background counts.

The equation assumes that the acceptable probabilities for Type I and Type II errors are equal to or less than 5%. Where background counts are large, such as at the FEMP, the 2.71 term is often omitted. In addition, the equation applies when the background and sample are counted for the same amount of time.

MDCs for a radiation measurement system are usually determined by using the system to take a sample measurement for which the radionuclides of interest are present or absent at background radiation levels. Gamma spectrometry measurement techniques, in a gamma ray spectrum such as the in-situ HPGe, are complicated by the fact that the counts of interest are contained in photopeaks that are superimposed on a continuum that results from other gamma emissions present in the background. This continuum is a major component of the background counts used to determine a MDC for a gamma detection system. Consequently, the MDC for a given radionuclide is affected by the presence of other radionuclides in the sample or at the measurement location, as well as upon the actual background radiation levels. The actual MDC for the HPGe will be a function of the total gamma activity present in the measurement area.

For the HPGe system, the MDCs were determined by making measurements in locations unaffected by FEMP activities. These locations were at the south end of the FEMP, near Willey Road. They did not include tilled soils or agricultural land. A gamma spectrum was accumulated for the same time period used as in data gathering for the comparability study. The number of counts in a spectrum continuum was determined at each position where a photopeak of interest would be found. MDCs were calculated for the photopeaks using the equation provided above. For those radionuclides which are quantified using an average of multiple peaks, the MDCs were averaged to give a representative value for that nuclide.

Table 5-5 lists the average of replicate MDCs on a wet weight basis, calculated for total uranium, thorium-232, radium-226, cesium-137, and potassium-40 for a 1.0 m HPGe detector height. These MDCs are based upon 15-minute count times at typical "low background" areas. Table 5-6 compares MDCs, converted to a dry weight basis, assuming a soil moisture control of 20%, measured with the HPGe to FEMP FRLs. The 95% upper confidence limits of all measured MDCs are less than the FRLs for the analyte of interest (see paragraph below).

By analogy with the statistical methodology used for certification testing (Section 6.2), the MDC acceptance criteria for a given analyte will be that the 95% upper confidence limit of the MDC must be less than the FRLs for ASL D. By analogy with radiochemistry performance specifications in the SCQ, a less stringent acceptance criterion for ASL B will be that the 90% upper confidence limit of the MDC must be less than the FRL of concern. Table 5-6 shows the 90 and 95% upper confidence limits in relation to the FRLs. Given the data in Table 5-6, the HPGe technique should easily be capable of detecting each radionuclide when it is present at the FRL. By analogy with the CLP and SW-846 conventions, MDCs will be established quarterly. Each quarter, the upper 90% and 95% confidence limits will be updated using the 12 most recent measurements.

5.5 CALIBRATION

In practice, the HPGe system records the number of gamma rays of a specific energy interacting with the detector. The system output is a gamma ray spectrum showing a series of photopeaks superimposed on a continuum. Calibration is the process of determining the relationship between photopeak counts and radionuclide concentration. Calibration measurements for the HPGe system are performed on an annual basis or after major instrument repairs using National Institute of Standards and Technology (NIST) traceable sources of various radionuclides. Additionally, performance checks are conducted at the beginning and end of each shift during which the HPGe is used.

FEMP personnel follow procedure EQT-22, *Characterization of Gamma Sensitive Detectors,* to calibrate the HPGe system. Specific detector parameters that are measured as part of the calibration include photopeak count rate as a function of gamma ray energy and angle of incidence. Currently, the calibration sources used contain americium-241, cobalt-60, cesium-137, and europium-152. The calibration sources are placed in a reproducible geometry in which they can be swept through an arc in a plane that includes the detector axis and is perpendicular to its face. Each source is counted at

source-to-detector angles between 0 and 90 degrees at 10-degree increments. The results of these measurements are used to generate curves defining the angular response of the detector and an energy response curve. These curves and other parameters are used to calculate the conversion factors relating the number of gamma rays detected to activity concentrations. The equations used for this calculation address modeling of the source geometry, the distribution of the analytes in the soil, and the soil density. These equations and the specific assumptions made are discussed in Appendix E.1.4.

In addition to the annual calibrations, instrument performance checks are conducted at the beginning and end of each shift that the systems are used. The daily checks use americium-241, cobalt-60, and cesium-137 (Table 5-7). A spectrum is collected for a short period of time for each of these nuclides. The spectra are evaluated against established acceptance criteria for peak resolution, peak position and number of counts in the photopeak. If the detectors fail to achieve the acceptance criteria, corrective action is taken. The annual calibration and daily instrument performance checks will be performed for both ASL D and ASL B analyses.

5.6 LINEARITY

The detector response should be linear over the activity range of interest for an analyte. For soil remediation, linearity should be demonstrable from approximately the MDC to well beyond the FRL or other regulatory limit for a given analyte. In turn, linearity should be observed over as much as three orders of magnitude for activities measured by HPGe.

All radiation detectors, including the HPGe systems used in this comparability study, function by absorbing some or all of the energy impinging on them as a result of exposure to a radiation field. The energy absorption process liberates free charges in the detector material, resulting in small surges of current which are counted as pulses by electronic modules coupled to the detector. This detection and counting process is accomplished in 50 microsecond or less time intervals, so a modern detector can easily process thousands of radiation events per second. The counts detected are proportional to the number of photons incident upon the detector; this, in turn, is proportional to the radioactivity concentration in the "sample" being analyzed. Over many decades of use, it has been firmly established that there is a linear relationship between the true sample activity and the HPGe detector response, i.e., the counts the detector registers regardless of the radioisotope or the gamma photon energy.

Linearity of the HPGe detector can be demonstrated by invoking the inverse square law of radiation transport. In its simplest form, it relates the fluence rate (ϕ) at a detector to a point source (S_0 of gamma photons) separated by distance r:

$$\phi = S_0/4\pi r^2 \quad \text{photons/sec} \bullet \text{cm}^2$$

With respect to linearity of detector response, moving a source of given strength further from the detector is equivalent to decreasing the source strength at a given distance from the detector. In each case, the detector "sees" a weaker source, and the detector response will decrease. Thus, for a given source, a graph of detector response (net counts) as a function of $1/r^2$ should be linear over a large range of counts. Figure 5-3 demonstrates such linearity for two sources: a cesium-137 source and a cobalt-60 source. Table 5-8 contains the data used to construct Figure 5-3.

Figures 5-4 and 5-5 demonstrate linearity of the HPGe measurements over nearly four orders of magnitude. In these two figures, HPGe measurements for all radionuclides (total uranium, thorium-232, radium-226, cesium-137 and potassium-40) are plotted and weighed against averaged laboratory data. The laboratory data were generated using accepted, validated methods and may be considered representative of the "true" soil activity. Despite the fact that laboratory data include both alpha and gamma measurements, overall linearity with a high degree of correlation (R^2=0.98) is observed for both 31 cm and 1 m detector heights. The data plotted along the X axis variable fundamentally represents the number of gamma rays incident upon the HPGe detector irrespective of the particular nuclear species emitting them. Thus, the graphs may be considered to be the HPGe detector response against the number of incident gamma ray photons. Both figures clearly demonstrate the linear relationship between the signal impinging upon the detector and measurement results.

5.7 ROBUSTNESS

Because the HPGe is field deployable, concerns exist with respect to system performance over a range of environmental conditions such as soil moisture, soil density, soil type, atmospheric temperature, and atmospheric humidity. Recent publications (for example, Miller, et. al., 1994) indicate that system performance is not particularly sensitive to soil density or soil composition. The field analogue of a laboratory control standard has been adopted to address factors such as soil moisture, atmospheric temperature, and humidity.

A field location with a total uranium content of approximately 75-80 ppm (close to the FRL of 82 ppm), as indicated by a 1.0 m HPGe reading, has been selected as a field quality control station (FCS). Two HPGe readings were taken (one in the morning and one in the afternoon) at a 1.0 meter height each day for ten consecutive work days. These 20 HPGe readings (Table 5-9A) were used to construct initial "means" control charts using typical conventions (warning limits are $\pm$ 2 standard deviations from the mean; control limits are $\pm$ 3 standard deviations from the mean) for the average of 20 readings for total uranium, radium-226, and potassium-40 (Figures 5-6, 5-7, and 5-8). All control charts are based upon wet weight data. The data used in constructing control charts are indicated by an asterisk in Table 5-9A. Data collected between April 8 and April 28, 1997 were used to construct initial warning and control limits. Data collected through May 27 are also displayed in Figures 5-6 through 5-11 and in Table 5-9A to provide additional information, evidence of trends, and frequency of out of control events to help assess validity of the initial delineation of warning and control limits.

Uranium was selected for control charting to demonstrate robustness to environmental conditions because it is the major COC at the FEMP. Radium-226 was selected because it is quantified by measuring gamma photons emitted by radon daughters. Differential loss of radon from soils due to changing environmental conditions should be evident on control charts by sudden peaks or valleys or by trends. Finally, potassium-40 was selected because it is easy to measure by gamma spectrometry and because peaks, valleys, and trends in control charts may signify differential detector responses to environmental conditions or to detector drift.

At first glance, temperature, humidity, and soil moisture data (measurements of these parameters were also recorded twice a day, corresponding to the times at which HPGe measurements were collected) show no evident correlation with control chart data for total uranium and potassium-40. This indicates that out of control events and trends in control chart data do not appear to correspond to environmental highs, lows, or trends. For example, though temperature varied from 18° F to 75° F, and humidity varied from 22% to 88%, the data in the control charts appear insensitive to variations within these ranges (Figures 5-9 and 5-10). More careful examination of environmental variables does indicate that at least soil moisture can affect the value of HPGe measurements for total uranium and potassium-40 as discussed below.

The utility in control charts with respect to environmental variables can be seen by examining the data for total uranium and potassium-40 between May 6 (Points 16a and 16p) and May 22 (Points 24a and 24p). Between these dates, a trend of increasing values leading to out of control data points (based upon the preliminary assignment of control limits) is clearly evident. The reason for these trends does not appear to be related to atmospheric temperature or humidity. Examination of soil moisture data (Figure 5-11), however, indicates a drying trend during this time period in which soil moisture drops from approximately 20% on May 6 to approximately 16% on May 22. By May 27, soil moisture had increased to 24%. Table 5-9B shows precipitation at the FEMP for April and May 1997. Between May 6 and May 22, only 0.6 inches of rain fell in a 17-day span. This accounts for the drying trend observed in soil moisture. From May 24 to May 26, two inches of rain fell at the FEMP, which accounts for the increased soil moisture measured on May 27.

Thus, the trend of increasing total uranium and potassium-40 HPGe measurments between May 6 and May 22 appears to reflect lack of rainfall and the resultant drying of surface soils. The sudden decrease in total uranium and potassium-40 observed on May 27 appears to reflect significant rainfall on May 24, 25, and 26 with a resulting increase in surface soil moisture content.. These observations are readily explainable simply on a mass basis: dry weight yields higher data concentrations than wet weight because of the diluting effect of water. Interestingly, however, radium-226 does not reflect the trend of increasing data values. Again, this indicates that radon emanation phenomena primarily dictate radium-226 HPGe concentration values.

The ratio of the standard deviation to the mean (expressed as percent), based upon the initial 20 points used to construct the control charts, is 3.01% for total uranium, 13.2% for radium-226, and 3.65% for potassium-40. The variation in measurements for radium-226 is much larger than those for total uranium and potassium-40. Further examination of Figure 5-7 and Table 5-9A reveals that radium-226 activities are often higher in the morning and lower in the afternoon. For example, the average and standard deviation of morning measurements between April 8 and May 1 is 0.94 pCi/g $\pm$ 0.20 pCi/g, while the average and standard deviation of afternoon measurements is 0.761 pCi/g $\pm$ 0.038 pCi/g. Thus, for this time period, radium activities were almost 25% greater when they were measured in the morning than when they were measured in the afternoon.

In summary, the data in the control charts and in Table 5-9A indicate that uranium and potassium-40 do not appear susceptible to temperature and humidity influences, but do reflect soil moisture values. Conversely, radium-226 activities appear to depend on several environmental influences. Additional time measurements at the field quality control station will allow additional assessment of the significance of the environmental influences, particularly for radium-226. Because radium-226 is determined from gamma rays emitted by radon-222 daughters, the differences between morning and afternoon measurements are related to buildup and emanation of radon from surface soils. As more data are gathered relative to environmental influences, particularly during the hot, dry summer months, control chart limits will undoubtedly be revised to take those influences into account. Similarly, as more data are acquired for total uranium that reflect drier soil conditions, control chart limits will be revised.

When the HPGe is deployed regularly for field measurements at ASL D data quality levels, a reading will be made at the FCS along with atmospheric temperature and soil moisture measurements. If the calculated activities are within control limits, the measurements collected throughout the day will be considered viable. If the measurements fall outside the control limits for one or more radionuclides, a second measurement will be taken. If the results of the second measurement fall outside control limits, corrective actions will be taken. For ASL B data quality levels, FCS measurements will not be required.

Standard conventions regarding the interpretation of control charts will be employed, particularly with respect to trending. Trends in control chart points could reflect trends in environmental conditions or instrument problems. Corrective actions will be taken if trends are spotted. A procedure for the use of control charts has been written and is in the review cycle. This procedure will detail all conventions used to construct and interpret control charts, how they will be used for HPGe instruments, how data will be interpreted, and how corrective actions will relate to control chart events.

5.8 SUMMARY

Table 5-10 summarizes important quality control elements, their frequencies, and acceptance criteria for ASL D and ASL B data quality levels. Adherence to Table 5-10 will ensure that data of known quality are generated. Although one HPGe instrument was used to generate FEMP data, multiple instruments will be used in soils remediation. Each instrument has to meet the QC acceptance criteria

in Table 5-10. All analytes investigated in this study meet all of the QC acceptance criteria for both ASL D and ASL B for all QC elements except accuracy. Total uranium, thorium-232, cesium-137, and potassium-40 meet the accuracy requirement for ASL D. Currently, radium-226 does not routinely meet proposed accuracy requirements for either ASL D or ASL B. Multiple method development studies are continuing to address this deficiency.

TABLE 5-1
SW846 AND CLP-SOW CRITERIA FOR ACCURACY AND PRECISION OF METALS

	% RPD	Data Validation Criteria to "J" Data	Laboratory Control Standard	Data Validation Criteria to "J" Data	Matrix Spike	Data Validation Criteria to "J" Data	Matrix Spike Duplicates	Data Validation Criteria to "J" Data
CLP-SOW for Inorganics	0-20% if result is greater than 5 x CRDL. If result is less than 5 x CRDL, % RPD is ± CRDL.	21-35% if result is greater than 5 x CRDL. If result is less than 5 x CRDL, %RPD is ± 2 x CRDL.	80-120% recovery (aqueous). Not specified for solids	50-79% recovery or > 120% recovery	75-125% recovery	30-74% recovery or > 125%	%RPD < 20	Not specified
SW846 for Metals	< 20%	FEMP specifies same as for CLP	75-125% or lab may set own limits based upon mean recovery ± 3 standard deviations	FEMP specifies same as for CLP	75-125% recovery	FEMP specifies same as for CLP	%RPD < 20	Not specified

TABLE 5-2
BIAS BETWEEN HPGe (1.0 m) AND LABORATORY DATA

Parameter	No. Times HPGe data are greater than weighted lab data	No. Times HPGe data are less than weighted lab data	No. Times HPGe data are equal to weighted lab data	Average % Bias of HPGe data[a]
Total Uranium[b]	7	3	0	-3.0
Thorium-232	7	2	1	-4.6
Radium-226	8	2	0	-22.6(-5.5[c])
Cesium-137	0	10	0	+.156
Potassium-40	0	10	0	+.173

[a] Average percent bias is calculated by averaging the percent relative deviation for the data in Tables 3-1 through 3-5. Unlike the closeness data in Tables 3-6 through 3-10, the absolute value of the difference between laboratory and HPGe data is not used in the bias calculation. Thus, negative biases tend to cancel out positive biases. Negative biases indicate HPGe data are greater than weighted lab data and positive biases indicate the reverse.

[b] Excluding sample PBC-03-01

[c] Value in parentheses includes PBC-10 and PBC-03. Number outside parentheses excludes PBC-10 and PBC-03.

TABLE 5-3
PERCENT RELATIVE PRECISION FOR HPGe DUPLICATE MEASUREMENTS - 31 cm HEIGHT

Area #	Total U Measurement (ppm)		% RP*
1	8.5	9.4	10.0
2	32.6	29.9	8.6
3	298.1	283.4	5.1
4	55.5	57.6	3.7
5	41.6	42.8	2.9
6	75.0	78.0	3.9
6	77.9	77.7	0.4
6	76.4	75.5	1.2
7	142.1	140.3	1.2
8	5.7	6.0	6.4
9	7.4	5.8	25.2
10	80.6	81.2	0.7

Area #	Thorium-232 Measurement (pCi/g)		% RP
1	0.54	0.50	7.1
2	0.62	0.65	4.1
3	2.2	2.17	1.4
4	0.79	0.81	2.2
5	0.80	0.79	1.1
6	0.77	0.80	3.4
6	0.85	0.83	2.7
6	0.82	0.80	1.9
7	1.0	0.98	1.2
8	0.55	0.56	0.9
9	0.62	0.64	3.8
10	5.82	5.81	0.2

Area #	Radium-226 Measurement (pCi/g)		% RP
1	0.63	0.65	2.8
2	0.67	0.66	1.2
3	4.30	4.09	5.0
4	0.85	0.80	5.7
5	0.74	0.69	7.1
6	0.79	0.79	0.4
6	0.80	0.80	0.1
6	0.81	0.82	1.5
7	0.79	0.81	2.5
8	0.66	0.64	2.5
9	0.75	0.71	5.2
10	1.90	1.85	2.7

Area #	Cesium-137 Measurement (pCi/g)		% RP
1	0.42	0.44	5.1
2	0.59	0.60	0.7
3	0.54	0.48	11.2
4	0.35	0.35	1.7
5	0.34	0.34	0.3
6	0.31	0.31	1.6
6	0.32	0.34	5.5
6	0.32	0.34	3.6
7	0.29	0.29	1.7
8	0.11	0.11	5.5
9	0.28	0.26	5.9
10	0.28	0.27	3.6

Area #	Potassium-40 Measurement (pCi/g)		% RP
1	11.6	11.3	2.6
2	7.8	7.8	0.1
3	11.5	10.7	7.2
4	9.4	9.5	1.9
5	11.0	10.9	0.9
6	9.2	9.0	2.1
6	9.3	8.9	3.6
6	9.0	9.1	1.8
7	9.1	8.9	2.7
8	8.7	8.7	0.1
9	9.1	9.2	0.7
10	10.5	10.5	0.0

* % RP = % Relative Precision

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TABLE

PERCENT RELATIVE PRECISION FOR HPGe DUPLICATE MEASUREMENTS - 1 M HEIGHT

Area #	Total Uranium Measurement (ppm)		% RP*
1	8.0	**	NA
2	27.9	24.0	15.0
3	281.0	292.2	3.9
4	59.9	57.3	4.6
5	46.7	49.1	5.0
6	74.4	81.2	8.8
6	76.1	72.9	4.4
6	74.4	76.4	2.8
7	141.8	138.9	2.1
8	5.5	5.1	7.4
9	6.5	7.3	10.4
10	73.7	74.3	0.9

Area #	Thorium-232 Measurement (pCi/g)		% RP
1	0.51	0.51	0.8
2	0.61	0.65	5.5
3	2.51	2.48	1.2
4	0.78	0.78	0.9
5	0.80	0.78	3.4
6	0.80	0.82	1.7
6	0.79	0.80	0.9
6	0.82	0.78	5.0
7	1.01	0.93	8.1
8	0.56	0.51	9.5
9	0.59	0.58	1.5
10	6.91	6.85	0.9

Area #	Radium-226 Measurement (pCi/g)		% RP
1	0.59	0.60	1.5
2	0.67	0.70	4.5
3	4.32	4.25	1.6
4	0.82	0.79	3.6
5	0.74	0.72	2.5
6	0.81	0.79	2.8
6	0.80	0.80	0.2
6	0.79	0.79	0.5
7	1.09	0.97	11.7
8	0.60	0.62	4.4
9	0.69	0.69	0.4
10	1.66	1.67	0.6

Area #	Cesium-137 Measurement (pCi/g)		% RP
1	0.39	0.38	1.6
2	0.51	0.48	5.1
3	0.46	0.46	0.2
4	0.34	0.33	0.6
5	0.36	0.34	4.3
6	0.31	0.32	1.3
6	0.31	0.34	8.8
6	0.34	0.31	10.2
7	0.27	0.28	6.5
8	0.11	0.12	0.9
9	0.27	0.26	3.8
10	0.31	0.29	4.4

Area #	Potassium-40 Measurement (pCi/g)		% RP
1	10.7	10.7	0.0
2	7.83	7.63	2.6
3	11.2	11.0	1.8
4	9.05	9.07	0.2
5	10.4	10.3	1.0
6	8.81	8.9	1.0
6	8.95	8.94	0.1
6	8.85	8.70	1.7
7	9.03	9.09	0.7
8	8.64	9.14	5.6
9	9.0	8.71	3.3
10	9.89	10.2	3.1

* % RP = % Relative Precision

** only one measurement; cannot determine %RP.

TABLE 5-5
HPGe MINIMUM DETECTABLE CONCENTRATIONS[a]

Total U ppm	MDC ppm	K-40 pCi/g	MDC pCi/g	Ra-226 pCi/g	MDC pCi/g	Th-232 pCi/g	MDC pCi/g	Cs-137 pCi/g	MDC pCi/g
8.0	4.4	10.7	0.60	0.59	0.06	0.51	0.06	0.39	0.05
7.6	6.3	10.7	0.60	0.6	0.06	0.51	0.06	0.38	0.05
5.5	5.2	8.64	0.54	0.6	0.06	0.56	0.06	0.11	0.03
5.1	5.2	9.14	0.55	0.62	0.06	0.51	0.06	0.12	0.03
6.5	4.3	9.0	0.55	0.69	0.07	0.59	0.06	0.27	0.04
7.3	4.4	8.71	0.54	0.69	0.06	0.58	0.06	0.26	0.04
8.5	4.7	11.6	0.60	0.63	0.06	0.54	0.06	0.42	0.05
9.4	5.2	11.3	0.60	0.65	0.06	0.50	0.06	0.44	0.05
5.7	4.5	8.7	0.50	0.66	0.06	0.55	0.06	0.11	0.03
6.0	3.7	8.7	0.50	0.64	0.06	0.56	0.06	0.11	0.03
7.4	3.9	9.1	0.50	0.75	0.06	0.62	0.06	0.28	0.04
5.8	4.1	9.2	0.50	0.71	0.06	0.64	0.06	0.26	0.04
Average = 4.6		Average= 0.55		Average = 0.061		Average= 0.06		Average = 0.04	
Std Dev = 0.72		Std Dev = 0.043		Std Dev = 0.003		Std Dev = 0.001		Std Dev =0.008	

[a] wet weight basis

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TABLE 5-6
HPGe MINIMUM DETECTABLE CONCENTRATIONS COMPARED TO FRLs

Analyte	MDC[a]	95% UCL[b]	90% UCL[c]	FRL
Total Uranium	5.8 ppm	6.2 ppm	6.1 ppm	82 ppm[d]
Thorium-232	0.075 pCi/g	0.076 pCi/g	0.075 pCi/g	1.5 pCi/g
Radium-226	0.076 pCi/g	0.078 pCi/g	0.077 pCi/g	1.7 pCi/g
Cesium-137	0.05 pCi/g	0.054 pCi/g	0.053 pCi/g	1.4 pCi/g
Potassium-40	0.69 pCi/g	0.71 pCi/g	0.71 pCi/g	NA

[a] dry weight basis, average soil moisture content = 20%
[b] upper confidence limit (UCL) of the MDC is given by:

$$UCL = \bar{x} + \frac{ts}{\sqrt{n}}$$

where

t = 1.796 at 11 degrees of freedom for a one-sided 95% confidence interval,
s = standard deviation from Table 5-4, n = 12, and is given in Table 5-5.

[c] where

t = 1.363 at 11 degrees of freedom for a one-sided 90% confidence interval.

[d] FRL for total uranium will be 20 ppm in production area

TABLE 5-7
HPGe PERFORMANCE CHECK ACCEPTANCE CRITERIA[a]

Isotope	Energy (keV)	Channel Acceptance Position[b]	Peak Resolution Acceptance	Photopeak Area Acceptance
Americium-241	59.5	157 ± 1	± 10% annual calibration value	± 10% annual calibration value
Cesium-137	661.6	1763 ± 2	± 10% annual calibration value	± 10% annual calibration value
Cobalt-60	1332.5	3553 ± 3	± 20% of manufacturer's warranted value	± 10% of manufacturer's specifications

[a] FDF Site Restoration Services Procedure EQT-22 contains acceptance criteria
[b] Channels are associated with given energy gamma photons. Thus, for example, in the multichannel analyzer used with the HPGe detectors, an energy of 59.5 keV has been associated with Channel Number 157. If the 59.5 keV photons appear in channels well removed from Number 157, it will be interpreted as a different energy photon. Thus, the channel acceptance positions are the allowable range of channels associated with each energy gamma photon to minimize misidentification and quantification errors.

TABLE 5-8
DATA USED TO DEMONSTRATE LINEARITY OF HPGe DETECTOR RESPONSE

Source to Detector Distance (R), meters	Factor $1/R^2$ (m^{-2})	Detector Response (net counts)	
		Cs-137*	Co-60**
0.5	4	470544	277184
1	1	117636	69296
2	0.25	29409	17324
4	0.0625	7352	4331
6	0.0278	3268	1924
8	0.0156	1838	1083
11.3	0.00784	987	--

* 661.6 keV gamma photon
** 1332.5 keV gamma photon

TABLE A
HPGe READINGS AT FIELD QUALITY CONTROL STATION

Index	Date	Time	% Soil Moisture	Atmospheric Temperature (°F)	% Humidity	Total Uranium (ppm)	Radium-226 (pCi/g)	Potassium-40 (pCi/g)
1a	4/8/97	0846	20.95	31.8		73.74*	1.04*	10.5*
1p	4/8/97	1517	20.26			76.42*	0.782*	10.8*
2a	4/9/97	0844	21.32	18		74.93*	0.779*	10.1*
2p	4/9/97	1541	18.96			74.38*	0.737*	10.8*
3a	4/10/97	0741	19.61	20	58	78.53*	1.07*	10.8*
3p	4/10/97	1527	19.03	48	27	74.97*	0.769*	10.6*
4a	4/14/97	0812	25.60	24	69	68.95*	0.974*	10.1*
4p	4/14/97	1603	23.78	52	34	74.32*	0.762*	10.1*
5a	4/15/97	0802	22.12	34	83	71.32*	1.36	10.6*
5p	4/15/97	1534	21.07	55	34	76.13*	0.752*	10.7*
6a	4/16/97	0924	21.94	50	42	71.94*	0.84*	9.53*
6p	4/16/97	1552	21.94	59	57	75.82*	0.873*	9.72*
7a	4/17/97	0833	20.89	35	70	74.33*	0.791*	10.7*
7p	4/17/97	1514	20.82	39	74	74.04*	0.805*	10.8*
8a	4/22/97	0743	22.36	47	88	71.63*	0.979*	10.3*
8p	4/22/97	1455	20.45	60	34	72.22*	0.738*	10.5*
9a	4/23/97	1126	20.51	57	66	76.13*	0.77*	10.1*
9p	4/23/97	1505	19.74	62	46	63.28	0.74*	10.1*
10a	4/24/97	0728	20.19	51	87	76.43*	0.861*	10.5*
10p	4/24/97	1356	19.55	57	47	77.03*	0.735*	10.7*
11a	4/28/97	0730	23.08	47	87	69.59	0.72*	10.2
11p	4/28/97	1521	21.26	58	55	74.07*	0.747	10.3

* Data on these dates used to construct control chart limits.

TABLE 5-9A
(continued)

Index	Date	Time	% Soil Moisture	Atmospheric Temperature (°F)	% Humidity	Total Uranium (ppm)	Radium-226 (pCi/g)	Potassium-40 (pCi/g)
12a	4/29/97	0810	20.89	54	74	73.45	0.976	10.3
12p	4/29/97	1455	19.55	65	29	74.39	0.733	10.5
13a	4/30/97	0635	19.55	35	71	75.83	1.27	10.5
13p	4/30/97	1515	19.03	75	49	77.36	0.747	10.3
14a	5/1/97	0817	24.47	47	63	71.04	0.73	10.7
14p	5/1/97	1437	23.49	49	60	73.75	0.736	10.4
15a	5/5/97	1022	20.63	59	36	73.75	0.755	10.3
15p	5/5/97	1600	21.26	62	44	74.07	0.758	10.1
16a	5/6/97	0853	19.35	52	60	73.73	0.722	9.72
16p	5/6/97	1534	20.00	64	36	73.76	0.706	10.2
17a	5/7/97	0903	20.51	50	49	75.84	0.92	9.77
17p	5/7/97	1509	20.00	72	26	77.04	0.79	10.20
18a	5/12/97	0902	21.81	46	63	75.25	0.77	10.60
18p	5/12/97	1613	19.48	62	37	74.66	0.74	10.70
19a	5/13/97	0754	19.16	51	59.4	78.21	1.14	10.90
19p	5/13/97	1500	19.42	61	32	80.92	0.80	11.20
20a	5/15/97	0933	17.56	53		77.34	0.81	10.80
21a	5/19/97	0802	17.70	70	68	77.39	0.80	11.50
21p	5/19/97	1437	18.23	82	58	80.65	0.80	11.20
22a	5/20/97	0638	16.87	47	70	78.29	0.81	11.00
22p	5/20/97	1525	17.15	63	24	80.98	0.75	11.70
23a	5/21/97	0800	18.10	47	61	82.48	0.80	11.00

ata on these dates used to construct control chart limits.

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TABLE 3A
(continued)

Index	Date	Time	% Soil Moisture	Atmospheric Temperature (°F)	% Humidity	Total Uranium (ppm)	Radium-226 (pCi/g)	Potassium-40 (pCi/g)
23p	5/21/97	1615	16.46	60	24	79.13	0.80	11.70
24a	5/22/97	0753	16.04	42	51	83.60	1.38	11.50
24p	5/22/97	1556	16.04	66	22	84.25	0.87	11.50
25a	5/27/97	0747	24.13	52	63	69.24	0.80	9.51
25p	5/27/97	1500	22.30	66	57	67.17	0.73	9.36

* Data on these dates used to construct control chart limits.

TABLE 5-9B
PRECIPITATION AT THE FEMP DURING APRIL & MAY 1997

Day	April*	May*
1	0.00	0.00
2	0.00	1.89
3	0.00	0.11
4	0.00	0.00
5	0.28	0.03
6	0.00	0.00
7	0.00	0.00
8	0.00	0.46
9	0.00	T
10	0.00	0.00
11	0.11	0.00
12	0.62	T
13	0.01	T
14	0.00	0.00
15	0.00	0.00
16	0.01	0.00
17	T	0.00
18	0.00	0.00
19	0.01	0.14
20	0.00	0.00
21	0.26	0.00
22	0.00	0.00
23	0.00	0.00
24	0.00	0.09
25	0.00	1.63
26	0.00	0.29
27	0.23	0.00
28	0.00	0.22
29	0.00	0.24
30	0.76	0.01
31		2.11
Total	2.29	7.22

* Precipitation in inches
T = trace

TABLE 5-10
HPGe QUALITY CONTROL ELEMENTS[a]

QC Element	Frequency	Acceptance Criteria
Accuracy	Annually	±20% RPD from the weighted average of laboratory measurements[b] ± 35% RPD from the weighted average of laboratory measurements[b] (ASL B)
Precision of Duplicates	Once per CU	±20% of the relative deviation[c]
MDC	Quarterly	95% UCL[d] < FRL 90% UCL < FRL (ASL B)
Detector Calibration	Annually	meets manufacturers specifications
Instrument Performance Checks	Daily	per Table D-6 for both ASL D and ASL B
Field Control Station (FCS)[e]	Daily	±3σ from mean of control chart[f]

[a] all QC elements and acceptance criteria are for ASL D unless otherwise specified. QC elements and acceptance criteria are for total uranium, thorium-232, radium-226, cesium-137 and potassium-40.
[b] location should be the FCS.
[c] the 20% criterion is for activities greater than 5 times the MDC. For activities less than five times the MDA, the criteria for precision of duplicates is ± MDC.
[d] UCL = upper control limit
[e] standard conventions will be used to interpret control charts as well as to identify trends. Will be detailed in procedure currently under review.
[f] not required for ASL B

Figure 5-1
Precision of Duplicates of HPGe Measurements (31cm) is Excellent As Shown by High Degree of Correlation

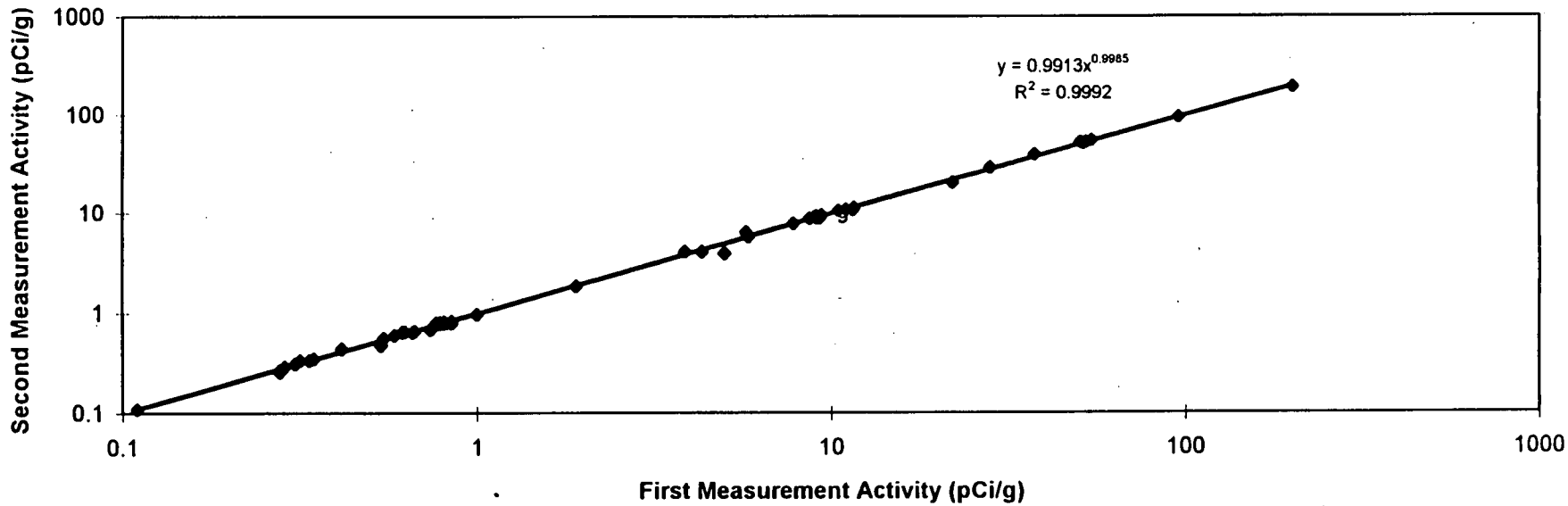

Figure 5-2
Precision of Duplicates of HPGe Measurements (1M) is Excellent as Shown By High Degree of Correlation

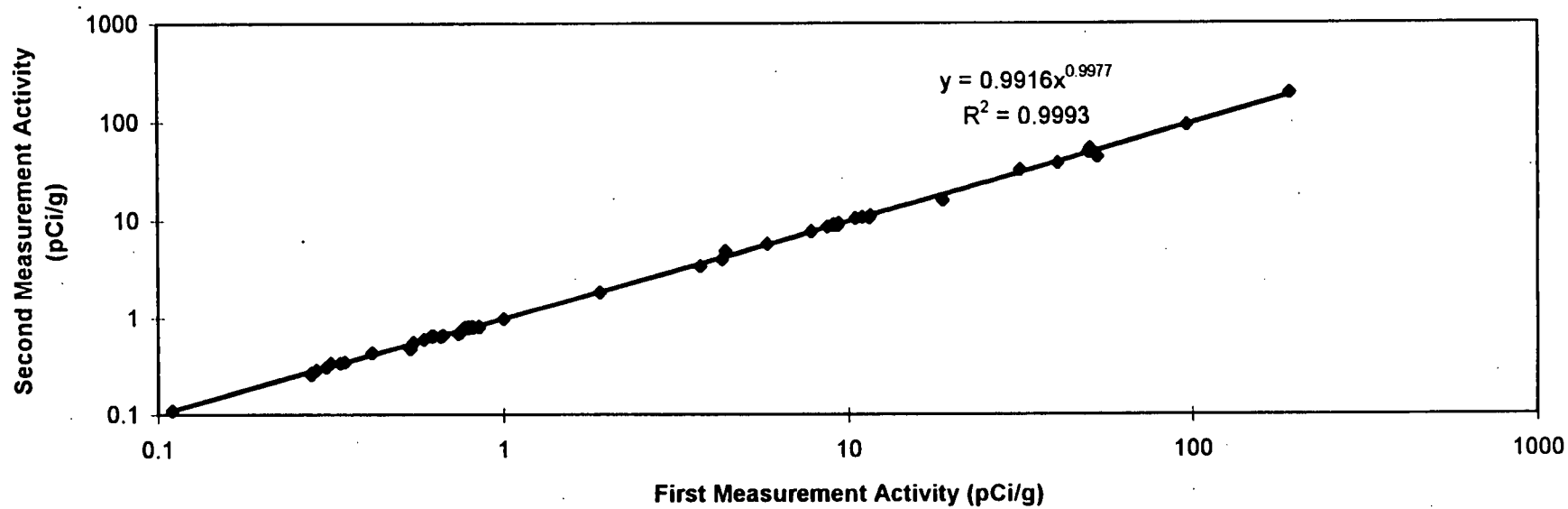

Figure 5-3
HPGe Detector Response Linearity

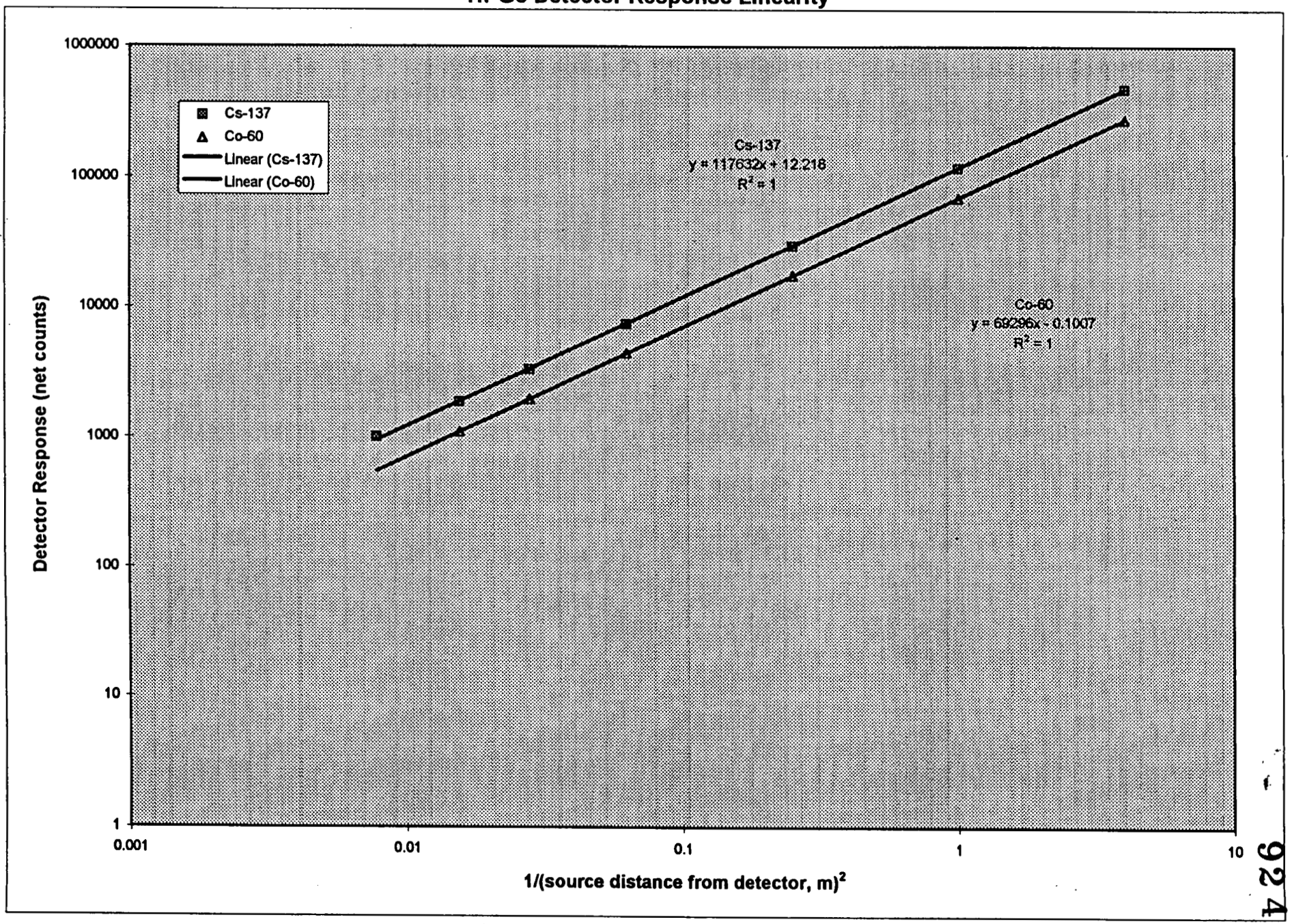

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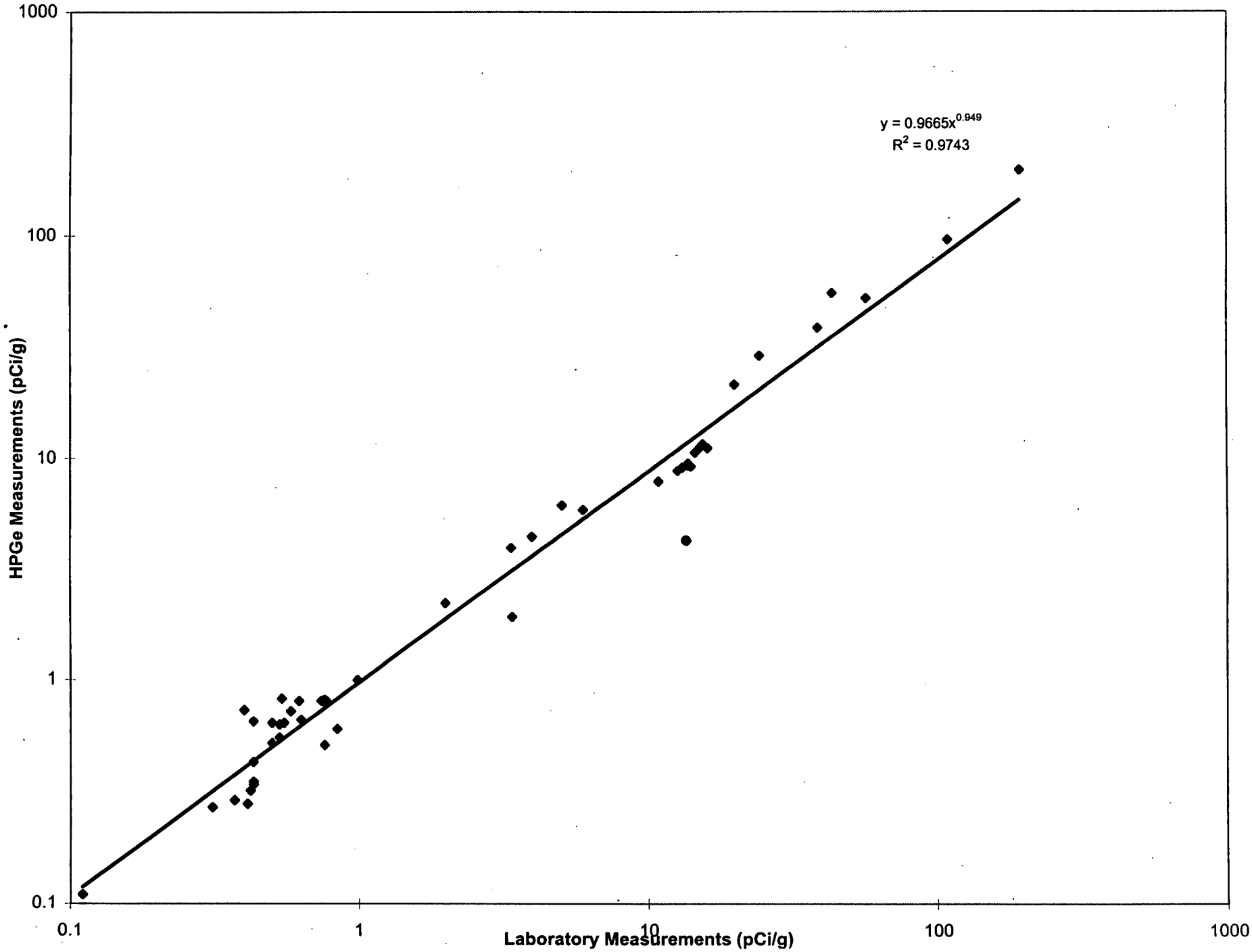
Figure 5-4

Excellent Correlation of Laboratory and HPGe Data (31cm) for all Radionuclides Demonstrates Detector Linearity



Fi[illegible] 5-5

Excellent Correlation of Laboratory and HPGe Data (10[illegible]m) for all Radionuclides Demonstrates Detector Li[illegible]rity

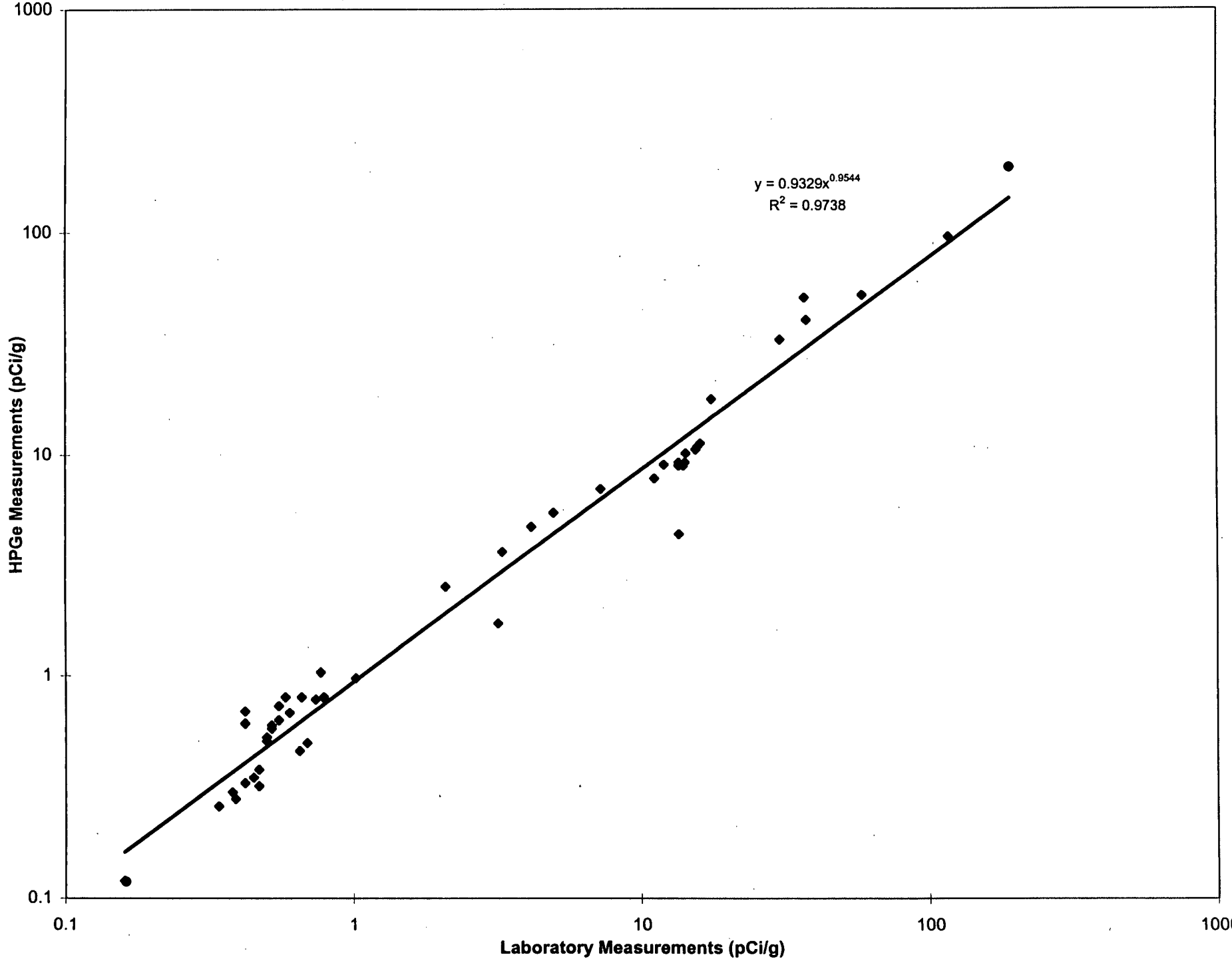
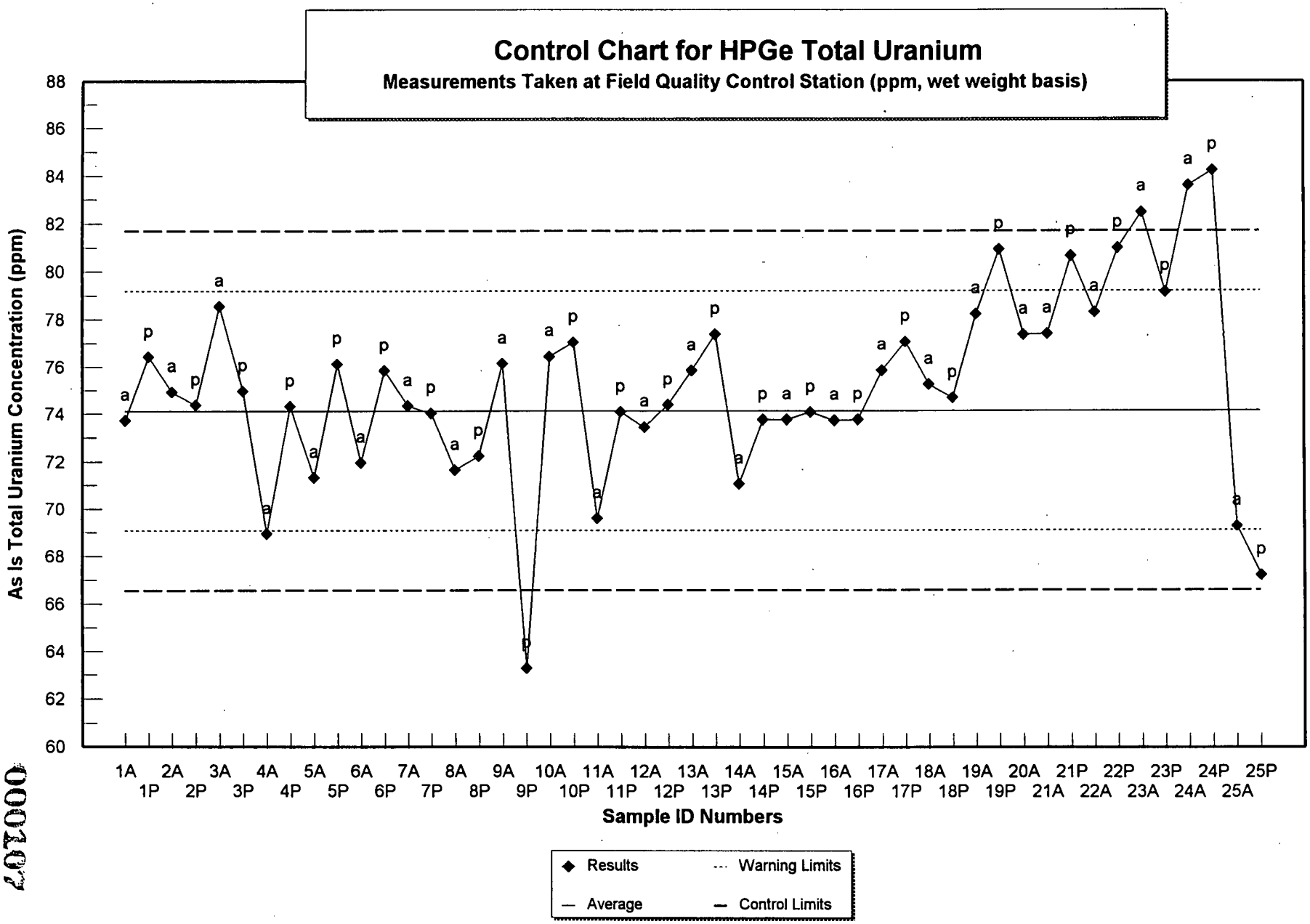
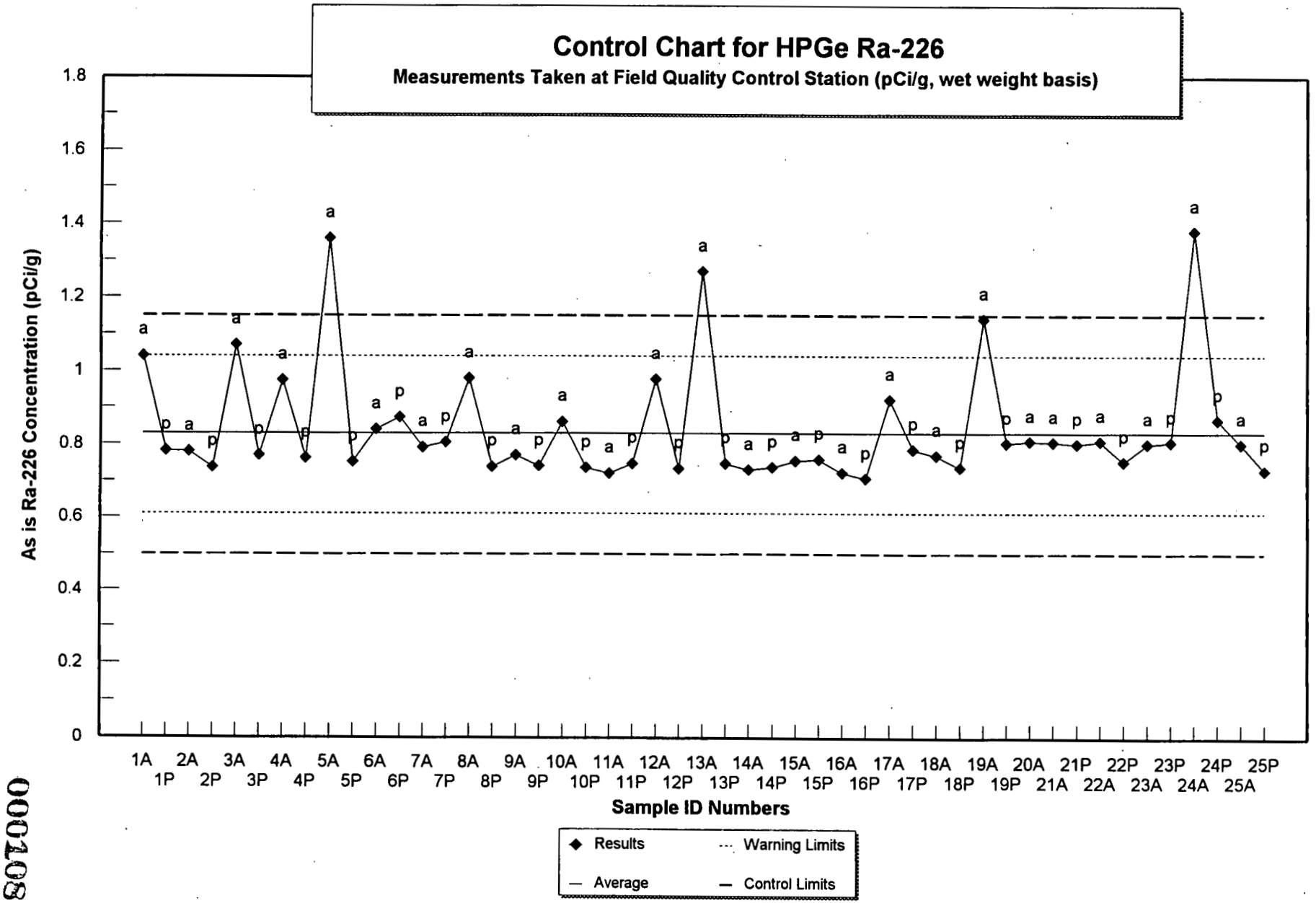


Figure 5-6



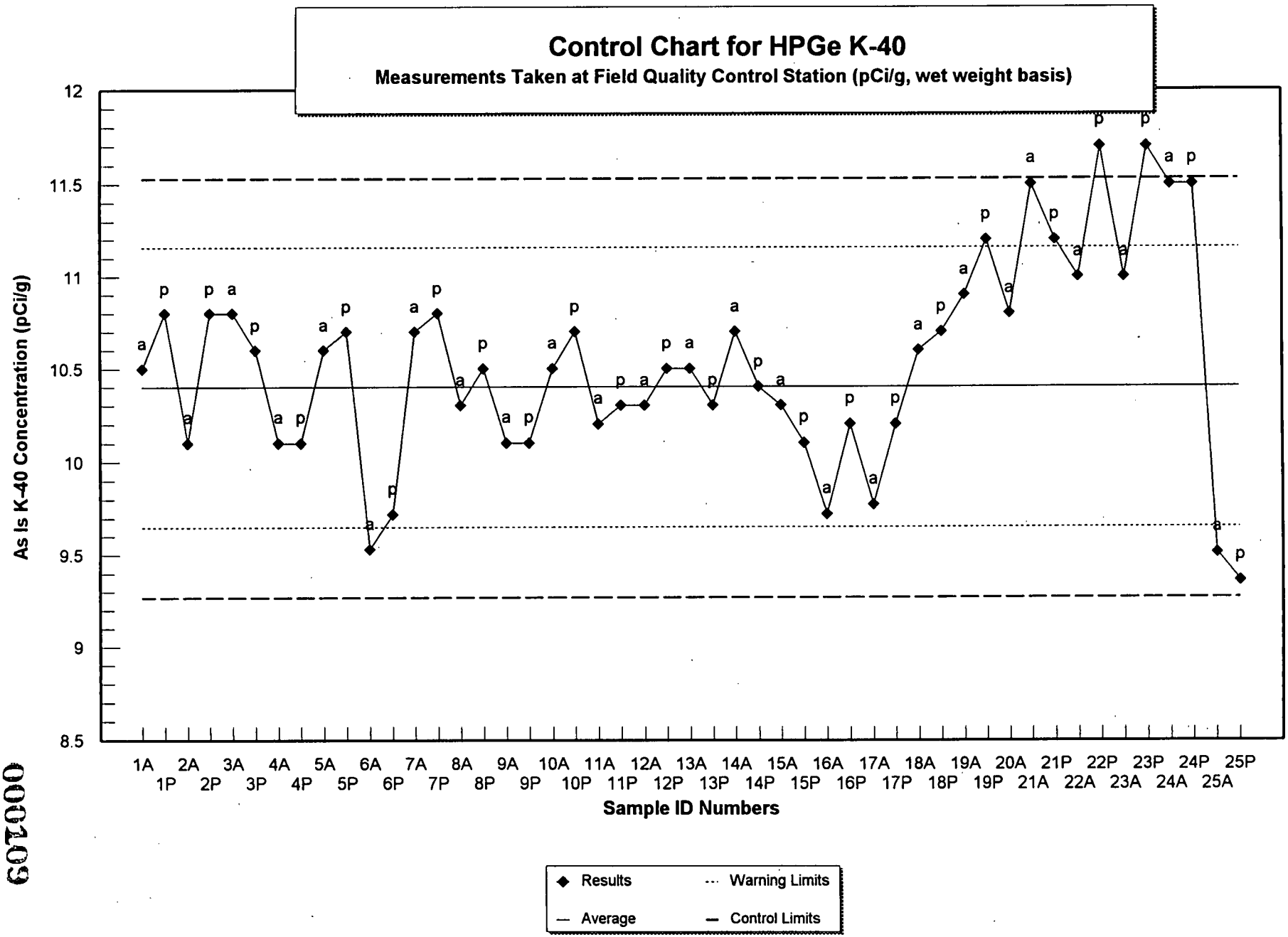
Average = 74.37 Std. Dev = 2.29 UWL = 78.94 LWL = 69.79 UCL = 81.22 LCL = 67.51

Figure 5-7



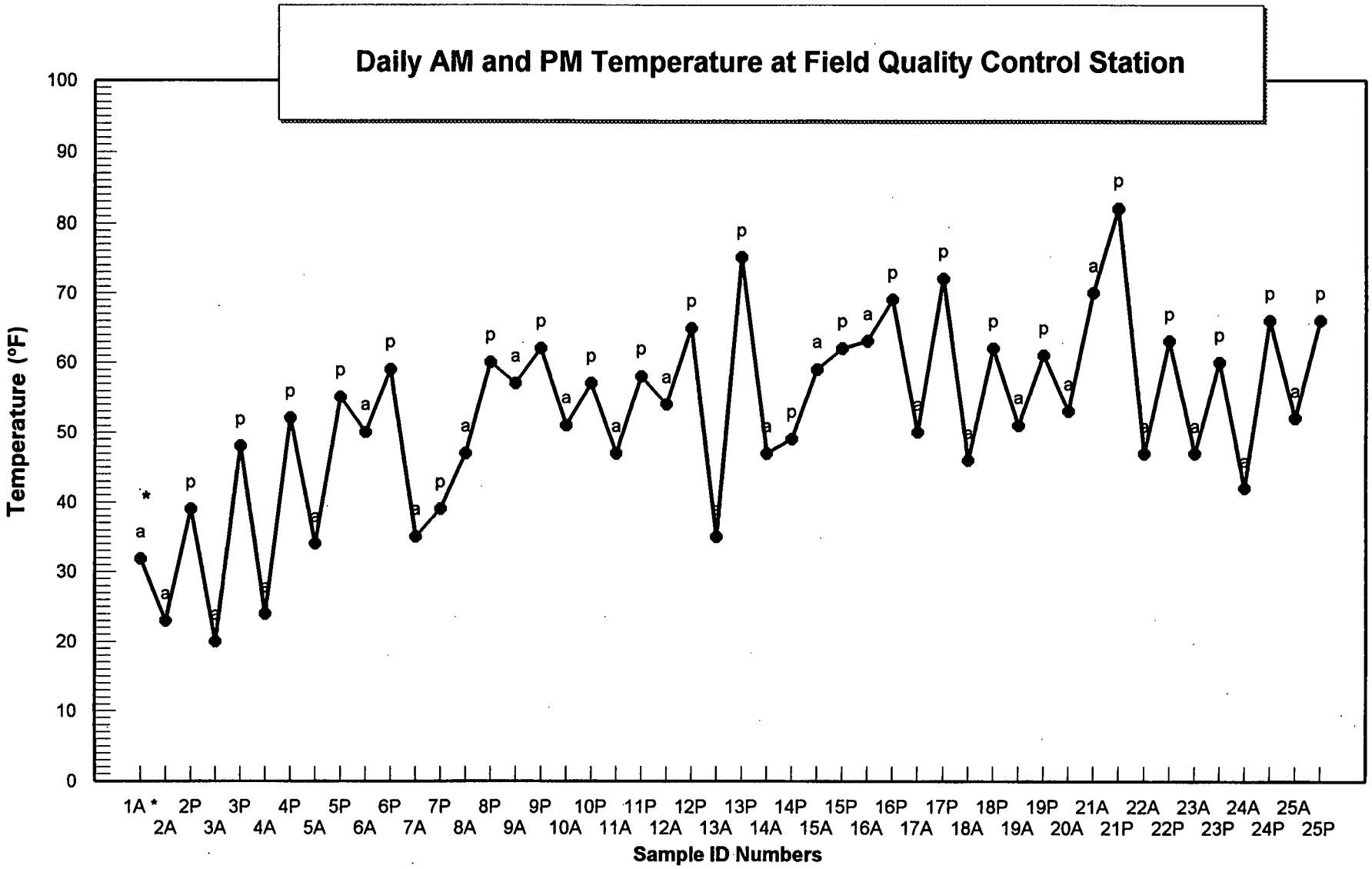
Average = 0.83 Std. Dev = 0.11 UWL = 1.04 LWL = 0.61 UCL = 1.15 LCL = 0.50

Figure 5-8



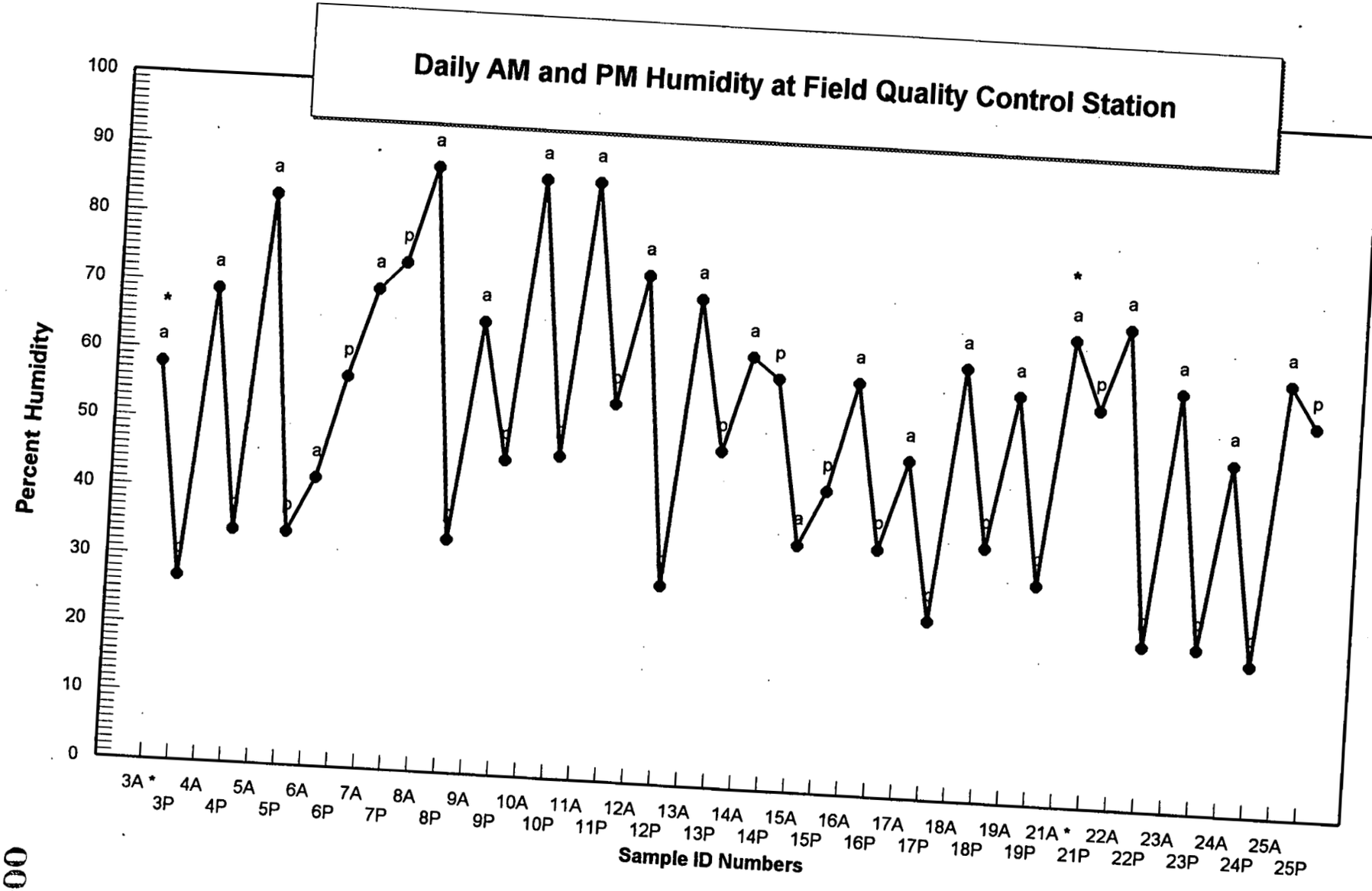
Average = 10.40 Std. Dev = 0.38 UWL = 11.16 LWL = 9.65 UCL = 11.53 LCL = 9.27

FIGURE 5-9



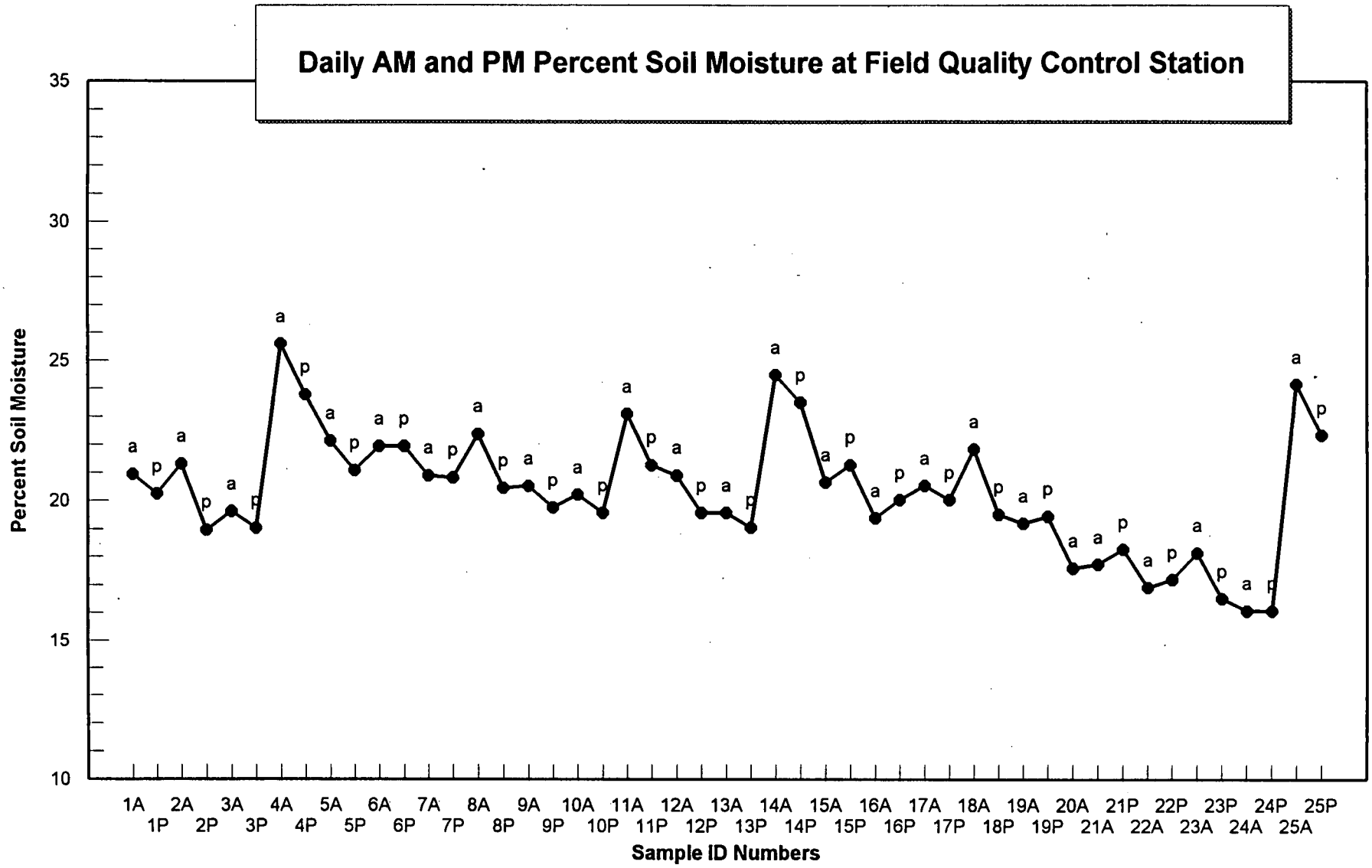
a - AM measurement
p - PM measurement
* - There was not any Temperature Data reported for Sample ID 1P.

FIGURE 5-10



a - AM measurement
p - PM measurement
* - There was not any Humidity Data reported for Sample IDs 1A, 1P, 2A, 2P, and 20A.

FIGURE 5-11



a - AM measurement
p - PM measurement

6.0 RESULTS AND ANALYSIS - PART A COMPARABILITY STUDY

Part A of this in-situ Comparability Study was performed to determine if a series of HPGe measurements in a given area will result in certification decisions identical to those based upon laboratory analysis of physical samples collected in the same given area. The HPGe readings were done in parallel with physical sample collection and analytical testing for primary and secondary radiological COCs in A1PI.

Certification for the primary radiological COCs, i.e., total uranium, thorium-232 and -228, and radium-228 and -226, in the designated A1PI CUs was accomplished by obtaining a minimum of 12 randomly located physical samples for these COCs per CU. Twelve random HPGe locations were also taken in the same CUs as the physical samples; however, by intention, the HPGe readings were not co-located with the physical samples. This was done to compare the data sets for the two methods on a CU basis, rather than on a point-to-point basis, to assess equivalency of certification decisions using the two methods.

The Part A Comparability Study addresses total uranium, thorium-232, radium-226, and cesium-137. As explained in Section 2.2.2, thorium-232, thorium-228 and radium-228 are all quantified by measuring gamma rays emitted by the same daughter products. Therefore, gamma spectrometry cannot differentiate among the three radionuclides. In gamma spectrometry, the convention is to assume secular equilibrium and assign equal activities to all three radionuclides. To be consistent with Part B of the Comparability Study, Part A examines equivalency of certification decisions for total uranium, thorium-232, radium-226, and cesium-137 only.

6.1 CERTIFICATION DECISION PROCESS

The goal of certification is to demonstrate that the average concentration of each COC in each CU is below the FRL and within the agreed upon confidence limits of 95% for primary COCs and 90% for secondary COCs. The following certification situations are possible:

1. The average concentration of each COC within the CU is below the FRLs and is within the confidence limits. The CU can be certified as having achieved cleanup standards.

2. The average concentration of at least one COC for a CU is above the FRL at the given confidence level. The CU will fail certification and will require additional FEMP management decisions.

3. The maximum concentration of any one COC for the CU is greater than the hot spot criteria. The CU fails certification and requires additional DOE management assessment.

6.2 DECISION METHODOLOGY

The parameters of interest in the certification program are the average surface soil concentrations and confidence limits for each COC within a CU as defined by the data generated during certification testing. This includes both data generated from the laboratory analysis of physical samples and data generated for HPGe measurements.

If the average radiological contamination in each CU is demonstrated to be below the FRLs within the agreed upon confidence level of 95% for primary COCs and 90% for secondary COCs, the CU can be certified as complying with the cleanup criteria. If a CU does not meet the FRL within the agreed upon confidence level for at least one assigned COC, that CU will not pass certification.

Based on the certification analytical data, the following formula will be used to determine if the average concentration of a COC in a given certification unit exceeds the FRL:

$$t = \frac{FRL - \bar{x}_i}{\sqrt{S_i^2/(n)}}$$

where:

t	= computed t value
FRL	= final remediation level of a given COC
$\bar{x}_i$	= mean of the (non-weighted) i^{th} CU for a given COC
S^2_i	= sample variance of the ith CU for a given COC
n	= number of samples from the ith CU for a given COC

If the computed t value exceeds the critical t value in the table of t values for student's distribution for alpha = 0.05, with a probability of a Type I error to 5% for primary COCs and alpha = 0.10 for secondary COCs at n-1 degrees of freedom, then the CU is certified as having an average COC concentration below the applicable FRL. A computed t value exceeding the critical value of t for alpha = 0.05 is equivalent to calculating a probability of a Type I error less than 5%. It also corresponds to a UCL less than a FRL. These are the actual parameters shown in Appendix C.

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The equation used to compute t values is sensitive to three factors: 1) the magnitude of the mean; 2) the variability among data points in any given data set; and 3) the number of data points considered in the data set. Given the equation, it is possible to fail certification if no single data point exceeds the FRL, but a high degree of variability exists within data points. Conversely, certification in a CU is also possible even if one or more data points individually exceed the FRL, providing the mean and standard deviation are reduced to an acceptable level by other data points in the data set. A greater number of sample results per data set, or CU in this instance, will increase representativeness of the data and act to buffer variability.

6.3 CERTIFICATION DATA AND RESULTS

Data obtained from the laboratory analysis of physical samples and from HPGe measurements are contained in Appendix B. The data in Appendix B have been analyzed statistically, and summary statistics are shown in Appendix C. The most important aspect of the statistics in Appendix C is if the 95% UCL for primary COCs and 90% for secondary COCs like cesium-137 exceed the FRL. When the UCL exceeds the FRL, the calculated t-value will be less than critical t-values in student's distribution for a probability of 0.05, and the probability of a Type I error will be greater than 5%.

Table 6-1 summarizes the statistical calculations by indicating if a given COC in a given CU exceeds the FRL. Certification decisions based upon HPGe results are identical to those based upon laboratory gamma and laboratory alpha spectrometry data for total uranium. Further, certification decisions based upon HPGe results are identical to those based upon laboratory alpha spectrometry data for thorium-232. However, based upon laboratory gamma spectroscopy, some CUs have 95% UCLs exceeding the FRL for thorium-232. No such situations occur for HPGe thorium-232 values or for laboratory alpha spectrometry thorium-232 data. This issue is discussed in more detail in the A1PI Certification Report (Section 4.1.2, Radiochemical Methods). Lastly, with one exception, certification decisions based upon HPGe results in Table 6-1 are identical to those based upon laboratory data for radium-226 and cesium-137 where the latter two analytes have been determined by gamma spectrometry. For CU Q18-40, radium-226 fails certification based upon gamma spectrometry, while it passes based upon HPGe.

6.4 IMPLICATIONS OF DATA VARIANCE FOR A1PI MEASUREMENTS

Examination of the data in Appendix C shows that the standard deviation (SD) of the measurements for the various radionuclides in a given CU is generally lower for in situ spectrometry (HPGe) as opposed to soil sample analysis. EML scientists have observed this in other studies as well. In principle, one would expect the in situ measurement to provide a data set with a tighter distribution since the measurement covers a large soil area and averages out the small scale inhomogeneities associated with soil samples. The one-meter in situ measurements tend to have smaller SDs than the one-foot in situ measurements, and this is consistent with averaging over a larger area based on their respective fields of view.

Ideally, the best average over the CU should be obtained in certification, which implies that the data set that gives the best average should also have the smallest SD. As such, the in situ methodology can present an important advantage. For a given number of measurements (samples), the rate of decision errors will be less for data sets that have smaller SDs. In effect, the value of the t statistic will be higher when the in situ data are used. Another perspective is that the 95% UCL will be lower, assuming all biases have been corrected and the measurement methods are comparable. For measurements near the FRL, a lower UCL (or higher t statistic) will be most advantageous to avoid unnecessary remediation. Situations where the mean concentration of a radionuclide is below the FRL but the sample SD is too high, thus causing the CU to fail, can be avoided to a large degree.

From another point of view, a smaller number of measurements would be needed to support a pass/fail decision if a smaller SD is expected. This would make for a more efficient survey design. It is possible that the SDs being found for the in situ measurements could be used to reevaluate the number of measurements needed in each type of area. On the other hand, a greater number of measurements would lead to an even lower UCL, which might be important when the mean is close to the FRL. Counting times could possibly be lessened without introducing significantly larger statistical errors, thus allowing time for more measurements.

The effect of the SD can be significant. For reported A1PI data, the average SD for thorium-232 was 0.22 for laboratory gamma spectrometry, 0.15 for laboratory alpha spectrometry, and 0.08 pCi/g for in situ measurements at one meter. For total uranium, the corresponding SDs are 9.1, 6.6 and 4.1 ppm on average. While some of the lab variability can be attributed to measurement error (as can be some

fraction of the in situ variability), the lack of homogeneity over the CU can be an important driver of the SD. This may be crucial for thorium-232 as the FRL is very close to background. With a 20 ppm FRL for total uranium in the production area, it may also become important given the magnitude of the SDs. The value of the t statistic is inversely proportional to the SD, i.e., a measurement set with half the SD value will double the t value, and the UCL will be 50% closer to the mean.

6.5 CONCLUSIONS

Table 6-1 shows that HPGe data and laboratory data result in overall equivalency of decisions with respect to CU certification. The same decisions are made for total uranium, radium-226 (with one exception), and cesium-137 regardless of whether HPGe or laboratory analytical methods are used. The situation is different with respect to thorium-232. Certification decisions based upon HPGe are equivalent to those for thorium-232 based upon alpha spectroscopy. This is not surprising given the comparability of HPGe and alpha spectrometry data as shown in the Part B Comparability Study. However, certification decisions based upon HPGe measurements sometimes differ from those based upon laboratory gamma spectrometry. This is also not surprising since laboratory gamma spectrometry data are almost always higher than laboratory alpha data (Appendices B and C), and, equally importantly, because the standard deviations of gamma spectrometry data for CUs are higher than those based upon HPGe or alpha spectrometry (Section 6.4). Hence, certification decisions based upon laboratory gamma spectrometry data sometimes differ from decisions based upon laboratory alpha spectrometry data. The issue of differences between laboratory alpha and laboratory gamma data will be addressed in a position paper to be submitted to USEPA and OEPA.

TABLE 6-1
CERTIFICATION RESULTS FOR LABORATORY AND HPGe ANALYZED SAMPLES

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
N19	Total U	12	Yes	12	Yes	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
O18	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
O19	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	No	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
O20	Total U	12	Yes	0	--	13	Yes	13	Yes
	Th-232	12	No	12	Yes	13	Yes	13	Yes
	Ra-226	12	Yes	--	NA	13	Yes	13	Yes
	Cs-137	12	Yes	--	NA	13	Yes	13	Yes
P17-22	Total U	13	Yes	0	--	12	Yes	12	Yes
	Th-232	13	No	13	Yes	12	Yes	12	Yes
	Ra-226	13	Yes	--	NA	12	Yes	12	Yes
	Cs-137	13	Yes	--	NA	12	Yes	12	Yes
P17-31	Total U	12	Yes	11	Yes	13	Yes	12	Yes
	Th-232	12	Yes	12	Yes	13	Yes	12	Yes
	Ra-226	12	Yes	--	NA	13	Yes	12	Yes
	Cs-137	12	Yes	--	NA	13	Yes	12	Yes

TABLE 6-1
(continued)

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
P17-32	Total U	12	Yes	7	Yes	12	Yes	12	Yes
	Th-232	12	No	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
P17-33	Total U	12	Yes	12	Yes	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
P17-40	Total U	14	Yes	10	Yes	12	Yes	12	Yes
	Th-232	14	Yes	14	Yes	12	Yes	12	Yes
	Ra-226	14	Yes	--	NA	12	Yes	12	Yes
	Cs-137	14	Yes	--	NA	12	Yes	12	Yes
P18	Total U	15	Yes	8	Yes	12	Yes	12	Yes
	Th-232	15	Yes	15	Yes	12	Yes	12	Yes
	Ra-226	15	Yes	--	NA	12	Yes	12	Yes
	Cs-137	15	Yes	--	NA	12	Yes	12	Yes
P18-11	Total U	12	Yes	11	Yes	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
P18-12	Total U	15	Yes	10	Yes	12	Yes	12	Yes
	Th-232	15	Yes	14	Yes	12	Yes	12	Yes
	Ra-226	15	Yes	--	NA	12	Yes	12	Yes
	Cs-137	15	Yes	--	NA	12	Yes	12	Yes

TABLE 6-1
(continued)

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
P18-20	Total U	13	Yes	0	--	14	Yes	13	Yes
	Th-232	13	Yes	14	Yes	14	Yes	13	Yes
	Ra-226	13	Yes	--	NA	14	Yes	13	Yes
	Cs-137	13	Yes	--	NA	14	Yes	13	Yes
P18-40	Total U	14	Yes	3	Yes	13	Yes	13	Yes
	Th-232	14	No	14	Yes	13	Yes	13	Yes
	Ra-226	14	Yes	--	NA	13	Yes	13	Yes
	Cs-137	14	Yes	--	NA	13	Yes	13	Yes
P19	Total U	12	Yes	--	--	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
P19-20	Total U	19	Yes	0	--	12	Yes	12	Yes
	Th-232	19	Yes	19	Yes	12	Yes	12	Yes
	Ra-226	19	Yes	--	NA	12	Yes	12	Yes
	Cs-137	19	Yes	--	NA	12	Yes	12	Yes
P19-23	Total U	18	Yes	12	Yes	13	Yes	13	Yes
	Th-232	18	Yes	18	Yes	13	Yes	13	Yes
	Ra-226	18	Yes	--	NA	13	Yes	13	Yes
	Cs-137	18	Yes	--	NA	13	Yes	13	Yes
P19-40	Total U	15	Yes	0	--	12	Yes	12	Yes
	Th-232	15	Yes	15	Yes	12	Yes	12	Yes
	Ra-226	15	Yes	--	NA	12	Yes	12	Yes
	Cs-137	15	Yes	--	NA	12	Yes	12	Yes

TABLE 6-1
(continued)

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
P20-30	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	no	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q16-33	Total U	13	Yes	1	Yes	12	Yes	12	Yes
	Th-232	13	Yes	13	Yes	12	Yes	12	Yes
	Ra-226	13	Yes	--	NA	12	Yes	12	Yes
	Cs-137	13	Yes	--	NA	12.	Yes	12	Yes
Q16-34	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q17-10	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q17-30	Total U	12	Yes	0	--	13	Yes	13	Yes
	Th-232	12	Yes	12	Yes	13	Yes	13	Yes
	Ra-226	12	Yes	--	NA	13	Yes	13	Yes
	Cs-137	12	Yes	--	NA	13	Yes	13	Yes
Q18-10	Total U	12	Yes	2	Yes	12	Yes	12	Yes
	Th-232	12	No	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes

TABLE 6-1
(continued)

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
Q18-30	Total U	12	Yes	4	Yes	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q18-40	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	No	12	Yes	12	Yes	12	Yes
	Ra-226	12	No	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q19-10	Total U	12	Yes	4	Yes	12	Yes	12	Yes
	Th-232	12	No	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q19-20	Total U	12	Yes	0	--	12	Yes	12	Yes
	Th-232	12	Yes	12	Yes	12	Yes	12	Yes
	Ra-226	12	Yes	--	NA	12	Yes	12	Yes
	Cs-137	12	Yes	--	NA	12	Yes	12	Yes
Q19-30	Total U	13	Yes	0	--	12	Yes	12	Yes
	Th-232	13	Yes	14	Yes	12	Yes	12	Yes
	Ra-226	13	Yes	--	NA	12	Yes	12	Yes
	Cs-137	13	Yes	--	NA	12	Yes	12	Yes
Q19-40	Total U	14	Yes	0	--	12	Yes	12	Yes
	Th-232	14	Yes	13	Yes	12	Yes	12	Yes
	Ra-226	14	Yes	--	NA	12	Yes	12	Yes
	Cs-137	14	Yes	--	NA	12	Yes	12	Yes

TABLE 6-1
(continued)

		Laboratory Gamma Measurements		Laboratory Alpha Measurements		HPGe Measurements			
Certification Unit	Parameter	No. Samples	95% Confidence Limit below FRL for lab gamma data?	No. Samples	95% Confidence Limit below FRL for lab alpha data?*	No. Samples	95% Confidence Limit below FRL for 1 Ft. HPGe data?	No. Samples	95% Confidence Limit below FRL for 1 M HPGe data?
Q20-20	Total U	13	Yes	0	--	12	Yes	13	Yes
	Th-232	13	Yes	13	Yes	12	Yes	13	Yes
	Ra-226	13	Yes	--	NA	12	Yes	13	Yes
	Cs-137	13	Yes	--	NA	12	Yes	13	Yes
Q20-30	Total U	17	Yes	11	Yes	12	Yes	12	Yes
	Th-232	17	Yes	17	Yes	12	Yes	12	Yes
	Ra-226	17	Yes	--	NA	12	Yes	12	Yes
	Cs-137	17	Yes	--	NA	12	Yes	12	Yes
Q20-40	Total U	13	Yes	14	Yes	12	Yes	12	Yes
	Th-232	13	Yes	14	Yes	12	Yes	12	Yes
	Ra-226	13	Yes	--	NA	12	Yes	12	Yes
	Cs-137	13	Yes	--	NA	12	Yes	12	Yes

*NA = not applicable

7.0 STRATEGY AND PATH FORWARD FOR FUTURE USE OF THE IN-SITU HPGe DETECTOR SYSTEM

General conclusions from Sections 3, 4, and 5 are that data generated by HPGe and laboratory alpha spectrometry are useful for thorium-232, total uranium, and cesium-137 analyses at both ASL D and ASL B data quality levels. Additional work is necessary before radium-226 can be used at ASL D or ASL B. Furthermore, certification decisions (did the UCL exceed the FRL at a given confidence limit?) based upon HPGe and laboratory measurements are comparable for total uranium, thorium-232 (when the laboratory measurement is alpha spectrometry), radium-226, and cesium-137. Based on the above conclusions, a strategy and path forward for future use of the HPGe are discussed below.

7.1 STRATEGY FOR USE OF THE HPGe

7.1.1 Representativeness of the HPGe Data

A traditional data quality indicator is the element of representativeness, that is, the degree to which sample data accurately represent characteristics or conditions being measured. Representativeness is primarily a planning issue. The key to enhancing representativeness is the proper formulation of the sampling/survey plan. The "Interim Final Guidance for Data Quality Objectives Process for Superfund" (EPA 1993) stresses that the objective of statistical sampling design is to minimize total error, which is a combination of sampling and measurement error, to acceptable levels.

Laboratory analysis of discrete samples tends to minimize measurement error. However, while analyzing only a limited number of discrete samples in the laboratory may be practical, each sample may only be representative of a small point in space. Thus, the sampling error may be large. Conversely, HPGe measurement error may be somewhat larger than laboratory analyses error. However, the advantages of HPGe measurements are that high quality measurements can be made quickly, a number of radionuclides can be analyzed simultaneously, and HPGe has a large field of view which enables it to characterize a sizeable area. Thus, HPGe tends to minimize sampling error and is superior to laboratory measurements of discrete points, particularly in heterogeneous areas. This point has been stressed in Section 6.4.

In the following section, a variety of potential HPGe uses are listed. A majority of these uses implicitly require one of the HPGe's primary strengths, representativeness of data.

7.1.2 Potential Uses of HPGe in Remediation Soils

A wide variety of potential uses for HPGe measurements exists in remediation operations at the FEMP. Some of the listed operations could be performed better by RTRAK than by HPGe (see Section 7.1.3). Nonetheless, this list is intended to illustrate the universe of applications that can be performed by HPGe rather than a subset of applications that actually will be performed.

There are three broad categories of applications in which the HPGe can be used to support soil remediation:

1. Operations Prior to Soil Remediation:

   - Conduct surveys in accessible areas to develop a general sense for contamination patterns and for general engineering planning and design.
   - Conduct surveys to identify potential WAC exceedance areas and potential hot spot problems.
   - Establish potential WAC exceedances as real exceedances and delineate the WAC exceedance footprint.
   - Delineate the footprint of potential hot spots and evaluate their magnitude.
   - Certify that soil meets FRLs based upon HPGe measurements where field surveys indicate no necessity to remediate soils in those areas.

2. Soil Remediation Operations:

   - Conduct surveys to help establish excavation footprints
   - Conduct surveys to determine heterogeneity within CUs to help determine how many physical samples or HPGe readings must be taken for certification
   - Conduct surveys to assist in assessing whether specific CUs are likely to fail.
   - Use HPGe measurements to help make dig/no dig decisions as excavation proceeds.
   - Support implementation of ALARA.

3. Operations Following Soil Remediation:

   - Conduct surveys to determine if potential hot spot problems exist after remediation
   - Verify that residual soils no longer meet hot spot criteria where hot spot remediation activities have occurred.
   - Verify that residual soils are below WAC where WAC remediation activities have occurred.
   - Certify that residual soils pass FRLs based upon HPGe data for areas that have been remediated.

Table 7-1 lists these potential HPGe uses, proposes data quality levels that might be associated with these uses, and indicates if HPGe can currently be used for the operation listed (i.e., meets ASL requirements). Where HPGe cannot currently be used, Section 7.2 indicates what additional method development work is necessary to allow usage.

7.1.3 Relation Between RTRAK and HPGe Usage

As noted in Section 7.1.2, some of the potential applications of HPGe in soil remediation operations are better performed by RTRAK. The RTRAK and HPGe systems complement each other. The RTRAK is able to provide rapid, 100% coverage of an area. Its precision and detection limits are sufficient to determine the degree of homogeneity and heterogeneity of a given area with respect to total uranium, thorium-232 and radium-226. Its data output is amenable to mapping. These features make the RTRAK ideal as a front-end survey tool to help focus and guide the use of HPGe.

The strengths of the HPGe are its ability to accurately quantify a variety of isotopes, its high degree of energy resolution (which makes interferences less likely), its ability to average data over either large or small areas, thereby minimizing sampling error and maximizing data representativeness, and its capability to delineate footprints of hot spots or WAC exceedances by lowering the detector height to focus in on smaller areas. These characteristics dictate the HPGe's use in providing high-quality data for certification/verification activities relative to remediation of soils for hot spots, WAC exceedances, and FRLs. Additionally, HPGe's strength in footprint delineation indicates that it should be used as a confirmatory tool to evaluate potential hot spot and WAC exceedance areas noted by RTRAK surveys.

7.2 ADDITIONAL METHOD DEVELOPMENT FOR HPGe

Based upon conclusions and discussion in Sections 3 and 5 and Table 7-1, several additional method development studies are required to complement those already performed. These should be completed as soon as feasible.

- Identify contamination areas where radium-226 activities are 1.0 to 2.5 pCi/g, and collect, per Section 2, HPGe measurements and physical samples having activities in this range in order to provide data to fill existing data gaps. This could lead to a better understanding of differences between HPGe and laboratory measurements of radium-226.

- Delineate and resolve possible laboratory issues contributing to differences between laboratory and HPGe measurements for radium-226.

- Identify, if possible, contamination areas where total uranium concentrations approach or exceed 1,000 ppm. Such locations would extend the range of comparability to allow HPGe to be used with confidence for WAC attainment analysis.

- Although Figures 3-3 and 3-4 exhibit excellent correlation between HPGe and laboratory thorium-232 data, only one data point greater than 3.0 pCi/g exists. If samples collected for additional radium and uranium data as described above appear to have thorium-232 concentrations greater than 3.0 pCi/g based upon HPGe measurements, those samples will be analyzed also to fill in thorium-232 data gaps.

- Continue to make measurements at the field quality control station twice a day to better assess the influence of environmental conditions on radium-226.

Activities pertaining to all four items have already been initiated. As these activities are completed and data are evaluated and integrated with previously generated data, separate, stand-alone memoranda will document and summarize the results. These stand-alone memoranda will constitute addenda to this report and should be regarded as incremental method development improvements.

In summary, the recommended strategy for HPGe implementation to implement and improve incrementally at the FEMP is similar to EPA strategies for promulgated laboratory methods. That is, use the HPGe per Table 7-1 for the uses for which it meets data quality level requirements, improve the process as described above, and fully integrate HPGe into soil remediation projects incrementally with each method development improvement.

TABLE 7-1
UTILIZATION OF HPGe AS A FUNCTION OF DATA QUALITY LEVEL

Potential HPGe Usage	Analyte*	ASL**	Does HPGe meet ASL Requirement for Usage?
1. Operations Prior to Soil Remediation			
• Identify WAC exceedance areas	Total U	A	Yes
• Identify potential hot spot problems	Total U, Th-232, Ra-226	A	Yes
• Develop a generic sense for patterns of contamination	Total U, Th-232, Ra-226, Cs-137	A	Yes
• Establish if potential WAC exceedances are real and delineate footprint	Total U	B	No***
• Delineate footprint and magnitude of potential hot spots	Total U, Th-232, Ra-226	B	Yes for Total U, Th-232; no for Ra-226
• Certify soils not requiring remediation	Total U, Th-232, Ra-226, Cs-137	D	Yes for Total U, Th-232, Cs-137; no for Ra-226
2. Soil Remediation Operations			
• Establish excavation footprint	Total U, Th-232, Ra-226	A	Yes
• Use for dig/no dig decisions	Total U, Th-232, Ra-226	A	Yes
• Delineate homogeneity within CU to determine number of certification samples	Total U, Th-232, Ra-226	A	Yes
• Assist in determining whether specific CUs are likely to pass or fail	Total U, Th-232, Ra-226, Cs-137	A	Yes
• Support Implementation of ALARA	Total U	A	Yes
3. Operations Following Soil Remediation			
• Conduct surveys to determine whether hot spot problems exist after remediation	Total U, Th-232, Ra-226	A	Yes
• Verify that residual soils after hot spot remediation no longer exceed hot spot criteria	Total U, Th-232, Ra-226	D	Yes for Total U, Th-232; no for Ra-226
• Where WAC remedition has occurred, verify that residual soils are below WAC	Total U	D	No***
• Certify that residual soils in remediation areas pass FRL criteria	Total U, Th-232, Ra-226	D	Yes for Total U, Th-232, Cs-137; no for Ra-226

* Activities of Ra-228 and Th-228 will be set equal to the activity of Th-232 because of secular equilibrium
** There are no specific QC requirements for ASL A in the SCQ.
***The range of HPGe comparability must be extended to areas having greater than 1,000 ppm if possible. See Section 7.2.

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APPENDIX A

HPGe READINGS AND PHYSICAL SAMPLE RESULTS FOR PART B OF THE CHARACTERIZATION COMPARABILITY STUDY

APPENDIX A
HPGe READINGS AND PHYSICAL SAMPLE RESULTS FOR PART B OF THE CHARACTERIZATION COMPARABILITY STUDY

This appendix contains the HPGe readings and physical sample results from Part B of the Comparability Study. The data are sorted by sample area and parameter; parameters include primary radiological COCs and the soil moisture content. Sample results are presented on a wet weight basis for both laboratory and field methods, and with corresponding field analytical results/laboratory analytical results and validation qualifier, and total propagated uncertainty/error (TPU/error). The TPU applies to the laboratory analysis, while the error applies to field instrumentation. The laboratory TPUs are presented as 1.96 σ values, while the HPGe uncertainties reflect 1.96 σ counting errors. Laboratory TPUs are greater than HPGe 1.96 σ counting errors because the former represents total system uncertainty, while the latter represents only one component of system uncertainty. Although the same form of the equation is used to calculate counting errors for laboratory data and HPGe data, counting errors cannot be compared between laboratory and HPGe data as they are highly dependent upon count times and sample volumes.

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA01-PBC												
FIELD RESULT												
PBC-1-1	.31	24.1	0.42	0.03	11.6	0.36	0.63	0.04	0.54	0.04	8.53	0.02
PBC-1-1	.31	24.1	0.44	0.03	11.3	0.36	0.65	0.04	0.50	0.04	9.42	0.02
PBC-1-1	1	24.1	0.39	0.03	10.7	0.36	0.59	0.04	0.51	0.04	7.97	0.02
PBC-1-1	1	24.1	0.38	0.03	10.7	0.35	0.60	0.04	0.51	0.04	0.06	0.02
LAB RESULT												
PBC-1-1		24.1	0.36	0.08	11.6	1.60	0.48	0.14	0.52	0.12	7.71	1.84
PBC-1-2		23.6	0.42	0.09	14.0	1.90	0.57	0.13	0.48	0.11	6.85	1.67
PBC-1-3		20.6	0.34	0.10	12.1	1.80	0.40	0.12	0.46	0.11	8.94	2.20
PBC-1-4		20.4	0.29	0.04	15.5	1.60	0.47	0.11	0.56	0.13	6.55	1.70
PBC-1-5		24.4	0.58	0.10	10.5	1.60	0.72	0.17	0.49	0.11	7.14	1.72
PBC-1-6		20.6	0.45	0.09	10.5	1.60	0.40	0.12	0.47	0.11	8.63	2.02
PBC-1-7		22.1	0.49	0.11	10.9	1.60	0.49	0.11	0.49	0.12	8.33	2.05

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA02-PBC												
FIELD RESULT												
PBC-2-1	.31	21.9	0.59	0.03	7.84	0.31	0.67	0.04	0.62	0.04	32.6	0.04
PBC-2-1	.31	21.9	0.60	0.03	7.83	0.31	0.66	0.04	0.65	0.04	29.9	0.04
PBC-2-1	1	21.9	0.51	0.03	7.83	0.31	0.67	0.04	0.61	0.05	27.9	0.04
PBC-2-1	1	21.9	0.48	0.03	7.63	0.30	0.70	0.04	0.65	0.05	24.0	0.04
LAB RESULT												
PBC-2-1		21.9	0.85	0.15	8.88	1.75	0.68	0.16	0.48	0.11	33.0	7.43
PBC-2-2		24.2	0.59	0.10	10.1	1.50	0.68	0.16	0.58	0.14	29.4	0.00
PBC-2-3		19.1	0.61	0.11	6.22	1.25	0.51	0.15	0.36	0.09	26.4	6.24
PBC-2-4		22	0.72	0.12	7.68	1.25	0.54	0.13	1.20	0.27	28.2	6.24
PBC-2-5		24.3	0.68	0.13	12.1	1.90	0.59	0.14	0.60	0.14	28.0	0.00
PBC-2-6		22.2	0.40	0.13	9.76	1.79	0.61	0.14	0.39	0.09	17.0	0.00
PBC-2-7		18.5	0.42	0.09	6.62	1.08	0.51	0.12	0.41	0.10	29.1	6.54
PBC-2-8		19	0.67	0.11	7.76	1.41	0.51	0.15	0.38	0.09	24.3	5.95
PBC-2-9		19	0.64	0.12	7.75	1.33	0.60	0.14	0.37	0.09	20.5	4.76
PBC-2-10		30.1	0.49	0.15	13.7	2.30	0.58	0.14	0.58	0.13	24.7	0.00
PBC-2-11		18.6	0.62	0.12	7.02	1.25	0.81	0.19	0.41	0.10	25.9	5.95

0001134

Sample Id	Det Ht	Moisture %	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Err	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Err	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Err	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
Area: AREA03-PBC												
FIELD RESULT												
PBC-3-1	.31	21.2	0.48	0.04	10.7	0.38	4.09	0.09	2.17	0.08	283.4	0.08
PBC-3-1	.31	21.2	0.54	0.04	11.5	0.38	4.30	0.09	2.20	0.08	298.1	0.08
PBC-3-1	1	21.2	0.46	0.04	11.2	0.39	4.32	0.09	2.51	0.09	281.0	0.08
PBC-3-1	1	21.2	0.46	0.04	11.0	0.39	4.25	0.09	2.48	0.09	292.2	0.08
LAB RESULT												
PBC-3-1		21.2	0.79	0.19	10.9	1.60	12.0	2.8	2.00	0.49	1933	446.1
PBC-3-2		25.9	0.70	0.14	11.6	1.70	11.1	2.5	2.00	0.44	270.9	62.4
PBC-3-3		26.1	0.76	0.14	12.1	1.80	13.0	3.0	2.30	0.53	241.2	53.5
PBC-3-4		25	0.76	0.14	14.5	2.20	25.0	5.6	2.10	0.48	294.7	68.4
PBC-3-5		17.4	0.16	0.10	14.0	2.10	20.0	4.4	2.00	0.45	357.2	80.3
PBC-3-6		22	0.48	0.11	12.9	1.90	7.10	1.70	1.60	0.36	238.2	53.5
PBC-3-7		21.7	0.59	0.13	12.1	2.10	24.0	5.4	2.30	0.52	446.4	104.1
PBC-3-8		24.1	0.29	0.09	13.2	2.10	22.0	5.0	1.70	0.38	169.8	38.7
PBC-3-9		22	0.49	0.15	11.6	1.90	13.5	3.0	3.20	0.73	250.1	59.5
PBC-3-10		17.3	0.25	0.13	12.9	2.10	14.8	3.3	2.00	0.46	226.3	53.5
PBC-3-11		18.2	0.54	0.19	12.4	2.10	9.47	2.10	1.80	0.41	357.2	80.3
PBC-3-12		23.1	0.50	0.19	12.9	2.40	8.30	1.90	2.30	0.53	279.9	65.4
PBC-3-13		27.3	0.91	0.15	14.7	2.00	4.98	1.10	2.80	0.63	238.2	56.5
PBC-3-14		28.6	0.74	0.15	13.7	2.00	4.80	1.09	1.90	0.43	276.9	62.4
PBC-3-15		24.4	0.51	0.14	12.4	1.80	5.43	1.20	1.80	0.41	327.4	74.3
PBC-3-16		21.1	0.28	0.14	13.7	2.10	5.13	1.20	1.20	0.29	294.7	71.4

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA04-PBC												
FIELD RESULT												
PBC-4-1	.31	27.3	0.35	0.03	9.53	0.33	0.80	0.04	0.81	0.04	57.6	0.03
PBC-4-1	.31	27.3	0.35	0.03	9.35	0.33	0.85	0.04	0.79	0.04	55.5	0.03
PBC-4-1	1	27.3	0.33	0.03	9.07	0.33	0.79	0.04	0.78	0.04	57.3	0.03
PBC-4-1	1	27.3	0.34	0.03	9.05	0.33	0.82	0.04	0.78	0.04	59.9	0.03
LAB RESULT												
PBC-4-1		27.3	0.39	0.08	10.1	1.40	0.44	0.13	0.80	0.18	57.7	13.4
PBC-4-2		24.9	0.42	0.10	12.4	1.80	0.71	0.16	0.77	0.18	47.9	11.0
PBC-4-3		26.3	0.42	0.09	12.4	1.80	0.67	0.15	0.75	0.17	59.8	13.7
PBC-4-4		26.6	0.40	0.12	10.5	1.70	0.66	0.15	0.71	0.16	62.8	14.3
PBC-4-5		23.1	0.32	0.09	12.4	1.80	0.53	0.12	0.70	0.16	39.0	8.92
PBC-4-6		26.3	0.23	0.10	10.5	1.60	0.62	0.15	0.67	0.15	47.9	11.0
PBC-4-7		25.3	0.29	0.10	11.3	1.70	0.68	0.16	0.69	0.16	44.9	0.00
PBC-4-8		29.5	0.38	0.09	10.5	1.80	0.51	0.12	0.74	0.17	71.7	16.4
PBC-4-9		26.7	0.42	0.16	12.1	1.80	0.52	0.12	0.76	0.17	62.8	14.6
PBC-4-10		24.6	0.43	0.14	11.4	2.00	0.50	0.12	0.79	0.18	53.9	0.00
PBC-4-11		25	0.38	0.10	11.6	1.70	0.58	0.14	0.79	0.18	59.8	14.0

000136

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA05-PBC												
FIELD RESULT												
PBC-5-1	.31	21.8	0.34	0.03	10.9	0.36	0.69	0.04	0.79	0.05	42.8	0.04
PBC-5-1	.31	21.8	0.34	0.03	11.0	0.36	0.74	0.04	0.80	0.05	41.6	0.04
PBC-5-1	1	21.8	0.36	0.03	10.4	0.35	0.74	0.04	0.80	0.05	46.7	0.04
PBC-5-1	1	21.8	0.34	0.03	10.3	0.35	0.72	0.04	0.78	0.05	49.1	0.04
LAB RESULT												
PBC-5-1		21.8	0.36	0.08	13.7	2.10	0.60	0.14	0.74	0.17	30.1	0.00
PBC-5-2		24	0.33	0.12	13.8	2.30	0.60	0.14	0.75	0.17	36.0	0.00
PBC-5-3		24.9	0.41	0.14	12.1	2.10	0.55	0.13	0.75	0.17	36.0	0.00
PBC-5-4		23.9	0.39	0.10	10.5	1.70	0.58	0.14	0.72	0.17	33.1	7.43
PBC-5-5		25.7	0.53	0.12	13.7	2.00	0.67	0.15	0.91	0.21	53.9	12.5
PBC-5-6		27.8	0.51	0.12	11.6	1.70	0.45	0.11	0.55	0.13	68.7	16.1
PBC-5-7		25.4	0.36	0.12	11.3	1.70	0.47	0.11	0.86	0.20	65.8	15.5
PBC-5-8		22.3	0.27	0.08	12.4	1.90	0.48	0.11	0.68	0.16	27.7	0.00
PBC-5-9		21.5	0.43	0.11	12.4	1.80	0.60	0.14	1.00	0.23	71.7	16.7
PBC-5-10		26	0.47	0.13	13.7	2.00	0.45	0.11	0.93	0.21	36.0	8.62
PBC-5-11		27.6	0.49	0.09	11.6	1.60	0.50	0.12	0.98	0.22	47.9	11.3

0001337

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA06-PBC												
FIELD RESULT												
PBC-6-1	.31	26.7	0.32	0.03	9.26	0.33	0.80	0.04	0.85	0.04	77.9	0.03
PBC-6-1	.31	26.7	0.34	0.03	9.14	0.33	0.82	0.04	0.80	0.04	75.5	0.03
PBC-6-1	.31	26.7	0.32	0.03	8.98	0.32	0.81	0.04	0.82	0.04	76.4	0.03
PBC-6-1	.31	26.7	0.34	0.03	8.93	0.33	0.80	0.04	0.83	0.04	77.7	0.03
PBC-6-1	.31	26.7	0.31	0.03	9.00	0.33	0.79	0.04	0.80	0.04	78.0	0.03
PBC-6-1	.31	26.7	0.31	0.03	9.19	0.33	0.79	0.04	0.77	0.04	75.0	0.03
PBC-6-1	1	26.7	0.31	0.03	8.81	0.32	0.81	0.04	0.80	0.04	74.4	0.03
PBC-6-1	1	26.7	0.31	0.03	8.70	0.32	0.79	0.04	0.78	0.04	76.4	0.03
PBC-6-1	1	26.7	0.34	0.03	8.94	0.33	0.80	0.04	0.80	0.04	72.9	0.03
PBC-6-1	1	26.7	0.31	0.03	8.95	0.33	0.80	0.04	0.79	0.04	76.1	0.03
PBC-6-1	1	26.7	0.32	0.03	8.90	0.32	0.79	0.04	0.81	0.04	81.2	0.03
PBC-6-1	1	26.7	0.34	0.03	8.85	0.33	0.79	0.04	0.82	0.04	74.4	0.03
LAB RESULT												
PBC-6-1		26.7	0.33	0.10	10.9	1.70	0.60	0.16	0.73	0.17	80.6	17.8
PBC-6-2		27.5	0.38	0.11	10.5	1.70	0.60	0.14	0.77	0.18	83.9	19.3
PBC-6-3		27	0.50	0.12	11.3	1.90	0.67	0.15	0.80	0.18	92.5	21.1
PBC-6-4		24.3	0.41	0.11	12.4	1.70	0.59	0.14	0.78	0.18	83.6	19.3
PBC-6-5		24.7	0.44	0.12	13.7	2.00	0.70	0.16	0.82	0.19	104.4	24.1
PBC-6-6		28.1	0.43	0.11	9.69	1.59	0.69	0.16	0.88	0.20	86.6	19.6
PBC-6-7		26.8	0.49	0.10	10.9	1.70	0.73	0.17	0.79	0.18	80.6	18.7
PBC-6-8		25.3	0.51	0.11	10.9	1.70	0.70	0.16	0.80	0.18	105.3	24.1
PBC-6-9		24.1	0.25	0.13	9.65	2.10	0.56	0.13	0.85	0.20	71.7	0.00
PBC-6-10		26.5	0.37	0.10	10.5	1.70	0.76	0.18	0.78	0.19	77.7	17.8

APPENDIX A - ANALYTICAL RESULTS FOR PA[illegible] B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
PBC-6-11		24.4	0.34	0.10	11.6	1.70	0.57	0.13	0.78	0.18	75.3	17.0

000139

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APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA07-PBC												
FIELD RESULT												
PBC-7-1	.31	28.4	0.29	0.03	8.86	0.32	0.81	0.04	0.98	0.05	140.3	0.04
PBC-7-1	.31	28.4	0.29	0.03	9.10	0.33	0.79	0.04	1.00	0.05	142.1	0.04
PBC-7-1	1	28.4	0.27	0.03	9.03	0.33	1.09	0.05	1.01	0.05	141.8	0.04
PBC-7-1	1	28.4	0.28	0.03	9.09	0.33	0.97	0.04	0.93	0.05	138.9	0.04
LAB RESULT												
PBC-7-1		28.4	0.33	0.11	10.1	1.50	0.69	0.16	0.97	0.22	152.0	0.00
PBC-7-2		29.5	0.30	0.09	10.1	1.60	0.78	0.18	0.99	0.23	166.9	41.6
PBC-7-3		28.4	0.32	0.09	9.69	1.48	0.64	0.15	1.00	0.23	143.1	35.7
PBC-7-4		26.6	0.27	0.08	10.9	1.70	0.73	0.17	0.95	0.22	137.1	35.7
PBC-7-5		27.5	0.40	0.12	10.5	1.60	1.01	0.23	0.96	0.22	185.6	41.6
PBC-7-6		27	0.32	0.11	10.9	1.50	0.79	0.18	1.10	0.26	208.8	46.7
PBC-7-7		27.2	0.36	0.09	11.6	1.70	0.87	0.20	1.10	0.25	180.8	40.4
PBC-7-8		25	0.38	0.13	12.9	2.10	0.74	0.17	1.20	0.27	163.9	38.7
PBC-7-9		28.7	0.38	0.11	9.69	1.51	0.61	0.14	0.91	0.21	152.0	38.7
PBC-7-10		27	0.43	0.12	11.6	1.80	0.67	0.15	1.00	0.23	137.1	32.7
PBC-7-11		27.7	0.30	0.10	10.5	1.60	0.68	0.16	0.96	0.22	131.2	0.00
PBC-7-12		28.5	0.53	0.12	11.6	1.80	1.03	0.26	1.30	0.29	202.6	47.6
PBC-7-13		28.6	0.27	0.11	10.5	1.70	0.62	0.14	0.85	0.20	357.2	80.3
PBC-7-14		23.7	0.46	0.15	13.0	2.20	1.30	0.29	1.20	0.27	157.9	0.00
PBC-7-15		28.9	0.31	0.16	10.5	1.80	0.83	0.19	1.10	0.25	181.7	0.00
PBC-7-16		27	0.31	0.09	10.9	1.70	0.20	0.05	0.99	0.23	166.9	38.7

080140

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA08-PBC												
FIELD RESULT												
PBC-8-1	.31	29.9	0.11	0.02	8.73	0.32	0.66	0.04	0.55	0.03	5.65	0.01
PBC-8-1	.31	29.9	0.11	0.02	8.74	0.32	0.64	0.04	0.56	0.04	6.02	0.02
PBC-8-1	1	29.9	0.11	0.02	8.64	0.32	0.60	0.04	0.56	0.04	5.47	0.02
PBC-8-1	1	29.9	0.12	0.02	9.14	0.33	0.62	0.04	0.51	0.04	5.09	0.00
LAB RESULT												
PBC-8-1		29.9	0.07	0.05	10.9	1.50	0.42	0.13	0.55	0.13	5.09	1.22
PBC-8-2		35.1	0.11	0.07	10.9	1.60	0.33	0.08	0.47	0.11	4.58	1.22
PBC-8-3		26.3	0.13	0.09	11.3	1.70	0.54	0.12	0.57	0.13	7.53	1.90
PBC-8-4		30.9	0.13	0.09	9.69	1.41	0.38	0.09	0.45	0.10	3.62	1.04
PBC-8-5		28.2	0.17	0.07	10.9	1.60	0.42	0.10	0.49	0.12	4.22	1.13
PBC-8-6		34	0.20	0.04	9.69	1.07	0.36	0.11	0.46	0.11	33.0	7.32
PBC-8-7		32.6	0.11	0.02	10.9	1.10	0.45	0.10	0.49	0.11	3.89	1.10

APPENDIX A - ANALYTICAL RESULTS FOR PART B COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht**	**Moisture %**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**	**Result**	**TPU/Err**
Area: AREA09-PBC												
FIELD RESULT												
PBC-9-1	.31	29.3	0.26	0.02	9.20	0.32	0.71	0.04	0.64	0.04	5.75	0.02
PBC-9-1	.31	29.3	0.28	0.02	9.14	0.33	0.75	0.04	0.62	0.04	7.41	0.02
PBC-9-1	1	29.3	0.26	0.02	8.71	0.32	0.69	0.04	0.58	0.04	7.26	0.02
PBC-9-1	1	29.3	0.27	0.02	9.00	0.33	0.69	0.04	0.59	0.04	6.55	0.02
LAB RESULT												
PBC-9-1		29.3	0.24	0.11	10.9	1.60	0.37	0.09	0.54	0.13	5.98	1.78
PBC-9-2		27.3	0.36	0.04	10.9	1.10	0.46	0.11	0.49	0.12	5.98	1.40
PBC-9-3		26.3	0.31	0.15	11.3	1.90	0.40	0.09	0.55	0.13	6.28	0.00
PBC-9-4		26.3	0.26	0.08	9.69	1.51	0.37	0.09	0.47	0.11	7.47	2.14
PBC-9-5		26.4	0.40	0.10	10.9	1.60	0.43	0.10	0.47	0.11	6.27	0.00
PBC-9-6		24.8	0.20	0.08	9.69	1.57	0.42	0.10	0.55	0.13	7.47	2.08
PBC-9-7		25.6	0.38	0.11	11.6	1.70	0.41	0.10	0.55	0.13	5.98	1.46

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Sample Id	Det Ht	Moisture %	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Err	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Err	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Err	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
Area: AREA10-PBC												
FIELD RESULT												
PBC-10-1	.31	20.8	0.28	0.04	10.5	0.37	1.90	0.07	5.82	0.09	80.6	0.05
PBC-10-1	.31	20.8	0.27	0.04	10.5	0.38	1.85	0.07	5.81	0.10	81.2	0.05
PBC-10-1	1	20.8	0.31	0.04	9.89	0.38	1.66	0.07	6.91	0.10	73.7	0.05
PBC-10-1	1	20.8	0.29	0.04	10.2	0.38	1.67	0.07	6.85	0.10	74.3	0.05
LAB RESULT												
PBC-10-1		20.8	0.41	0.13	12.1	1.80	3.30	0.74	5.90	1.30	72.3	16.4
PBC-10-2		19.1	0.22	0.10	12.9	2.00	4.91	1.10	5.10	1.10	47.9	41.0
PBC-10-3		17.4	0.43	0.10	10.9	1.60	6.35	1.40	5.40	1.20	62.2	14.6
PBC-10-4		18.8	0.24	0.09	10.1	1.50	2.10	0.46	3.40	0.75	65.7	15.2
PBC-10-5		21.8	0.44	0.12	11.3	2.00	1.86	0.42	3.90	0.88	71.7	16.1
PBC-10-6		16.7	0.49	0.18	12.4	1.90	3.94	0.91	15.0	3.40	41.1	9.22
PBC-10-7		18.8	0.03	0.01	10.9	1.60	5.00	1.10	4.00	0.90	29.8	6.84
PBC-10-8		18.8	0.39	0.12	12.1	1.80	2.00	0.44	15.0	3.40	30.7	7.43
PBC-10-9		16.8	0.26	0.17	11.3	2.10	2.30	0.52	23.0	5.30	53.9	12.5
PBC-10-10		20.5	0.37	0.10	13.2	1.90	3.40	0.77	2.20	0.51	71.7	16.4
PBC-10-11		19.3	0.33	0.11	11.3	1.80	3.39	0.76	3.80	0.86	42.0	9.52
PBC-10-12		20.4	0.33	0.09	10.9	1.70	1.50	0.34	5.30	1.20	47.6	11.0
PBC-10-13		16.6	0.33	0.10	11.6	1.70	1.40	0.32	6.70	1.50	50.9	11.6
PBC-10-14		17.8	0.26	0.13	10.5	1.70	1.70	0.38	4.70	1.00	50.9	11.3
PBC-10-15		18.4	0.43	0.14	10.5	1.80	2.00	0.45	14.0	3.20	59.8	13.7
PBC-10-16		15.2	0.23	0.09	10.9	1.60	6.20	1.40	3.70	0.84	56.8	12.8

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APPENDIX B

CERTIFICATION AND HIGH-PURITY GERMANIUM DETECTOR RESULTS FOR PART A OF THE CHARACTERIZATION COMPARABILITY STUDY

APPENDIX B
CERTIFICATION AND HIGH-PURITY GERMANIUM DETECTOR RESULTS FOR PART A OF THE COMPARABILITY STUDY

This appendix contains certification results and high purity germanium detector (HPGe) results for Part A of the Comparability Study. The results are for analysis of radiological primary COCs, and are sorted by CU. All samples taken in each CU are listed by sample number, and the results are presented with the total propagated uncertainty/error (TPU/error) as a function of the analytical method. The TPU represents 1.96 σ TPU and applies to the laboratory analysis, while the error applies to field instrumentation and represents 1.96 σ counting error. The second column of data presents the detector height for the HPGe samples only. The third column gives % moisture data for both HPGe and laboratory data. Both HPGe and laboratory data are moisture corrected and are presented on a dry weight basis.

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: N19												
FIELD RESULT												
N19-00-1-G	.31	27.5	0.49	0.04	13.3	0.49	0.82	0.05	0.83	0.05	29.6	3.89
N19-00-10-G	.31	27.5	0.47	0.04	16.6	0.55	0.86	0.05	0.95	0.06	24.5	3.66
N19-00-11-G	.31	27.5	0.51	0.04	13.9	0.50	0.67	0.05	0.77	0.05	12.9	3.31
N19-00-12-G	.31	27.5	0.50	0.04	19.4	0.59	0.79	0.05	0.98	0.06	20.7	3.61
N19-00-13-G	.31	27.5	0.50	0.04	20.4	0.63	0.77	0.05	1.01	0.06	18.7	3.50
N19-00-13-G	.31	27.5	0.00	0.00	19.2	0.60	0.49	0.05	0.68	0.06	9.03	4.38
N19-00-13-G	.31	27.5	0.39	0.04	19.9	0.63	0.62	0.06	0.63	0.06	0.00	0.00
N19-00-14-G	.31	27.5	0.49	0.04	22.1	0.63	0.70	0.05	1.02	0.06	28.1	3.66
N19-00-2-G	.31	27.5	0.49	0.04	14.3	0.51	0.79	0.05	0.81	0.05	28.4	3.89
N19-00-3-G	.31	27.5	0.47	0.04	12.3	0.50	0.82	0.05	0.81	0.06	20.6	3.75
N19-00-5-G	.31	27.5	0.48	0.04	12.6	0.50	0.89	0.06	0.83	0.05	20.7	3.65
N19-00-6-G	.31	27.5	0.50	0.04	13.5	0.52	0.95	0.06	0.87	0.06	23.1	3.72
N19-00-8-G	.31	27.5	0.46	0.04	15.9	0.56	0.98	0.06	0.90	0.06	19.7	3.65
N19-00-9-G	.31	27.5	0.39	0.04	17.2	0.56	0.82	0.05	0.86	0.05	12.2	3.92
N19-00-1-G	1	27.5	0.47	0.04	13.2	0.49	0.86	0.05	0.78	0.06	24.2	3.99
N19-00-10-G	1	27.5	0.48	0.04	16.0	0.55	0.95	0.06	0.92	0.06	20.3	3.72
N19-00-11-G	1	27.5	0.50	0.04	14.2	0.51	0.70	0.05	0.76	0.05	14.6	3.56

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
N19-00-12-G	1	27.5	0.43	0.04	19.3	0.59	0.79	0.06	0.89	0.06	16.2	3.72
N19-00-13-G	1	27.5	0.46	0.04	19.0	0.62	0.72	0.05	0.85	0.06	14.6	3.57
N19-00-13-G	1	27.5	0.50	0.04	19.2	0.62	0.73	0.05	0.89	0.06	14.0	3.93
N19-00-14-G	1	27.5	0.42	0.04	20.6	0.61	0.69	0.05	0.88	0.06	26.9	3.74
N19-00-2-G	1	27.5	0.50	0.04	14.1	0.51	0.82	0.05	0.82	0.06	25.4	3.91
N19-00-3-G	1	27.5	0.51	0.04	12.4	0.49	0.85	0.06	0.84	0.06	17.8	3.88
N19-00-5-G	1	27.5	0.44	0.04	12.3	0.50	0.91	0.06	0.82	0.06	23.1	3.79
N19-00-6-G	1	27.5	0.45	0.04	12.7	0.51	0.92	0.06	0.84	0.06	25.4	3.84
N19-00-8-G	1	27.5	0.43	0.04	15.4	0.55	0.95	0.06	0.85	0.06	18.0	3.83
N19-00-9-G	1	27.5	0.41	0.04	16.1	0.54	0.79	0.05	0.83	0.05	15.4	3.49
LAB RESULT - GAMMA												
N19-00C-1-R		28.2	0.64	0.10	20.0	1.50	1.40	0.19	1.30	0.14	14.5	2.97
N19-00C-11-R		28.2	0.65	0.09	22.0	1.70	1.40	0.17	1.30	0.14	13.4	2.86
N19-00C-12-R		26.6	0.50	0.07	22.0	1.70	1.40	0.16	1.30	0.15	11.5	2.68
N19-00C-12-R-D		28.8	0.51	0.09	22.0	1.80	1.30	0.19	1.30	0.15	11.4	2.45
N19-00C-14-R		29.6	0.69	0.09	29.0	2.20	1.20	0.16	1.50	0.16	16.9	2.97
N19-00C-15-R		27.8	0.68	0.15	21.0	1.20	1.50	0.20	1.40	0.19	5.24	2.29
N19-00C-2-R		23.9	0.55	0.09	18.0	1.70	1.50	0.18	1.20	0.14	19.3	3.87
N19-00C-3-R		27.1	0.96	0.10	18.0	1.60	1.40	0.18	1.30	0.15	23.9	3.87
N19-00C-5-R		27.6	0.66	0.08	18.0	1.40	1.60	0.18	1.50	0.16	8.11	1.70

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
N19-00C-6-R		25.9	0.57	0.09	22.0	1.60	1.40	0.16	1.30	0.15	13.3	2.98
N19-00C-7-R		29.7	0.56	0.09	18.0	1.40	1.50	0.16	1.40	0.16	0.80	1.64
N19-00C-8-R		30.4	0.59	0.09	19.0	1.60	1.40	0.16	1.20	0.14	12.8	2.53
N19-00C-9-R		29.5	0.54	0.08	19.0	1.70	1.50	0.17	1.30	0.15	9.87	2.63
LAB RESULT - ALPHA												
N19-00C-1-R		28.2							1.30	0.55	24.2	8.92
N19-00C-11-R		28.2							1.10	0.39	17.1	6.84
N19-00C-12-R		26.6							1.20	0.46	15.3	5.95
N19-00C-12-R-D		28.8							1.20	0.42	14.0	5.06
N19-00C-14-R		29.6							1.70	0.64	20.8	7.73
N19-00C-15-R		27.8							1.20	0.44	13.6	5.65
N19-00C-2-R		23.9							1.20	0.51	23.8	8.33
N19-00C-3-R		27.1							1.40	0.52	25.9	9.52
N19-00C-5-R		27.6							1.10	0.44	18.9	6.84
N19-00C-6-R		25.9							1.20	0.54	17.4	6.25
N19-00C-7-R		29.7							1.00	0.39	16.6	5.95
N19-00C-8-R		30.4							1.00	0.42	18.7	7.44
N19-00C-9-R		29.5							1.00	0.40	14.0	5.06

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: O18												
FIELD RESULT												
O18-00-1-G	.31	22.0	0.47	0.04	14.4	0.52	0.83	0.05	0.80	0.05	26.9	3.79
O18-00-10-G	.31	28.0	0.50	0.04	11.7	0.44	1.03	0.05	0.92	0.05	34.4	3.88
O18-00-11-G	.31	29.1	0.50	0.04	12.0	0.48	0.93	0.06	0.85	0.06	30.6	3.92
O18-00-12-G	.31	26.0	0.53	0.04	11.4	0.43	0.83	0.05	0.81	0.05	28.6	3.60
O18-00-15-G	.31	28.6	0.46	0.04	15.1	0.55	0.91	0.06	0.89	0.06	26.0	4.17
O18-00-2-G	.31	25.4	0.44	0.04	14.3	0.53	0.95	0.06	0.83	0.06	28.8	3.97
O18-00-3-G	.31	25.5	0.41	0.04	12.5	0.49	0.83	0.05	0.85	0.06	29.0	3.94
O18-00-4-G	.31	31.8	0.52	0.04	16.4	0.56	1.00	0.06	0.99	0.06	30.1	4.13
O18-00-5-G	.31	27.4	0.50	0.04	14.7	0.52	0.89	0.06	0.95	0.06	27.7	3.86
O18-00-7-G	.31	29.2	0.53	0.04	12.4	0.45	0.89	0.05	0.97	0.05	37.1	3.83
O18-00-8-G	.31	27.5	0.49	0.04	14.9	0.52	0.81	0.05	0.80	0.05	29.2	4.11
O18-00-9-G	.31	25.8	0.37	0.03	14.7	0.51	0.86	0.05	0.80	0.05	24.7	3.89
O18-00-1-G	1	22.0	0.39	0.04	14.6	0.50	0.78	0.05	0.78	0.05	23.4	4.36
O18-00-10-G	1	28.0	0.46	0.04	11.0	0.43	0.95	0.05	0.87	0.05	30.9	3.97
O18-00-11-G	1	29.1	0.50	0.04	12.2	0.48	1.02	0.06	0.90	0.06	35.4	4.12
O18-00-12-G	1	26.0	0.50	0.04	10.8	0.41	0.85	0.05	0.79	0.05	33.2	3.77
O18-00-15-G	1	28.6	0.44	0.04	14.9	0.55	0.84	0.06	0.86	0.06	24.9	4.39

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
O18-00-2-G	1	25.4	0.47	0.04	13.8	0.50	0.95	0.06	0.86	0.06	29.4	4.15
O18-00-3-G	1	25.5	0.43	0.04	12.7	0.50	0.82	0.06	0.86	0.06	33.4	4.22
O18-00-4-G	1	31.8	0.49	0.04	16.3	0.56	0.98	0.06	1.02	0.06	30.5	4.36
O18-00-5-G	1	27.4	0.41	0.04	13.7	0.50	0.87	0.06	0.94	0.06	27.6	3.99
O18-00-7-G	1	29.2	0.50	0.04	12.0	0.45	0.92	0.05	0.91	0.06	31.2	3.99
O18-00-8-G	1	27.5	0.49	0.04	15.1	0.53	0.84	0.06	0.84	0.06	30.9	4.25
O18-00-9-G	1	25.8	0.44	0.04	14.2	0.51	0.88	0.05	0.79	0.06	27.9	4.08
LAB RESULT - GAMMA												
O18-00C-1-R		23.3	0.68	0.14	21.0	2.60	1.00	0.22	1.20	0.18	30.1	8.62
O18-00C-10-R		27.3	0.81	0.12	19.0	2.10	1.10	0.17	1.30	0.18	33.0	7.14
O18-00C-11-R		26.7	0.68	0.10	18.0	2.30	1.10	0.19	1.30	0.19	33.3	9.81
O18-00C-14-R		25.9	0.65	0.14	15.0	2.00	1.00	0.21	1.10	0.18	27.9	7.14
O18-00C-15-R		24.1	0.58	0.10	20.0	2.30	1.10	0.19	1.20	0.16	26.7	7.14
O18-00C-16-R		24.0	0.67	0.10	19.0	2.10	1.10	0.18	1.30	0.18	25.2	5.95
O18-00C-3-R		22.7	0.62	0.09	20.0	2.40	1.20	0.19	1.20	0.18	26.0	7.73
O18-00C-5-R		22.7	0.59	0.10	19.0	2.30	1.10	0.18	1.20	0.18	25.2	7.14
O18-00C-6-R		21.2	0.58	0.08	20.0	2.40	1.10	0.18	1.00	0.15	21.2	7.14
O18-00C-7-R		25.4	0.68	0.11	18.0	2.20	1.20	0.19	1.20	0.18	42.1	10.1
O18-00C-7-R-D		26.0	0.62	0.10	17.0	2.00	1.10	0.18	1.40	0.21	39.2	9.52
O18-00C-8-R		22.7	0.79	0.11	20.0	2.40	1.00	0.17	1.10	0.16	36.3	9.52

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O18-00C-9-R		25.8	0.98	0.14	24.0	2.60	1.10	0.18	1.30	0.18	36.0	8.03
LAB RESULT - ALPHA												
O18-00C-1-R		23.3							1.10	0.23		
O18-00C-10-R		27.3							1.30	0.27		
O18-00C-11-R		26.7							1.20	0.24		
O18-00C-14-R		25.9							1.10	0.24		
O18-00C-15-R		24.1							1.00	0.22		
O18-00C-16-R		24.0							0.94	0.21		
O18-00C-3-R		22.7							1.10	0.26		
O18-00C-5-R		22.7							0.95	0.22		
O18-00C-6-R		21.2							1.20	0.26		
O18-00C-7-R		25.4							1.40	0.26		
O18-00C-7-R-D		26.0							1.20	0.26		
O18-00C-8-R		22.7							1.20	0.26		
O18-00C-9-R		25.8							1.10	0.25		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: O19												
FIELD RESULT												
O19-00-10-G	.31	27.3	0.42	0.04	15.8	0.53	0.83	0.05	0.72	0.05	22.4	3.70
O19-00-11-G	.31	27.3	0.62	0.04	19.0	0.61	0.84	0.06	1.00	0.06	24.9	3.73
O19-00-12-G	.31	27.3	0.60	0.04	16.9	0.58	1.06	0.06	0.91	0.06	26.5	3.83
O19-00-13-G	.31	27.3	0.49	0.04	20.8	0.57	0.84	0.05	1.05	0.06	24.1	3.55
O19-00-14-G	.31	27.3	0.44	0.04	15.7	0.53	0.83	0.05	0.79	0.05	18.3	3.65
O19-00-15-G	.31	27.3	0.46	0.04	14.0	0.47	0.75	0.05	0.71	0.05	18.1	3.43
O19-00-16-G	.31	27.3	0.53	0.04	16.2	0.54	0.90	0.05	0.84	0.05	22.3	3.67
O19-00-3-G	.31	27.3	0.44	0.04	13.6	0.50	0.85	0.05	0.82	0.05	28.3	3.80
O19-00-5-G	.31	27.3	0.57	0.04	15.4	0.55	0.96	0.06	0.94	0.06	24.1	3.79
O19-00-5-G	.31	27.3	0.41	0.04	12.6	0.48	1.01	0.06	0.69	0.05	21.0	3.59
O19-00-6-G	.31	27.3	0.47	0.04	15.0	0.48	0.90	0.05	0.73	0.05	17.6	3.53
O19-00-7-G	.31	27.3	0.47	0.04	14.3	0.51	0.81	0.05	0.74	0.05	20.9	3.70
O19-00-8-G	.31	27.3	0.52	0.04	14.0	0.48	0.69	0.05	0.76	0.05	26.6	3.54
O19-00-10-G	1	27.3	0.40	0.04	15.1	0.53	0.90	0.05	0.75	0.05	16.6	3.75
O19-00-11-G	1	27.3	0.51	0.04	15.1	0.50	0.78	0.05	0.79	0.05	18.0	3.61
O19-00-11-G	1	27.3	0.59	0.04	18.2	0.60	0.82	0.06	0.93	0.06	23.9	3.87
O19-00-12-G	1	27.3	0.50	0.04	16.5	0.58	0.99	0.06	0.86	0.06	22.3	3.89

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O19-00-13-G	1	27.3	0.46	0.04	20.5	0.57	0.75	0.05	0.97	0.06	16.8	3.75
O19-00-13-G	1	27.3	0.51	0.04	21.2	0.59	0.86	0.05	1.08	0.06	25.1	3.70
O19-00-14-G	1	27.3	0.46	0.04	15.4	0.54	0.82	0.05	0.83	0.05	19.7	3.83
O19-00-15-G	1	27.3	0.47	0.04	13.3	0.47	0.74	0.05	0.68	0.05	20.5	3.55
O19-00-16-G	1	27.3	0.53	0.04	15.7	0.53	0.86	0.05	0.82	0.05	20.5	3.70
O19-00-3-G	1	27.3	0.46	0.04	12.9	0.49	0.89	0.05	0.77	0.05	25.6	3.85
O19-00-5-G	1	27.3	0.55	0.04	15.3	0.55	0.94	0.06	0.92	0.06	23.8	3.92
O19-00-5-G	1	27.3	0.40	0.04	11.6	0.46	1.02	0.06	0.67	0.05	20.1	3.60
O19-00-6-G	1	27.3	0.37	0.03	14.4	0.48	0.84	0.05	0.74	0.05	17.1	3.65
O19-00-7-G	1	27.3	0.47	0.04	15.3	0.53	0.81	0.05	0.79	0.05	26.6	3.90
O19-00-8-G	1	27.3	0.53	0.04	14.0	0.48	0.76	0.05	0.75	0.05	27.2	3.66
LAB RESULT - GAMMA												
O19-00C-1-R		19.8	0.41	0.22	21.2	3.80	1.02	0.30	2.05	0.63	33.6	17.0
O19-00C-10-R		26.0	0.50	0.11	18.2	2.50	0.83	0.21	0.88	0.48	21.8	9.52
O19-00C-11-R		28.1	0.63	0.16	21.3	3.10	1.32	0.30	1.51	0.47	36.2	12.8
O19-00C-14-R		35.5	0.75	0.20	31.6	4.00	1.42	0.33	1.00	0.64	19.2	12.8
O19-00C-15-R		29.0	0.76	0.17	19.3	3.10	1.29	0.35	1.65	0.61	17.9	11.3
O19-00C-16-R		25.9	0.94	0.22	21.0	3.10	1.37	0.34	1.50	0.61	28.5	11.9
O19-00C-4-R		29.8	0.98	0.18	16.6	2.70	1.08	0.28	1.28	0.56	31.1	10.7
O19-00C-5-R		24.6	0.59	0.18	19.5	2.80	1.09	0.35	1.08	0.59	25.0	10.7

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O19-00C-6-R		23.9	0.53	0.15	16.5	2.50	1.15	0.29	1.08	0.63	18.1	10.7
O19-00C-7-R		32.8	0.58	0.15	20.4	2.90	0.95	0.28	1.46	0.60	27.1	9.52
O19-00C-8-R		23.7	0.34	0.12	18.0	2.70	1.04	0.25	1.33	0.59	24.5	10.1
O19-00C-9-R		28.0	0.69	0.16	19.6	2.70	1.27	0.28	1.51	0.53	20.8	8.33
LAB RESULT - ALPHA												
O19-00C-1-R		19.8							1.27	0.10		
O19-00C-10-R		26.0							1.15	0.09		
O19-00C-11-R		28.1							1.17	0.10		
O19-00C-14-R		35.5							1.32	0.10		
O19-00C-15-R		29.0							1.19	0.09		
O19-00C-16-R		25.9							1.11	0.09		
O19-00C-4-R		29.8							1.17	0.10		
O19-00C-5-R		24.6							1.08	0.10		
O19-00C-6-R		23.9							1.18	0.09		
O19-00C-7-R		32.8							1.18	0.09		
O19-00C-8-R		23.7							1.25	0.10		
O19-00C-9-R		28.0							1.11	0.09		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: O20												
FIELD RESULT												
O20-00-1-G	.31	30.0	0.24	0.04	16.6	0.60	0.34	0.06	0.46	0.06	9.63	4.93
O20-00-1-G	.31	30.0	0.13	0.04	7.11	0.57	0.28	0.06	0.30	0.06	15.0	3.99
O20-00-10-G	.31	30.0	0.10	0.03	11.9	0.67	0.35	0.07	0.38	0.06	6.22	0.08
O20-00-12-G	.31	30.0	0.60	0.04	20.4	0.58	0.85	0.05	0.98	0.06	20.9	3.67
O20-00-3A-G	.31	30.0	0.13	0.04	7.11	0.57	0.28	0.06	0.30	0.06	15.0	3.99
O20-00-3A-G	.31	30.0	0.17	0.04	15.4	0.62	0.36	0.06	0.41	0.06	44.5	9.44
O20-00-3B-G	.31	30.0	0.54	0.04	17.9	0.60	0.74	0.05	0.86	0.06	28.7	3.79
O20-00-4-G	.31	30.0	0.51	0.04	17.6	0.60	0.97	0.06	0.88	0.06	18.1	3.87
O20-00-5A-G	.31	30.0	0.50	0.04	18.3	0.55	0.86	0.05	0.93	0.06	20.3	3.61
O20-00-6A-G	.31	30.0	0.54	0.04	19.3	0.60	0.95	0.06	1.01	0.06	23.7	3.88
O20-00-6B-G	.31	30.0	0.57	0.04	19.3	0.56	1.05	0.06	0.98	0.06	24.0	3.69
O20-00-6B-G	.31	30.0	0.58	0.04	18.3	0.55	0.97	0.06	0.99	0.06	24.0	3.64
O20-13-G	.31	30.0	0.08	0.03	19.9	0.64	1.39	0.07	1.29	0.07	32.4	3.90
O20-14-G	.31	30.0	0.08	0.03	20.3	0.62	1.33	0.06	1.29	0.06	24.3	3.76
O20-15-G	.31	30.0	0.07	0.03	19.1	0.62	1.24	0.06	1.27	0.06	17.7	3.63
O20-16-G	.31	30.0	0.14	0.03	18.4	0.61	1.33	0.07	1.15	0.06	68.7	4.26
O20-00-1-G	1	30.0	0.50	0.04	20.3	0.65	0.80	0.06	0.97	0.06	28.4	4.00

000255

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O20-00-10-G	1	30.0	0.21	0.04	21.0	0.64	0.68	0.06	0.76	0.06	0.00	0.00
O20-00-10-G	1	30.0	0.26	0.03	20.9	0.65	0.94	0.06	0.97	0.06	11.5	4.18
O20-00-12-G	1	30.0	0.58	0.04	20.1	0.58	0.91	0.06	1.00	0.06	19.9	3.83
O20-00-3A-G	1	30.0	0.19	0.04	13.1	0.61	0.36	0.06	0.37	0.06	21.1	4.53
O20-00-3A-G	1	30.0	0.30	0.04	17.6	0.61	0.75	0.06	0.72	0.06	27.3	4.25
O20-00-3B-G	1	30.0	0.27	0.04	15.9	0.61	0.34	0.06	0.49	0.06	0.11	0.04
O20-00-3B-G	1	30.0	0.54	0.04	18.4	0.62	0.74	0.06	0.90	0.06	32.3	4.01
O20-00-4-G	1	30.0	0.47	0.04	17.3	0.60	0.96	0.06	0.96	0.06	21.2	3.95
O20-00-5A-G	1	30.0	0.51	0.04	18.3	0.55	0.92	0.06	0.88	0.06	19.7	3.84
O20-00-5B-G	1	30.0	0.43	0.04	19.3	0.63	0.96	0.06	1.06	0.06	22.1	3.98
O20-00-6A-G	1	30.0	0.53	0.04	18.6	0.59	0.98	0.06	0.92	0.06	22.0	3.97
O20-00-6B-G	1	30.0	0.51	0.04	17.9	0.55	0.99	0.06	0.92	0.06	23.2	3.85
O20-13-G	1	30.0	0.12	0.03	18.0	0.61	1.30	0.07	1.15	0.06	34.1	3.96
O20-14-G	1	30.0	0.15	0.03	18.1	0.59	1.29	0.06	1.16	0.06	28.1	3.95
O20-15-G	1	30.0	0.15	0.03	17.1	0.60	1.22	0.06	1.07	0.06	19.2	3.80
O20-16-G	1	30.0	0.21	0.03	16.6	0.59	1.31	0.07	1.09	0.06	60.1	4.23
LAB RESULT - GAMMA												
O20-00C-1-R		27.7	0.38	0.07	20.0	2.40	0.99	0.18	1.30	0.19	22.0	7.44
O20-00C-10-R		31.8	0.80	0.22	30.5	4.20	0.76	0.38	1.95	0.88	38.7	13.7
O20-00C-12A-R		27.1	0.53	0.19	34.0	4.60	1.37	0.38	1.70	0.68	13.9	13.4

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O20-00C-12B-R		25.7	0.47	0.26	32.9	4.90	0.84	0.38	1.70	0.84	9.48	14.3
O20-00C-2-R		29.8	0.74	0.27	28.9	4.40	1.09	0.34	2.46	0.85	53.0	17.8
O20-00C-3-R		32.0	0.67	0.21	31.9	5.30	0.89	0.35	1.60	0.90	47.7	14.6
O20-00C-4-R		26.6	0.72	0.16	26.4	3.80	1.33	0.38	1.51	0.62	9.21	8.92
O20-00C-5-R		26.6	0.53	0.26	26.2	4.80	1.05	0.46	1.99	0.89	32.7	14.9
O20-00C-6-R		34.0	0.94	0.19	23.0	3.20	1.28	0.31	1.89	0.71	29.8	11.9
O20-00C-6-R-D		35.3	0.88	0.20	24.8	3.20	1.39	0.31	1.85	0.61	28.4	13.7
O20-00C-7A-R		34.5	0.55	0.16	16.1	2.70	1.16	0.29	1.65	0.56	16.3	11.0
O20-00C-7B-R		39.8	0.62	0.17	15.1	2.90	1.38	0.32	1.24	0.65	205.8	23.2
O20-00C-9-R		23.0	0.21	0.11	11.0	2.60	0.59	0.22	0.84	0.52	3.54	7.73
LAB RESULT - ALPHA												
O20-00C-1-R		27.7							0.94	0.28		
O20-00C-10-R		31.8							1.45	0.11		
O20-00C-12A-R		27.1							1.40	0.11		
O20-00C-12B-R		25.7							1.15	0.09		
O20-00C-2-R		29.8							1.61	0.12		
O20-00C-3-R		32.0							1.39	0.11		
O20-00C-4-R		26.6							1.33	0.11		
O20-00C-5-R		26.6							1.34	0.10		
O20-00C-6-R		34.0							1.32	0.10		

000257

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
O20-00C-6-R-D		35.3							1.22	0.09		
O20-00C-7A-R		34.5							1.11	0.09		
O20-00C-7B-R		39.8							1.04	0.09		
O20-00C-9-R		23.0							1.22	0.10		
O20HS-1-R-13-D		19.4									13.0	1.96

000158

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P17-22												
FIELD RESULT												
P17-22-10-G	.31	18.1	0.24	0.03	15.2	0.52	1.26	0.06	1.14	0.06	28.0	3.64
P17-22-11-G	.31	15.7	0.19	0.03	15.5	0.46	1.14	0.05	1.13	0.05	25.0	3.39
P17-22-12-G	.31	12.8	0.18	0.03	16.1	0.49	1.26	0.05	1.10	0.05	25.1	3.35
P17-22-13-G	.31	15.4	0.19	0.03	16.3	0.52	1.18	0.06	1.13	0.06	26.2	3.51
P17-22-14-G	.31	13.1	0.27	0.03	15.5	0.45	1.14	0.05	1.08	0.05	35.1	3.31
P17-22-15-G	.31	19.0	0.31	0.03	15.3	0.50	1.25	0.06	1.14	0.06	34.5	3.72
P17-22-16-G	.31	15.2	0.05	0.02	19.2	0.55	1.35	0.06	1.15	0.06	15.1	3.27
P17-22-2-G	.31	20.1	0.08	0.03	19.0	0.56	1.27	0.06	1.15	0.06	15.1	3.60
P17-22-4-G	.31	13.9	0.10	0.03	17.0	0.51	1.07	0.05	1.06	0.05	17.4	3.25
P17-22-6-G	.31	17.2	0.20	0.03	15.4	0.52	1.15	0.06	1.11	0.06	26.0	3.56
P17-22-7-G	.31	14.4	0.14	0.03	14.6	0.44	1.19	0.05	1.10	0.05	19.6	3.32
P17-22-9-G	.31	12.2	0.24	0.03	14.6	0.49	1.13	0.05	1.04	0.06	27.2	3.50
P17-22-10-G	1	18.1	0.23	0.03	15.6	0.52	1.23	0.06	1.12	0.06	28.9	3.86
P17-22-11-G	1	15.7	0.19	0.03	15.7	0.47	1.22	0.05	1.10	0.05	22.9	3.48
P17-22-12-G	1	12.8	0.20	0.03	15.7	0.50	1.22	0.06	1.06	0.05	27.2	3.52
P17-22-13-G	1	15.4	0.16	0.03	16.0	0.52	1.28	0.06	1.11	0.06	21.4	3.64
P17-22-14-G	1	13.1	0.25	0.03	15.0	0.45	1.19	0.05	1.05	0.05	30.8	3.51

000159

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P17-22-15-G	1	19.0	0.32	0.03	15.7	0.51	1.28	0.06	1.18	0.06	35.9	3.88
P17-22-16-G	1	15.2	0.04	0.02	17.7	0.53	1.37	0.06	1.09	0.06	12.3	3.43
P17-22-2-G	1	20.1	0.10	0.03	18.0	0.55	1.21	0.06	1.14	0.06	19.6	3.76
P17-22-4-G	1	13.9	0.07	0.03	17.4	0.52	1.06	0.05	1.02	0.05	17.6	3.39
P17-22-6-G	1	17.2	0.20	0.03	15.1	0.52	1.07	0.06	1.13	0.06	28.7	3.78
P17-22-7-G	1	14.4	0.13	0.03	14.5	0.45	1.17	0.05	1.12	0.05	21.1	3.48
P17-22-9-G	1	12.2	0.18	0.03	14.8	0.49	1.13	0.06	1.03	0.06	23.8	3.55
LAB RESULT - GAMMA												
P17-22C2-R-1		18.7	0.00	0.08	1.00	1.40	1.40	0.20	1.60	0.20	1.74	0.69
P17-22C2-R-1-D		18.8	0.13	0.07	20.0	1.60	1.50	0.15	1.50	0.17	5.80	2.56
P17-22C2-R-10		16.1	0.07	0.07	19.0	1.50	1.40	0.15	1.70	0.22	3.18	1.43
P17-22C2-R-11		17.2	0.07	0.13	16.0	1.50	1.50	0.61	1.00	1.40	7.45	2.48
P17-22C2-R-12		22.0	0.29	0.08	18.0	1.50	1.30	0.18	1.30	0.15	18.8	3.27
P17-22C2-R-13		23.2	0.45	0.07	14.0	1.30	1.10	0.15	1.10	0.18	26.0	4.46
P17-22C2-R-13-D		22.3	0.36	0.07	17.0	1.40	1.30	0.20	1.30	1.50	20.0	3.57
P17-22C2-R-2		18.4	0.02	0.08	19.0	1.50	1.30	0.14	1.60	0.21	1.69	0.72
P17-22C2-R-3		19.8	0.14	0.05	17.0	1.50	1.40	0.19	1.30	0.20	10.0	2.44
P17-22C2-R-4		16.3	0.18	0.07	19.0	1.50	1.40	0.18	1.40	0.16	9.72	2.44
P17-22C2-R-5		16.2	0.18	0.06	15.0	1.40	1.20	0.16	1.20	0.19	12.1	2.59
P17-22C2-R-6		15.2	0.21	0.06	20.0	1.50	1.40	0.16	1.50	1.60	17.6	3.27

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-22C2-R-7		16.8	-0.02	0.08	19.0	1.60	1.30	0.14	1.70	0.22	1.50	0.90
P17-22C2-R-8		19.6	-0.10	0.14	19.0	1.60	1.60	0.18	1.50	0.22	3.57	2.51
P17-22C2-R-9		16.2	0.15	0.05	20.0	1.60	1.40	0.18	1.50	1.70	14.3	2.83
LAB RESULT - ALPHA												
P17-22C2-R-1		18.7							1.30	0.45		
P17-22C2-R-1-D		18.8							1.10	0.41		
P17-22C2-R-10		16.1							1.30	0.48		
P17-22C2-R-11		17.2							1.20	0.46		
P17-22C2-R-12		22.0							1.20	0.51		
P17-22C2-R-13		23.2							1.20	0.50		
P17-22C2-R-13-D		22.3							1.20	0.55		
P17-22C2-R-2		18.4							1.20	0.47		
P17-22C2-R-3		19.8							1.20	0.45		
P17-22C2-R-4		16.3							1.40	0.58		
P17-22C2-R-5		16.2							1.20	0.51		
P17-22C2-R-6		15.2							1.10	0.48		
P17-22C2-R-7		16.8							1.20	0.49		
P17-22C2-R-8		19.6							1.30	0.51		
P17-22C2-R-9		16.2							1.20	0.45		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: P17-31												
FIELD RESULT												
P17-31-1	.31	15.0	0.25	0.04	14.0	0.48	0.88	0.06	1.02	0.07	29.2	5.19
P17-31-11	.31	15.0	0.26	0.03	15.2	0.50	0.98	0.06	0.93	0.06	27.0	4.60
P17-31-12	.31	15.0	0.15	0.03	13.9	0.48	0.87	0.06	0.80	0.06	18.9	4.16
P17-31-14	.31	15.0	0.00	0.00	11.7	0.44	0.68	0.05	0.55	0.05	12.7	6.30
P17-31-16	.31	15.0	0.04	0.00	15.3	0.50	0.92	0.06	0.84	0.06	15.3	4.20
P17-31-2	.31	15.0	0.08	0.03	13.2	0.45	0.79	0.05	0.81	0.06	16.5	4.50
P17-31-3	.31	15.0	0.32	0.03	14.9	0.48	0.96	0.06	1.03	0.06	37.3	4.82
P17-31-4	.31	15.0	0.06	0.03	13.9	0.47	1.02	0.06	1.02	0.06	19.8	4.29
P17-31-6	.31	15.0	0.05	0.03	11.6	0.44	0.79	0.06	0.78	0.06	19.9	4.80
P17-31-7	.31	15.0	0.09	0.03	13.9	0.45	0.93	0.06	0.87	0.06	20.8	4.42
P17-31-8	.31	15.0	0.00	0.00	13.8	0.45	0.96	0.06	0.96	0.06	14.6	5.74
P17-31-9	.31	15.0	0.08	0.03	10.4	0.42	0.76	0.05	0.64	0.05	16.7	4.46
P17-33-1	.31	15.0	0.12	0.03	13.6	0.47	0.75	0.06	0.70	0.06	17.1	4.78
P17-31-1	1	15.0	0.23	0.03	12.9	0.43	0.94	0.06	1.02	0.06	28.0	4.97
P17-31-11	1	15.0	0.24	0.03	14.6	0.45	0.95	0.06	0.95	0.06	26.1	4.58
P17-31-12	1	15.0	0.16	0.03	13.9	0.44	0.88	0.05	0.80	0.05	16.9	4.12
P17-31-14	1	15.0	0.06	0.03	14.1	0.47	0.89	0.06	0.69	0.06	16.4	6.67

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-31-16	1	15.0	0.06	0.03	14.8	0.45	0.88	0.05	0.86	0.05	17.8	4.10
P17-31-2	1	15.0	0.07	0.03	14.7	0.48	0.97	0.06	0.90	0.06	21.8	4.83
P17-31-3	1	15.0	0.30	0.03	14.0	0.47	0.94	0.06	1.00	0.06	34.2	4.97
P17-31-4	1	15.0	0.08	0.03	13.5	0.43	1.10	0.06	1.02	0.06	18.1	4.26
P17-31-6	1	15.0	0.08	0.03	14.6	0.48	1.06	0.06	1.11	0.06	22.1	5.08
P17-31-7	1	15.0	0.08	0.03	14.2	0.44	0.95	0.06	0.98	0.06	18.7	4.54
P17-31-7	1	15.0	0.08	0.03	14.5	0.48	0.88	0.06	0.95	0.06	23.8	7.16
P17-31-9	1	15.0	0.12	0.03	10.4	0.38	0.82	0.05	0.68	0.05	21.3	4.46
P17-33-1	1	15.0	0.08	0.03	13.3	0.46	0.81	0.05	0.70	0.05	19.3	4.51
LAB RESULT - GAMMA												
P17-31C-617931		0.00	0.38	0.06	19.0	2.10	0.90	0.14	1.10	0.16	25.0	5.95
P17-31C-629859		13.0	0.11	0.08	20.0	1.50	0.95	0.11	1.20	0.14	11.0	2.65
P17-31C-671888		17.4	0.11	0.13	24.0	1.90	1.60	0.09	1.30	0.15	4.87	2.66
P17-31C-686817		17.5	0.06	0.07	21.0	1.60	1.50	0.17	1.30	0.15	9.09	2.32
P17-31C-712816		13.5	0.08	0.16	22.0	1.80	1.50	0.19	1.30	0.15	7.38	2.60
P17-31C-717890		15.7	0.11	0.07	19.0	1.50	1.40	0.17	1.20	0.14	12.4	2.77
P17-31C-725916		14.6	0.10	0.14	20.0	1.70	1.20	0.16	1.20	0.13	13.9	2.86
P17-31C-741994		11.2	0.02	0.07	19.0	1.40	0.85	0.11	0.86	0.10	7.33	1.76
P17-31C-769970		11.0	0.02	0.13	19.0	1.60	1.00	0.15	0.99	0.14	6.47	2.60
P17-31C-784863		16.7	0.05	0.09	22.0	1.50	1.40	0.13	1.40	0.14	5.31	2.21

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-31C-791838		13.8	0.05	0.07	19.0	1.50	1.60	0.16	1.30	0.15	5.76	1.99
P17-31C-795925		21.0	0.07	0.01	19.0	1.50	1.60	0.17	1.20	0.15	3.02	1.67
LAB RESULT - ALPHA												
P17-31C-617931		0.00							1.20	0.23		
P17-31C-629859		13.0							0.83	0.37	13.6	5.06
P17-31C-671888		17.4							1.30	0.57	1.30	2.74
P17-31C-686817		17.5							1.10	0.39	10.9	3.87
P17-31C-712816		13.5							1.10	0.41	11.3	4.17
P17-31C-717890		15.7							1.00	0.46	20.1	7.73
P17-31C-725916		14.6							1.10	0.42	22.3	6.86
P17-31C-741994		11.2							0.80	0.32	10.2	3.57
P17-31C-769970		11.0							0.75	0.29	6.94	2.60
P17-31C-784863		16.7							1.40	0.03	5.45	2.05
P17-31C-791838		13.8							1.20	0.44	7.26	2.62
P17-31C-795925		21.0							1.30	0.49	4.86	1.90

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: P17-32												
FIELD RESULT												
P17-32-1-G	.31	18.8	0.37	0.03	17.0	0.49	1.05	0.05	1.24	0.06	39.9	4.19
P17-32-10-G	.31	18.8	0.05	0.03	15.0	0.52	1.15	0.06	1.18	0.06	12.2	4.31
P17-32-11-G	.31	18.8	0.21	0.03	13.2	0.47	1.01	0.05	1.05	0.06	28.6	4.05
P17-32-12-G	.31	18.8	0.19	0.03	14.2	0.50	0.94	0.06	0.99	0.06	20.0	4.04
P17-32-13-G	.31	18.8	0.14	0.03	16.1	0.51	1.00	0.06	1.10	0.06	21.3	4.06
P17-32-16-G	.31	18.8	0.10	0.03	13.7	0.47	1.07	0.06	1.01	0.06	19.0	3.95
P17-32-2-G	.31	18.8	0.21	0.03	18.3	0.55	1.16	0.06	1.22	0.06	34.4	4.10
P17-32-5-G	.31	18.8	0.10	0.03	17.1	0.53	1.02	0.06	1.17	0.06	20.7	4.36
P17-32-6-G	.31	18.8	0.04	0.03	16.4	0.52	1.20	0.06	1.22	0.06	13.0	3.70
P17-32-7-G	.31	18.8	0.29	0.04	12.7	0.48	0.96	0.06	0.98	0.06	28.4	4.10
P17-32-8-G	.31	18.8	0.28	0.03	12.8	0.48	0.94	0.06	0.95	0.06	26.3	4.21
P17-32-9-G	.31	18.8	0.17	0.03	17.0	0.49	1.07	0.05	1.24	0.06	30.0	3.71
P17-32-1-G	1	18.8	0.28	0.03	16.6	0.49	1.07	0.06	1.16	0.06	39.1	4.25
P17-32-10-G	1	18.8	0.03	0.00	14.2	0.51	1.10	0.06	1.05	0.06	16.1	4.52
P17-32-11-G	1	18.8	0.19	0.03	13.4	0.48	0.97	0.05	0.98	0.06	25.7	4.22
P17-32-12-G	1	18.8	0.18	0.03	13.3	0.49	0.94	0.06	0.93	0.06	25.0	4.24
P17-32-13-G	1	18.8	0.14	0.03	16.3	0.52	0.99	0.06	1.09	0.06	24.6	4.24

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-32-16-G	1	18.8	0.13	0.03	13.1	0.47	1.05	0.06	1.06	0.06	21.1	4.07
P17-32-2-G	1	18.8	0.14	0.03	17.9	0.54	1.08	0.06	1.13	0.06	28.8	4.13
P17-32-5-G	1	18.8	0.07	0.03	16.9	0.53	1.07	0.06	1.14	0.06	20.2	4.40
P17-32-6-G	1	18.8	0.07	0.03	16.1	0.52	1.19	0.06	1.14	0.06	15.5	3.90
P17-32-7-G	1	18.8	0.22	0.03	13.1	0.49	0.95	0.06	0.96	0.06	25.7	4.33
P17-32-8-G	1	18.8	0.23	0.03	13.2	0.49	0.97	0.06	0.92	0.06	27.6	4.22
P17-32-9-G	1	18.8	0.14	0.03	17.1	0.50	1.04	0.05	1.19	0.06	28.5	3.91
LAB RESULT - GAMMA												
P17-32C-803857		17.3	0.07	0.07	19.0	1.50	1.40	0.16	1.40	0.16	2.98	2.08
P17-32C-820936		15.0	0.06	0.07	20.0	1.60	1.40	0.14	1.30	0.15	12.1	2.23
P17-32C-826838		18.5	0.08	0.04	21.0	2.40	1.30	0.18	1.30	0.17	12.7	4.76
P17-32C-835924		22.0	0.15	0.03	22.0	2.30	0.91	0.14	1.40	0.19	17.6	4.46
P17-32C-835924-D		21.7	0.15	0.04	21.0	2.30	1.30	0.19	1.60	0.23	20.5	5.35
P17-32C-839950		19.6	0.13	0.07	19.0	1.50	1.40	0.16	1.80	0.21	6.68	1.64
P17-32C-843800		18.4	0.12	0.03	2.00	2.10	1.10	0.15	1.20	0.16	14.2	4.46
P17-32C-850822		22.3	0.07	0.04	23.0	2.40	1.20	0.18	1.50	0.20	10.3	4.76
P17-32C-858878		18.2	0.02	0.14	18.0	1.70	1.40	0.16	1.50	0.16	4.02	2.45
P17-32C-860812		18.3	0.10	0.03	18.0	2.00	1.10	0.15	1.30	0.16	12.4	4.16
P17-32C-879990		16.0	0.02	0.08	15.0	1.20	1.20	0.13	1.80	0.18	5.23	1.35
P17-32C-881901		22.0	0.69	0.10	17.0	1.50	1.30	0.20	1.50	0.15	25.8	3.87

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-32C-883831		18.5	0.16	0.06	18.0	1.70	1.30	0.15	1.40	0.15	18.5	3.87
LAB RESULT - ALPHA												
P17-32C-803857		17.3							1.10	0.43	3.68	1.34
P17-32C-820936		15.0							1.10	0.41	15.6	6.25
P17-32C-826838		18.5							1.30	0.25		
P17-32C-835924		22.0							1.40	0.29		
P17-32C-835924-D		21.7							1.30	0.25		
P17-32C-839950		19.6							1.60	0.59	10.9	4.46
P17-32C-843800		18.4							1.30	0.25		
P17-32C-850822		22.3							1.10	0.21		
P17-32C-858878		18.2							1.40	0.46	4.58	1.64
P17-32C-860812		18.3							1.10	0.22		
P17-32C-879990		16.0							1.40	0.59	4.62	1.79
P17-32C-881901		22.0							1.60	0.59	33.7	1.37
P17-32C-883831		18.5							1.20	0.57	24.0	8.62

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P17-33												
FIELD RESULT												
P17-33-1-G	.31	11.2	0.10	0.02	13.3	0.44	0.85	0.05	0.69	0.05	17.6	3.45
P17-33-10	.31	11.2	0.15	0.03	13.5	0.46	0.79	0.05	0.75	0.05	18.4	3.89
P17-33-11	.31	11.2	0.19	0.03	13.3	0.46	0.84	0.05	0.94	0.06	21.5	3.98
P17-33-12	.31	11.2	0.04	0.02	14.0	0.47	0.84	0.05	0.72	0.05	13.1	3.55
P17-33-15	.31	11.2	0.09	0.03	13.6	0.46	0.79	0.05	0.75	0.05	12.7	3.72
P17-33-16	.31	11.2	0.13	0.03	14.1	0.47	0.79	0.05	0.75	0.05	14.7	3.95
P17-33-2	.31	11.2	0.08	0.02	11.6	0.41	0.69	0.05	0.60	0.05	13.5	4.76
P17-33-2	.31	11.2	0.07	0.02	14.6	0.46	0.86	0.05	0.72	0.05	14.9	3.30
P17-33-4	.31	11.2	0.15	0.03	14.0	0.47	0.82	0.05	0.74	0.05	15.8	4.15
P17-33-5	.31	11.2	0.19	0.03	11.0	0.39	0.73	0.05	0.64	0.05	15.9	3.85
P17-33-6	.31	11.2	0.08	0.03	13.1	0.44	0.72	0.05	0.61	0.05	16.1	3.98
P17-33-7	.31	11.2	0.11	0.03	14.1	0.47	0.84	0.05	0.78	0.05	18.5	4.11
P17-33-9	.31	11.2	0.21	0.03	14.9	0.47	0.89	0.05	0.92	0.05	20.3	3.49
P17-33-1-G	1	11.2	0.12	0.03	13.5	0.45	0.90	0.05	0.69	0.05	17.3	3.59
P17-33-10	1	11.2	0.17	0.03	13.2	0.42	0.80	0.05	0.76	0.05	21.0	3.84
P17-33-11	1	11.2	0.16	0.03	13.2	0.42	0.84	0.05	0.87	0.05	20.5	3.96
P17-33-12	1	11.2	0.04	0.02	13.2	0.41	0.77	0.05	0.72	0.05	11.5	3.75

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P17-33-15	1	11.2	0.10	0.03	12.7	0.41	0.83	0.05	0.75	0.05	14.3	3.66
P17-33-16	1	11.2	0.10	0.02	13.1	0.41	0.88	0.05	0.75	0.05	13.9	3.76
P17-33-2	1	11.2	0.09	0.03	13.1	0.45	0.68	0.06	0.60	0.05	12.3	6.06
P17-33-2	1	11.2	0.10	0.02	14.9	0.47	0.86	0.05	0.75	0.05	18.3	3.51
P17-33-4	1	11.2	0.11	0.03	13.3	0.42	0.82	0.05	0.69	0.05	17.7	3.75
P17-33-5	1	11.2	0.17	0.03	12.2	0.43	0.81	0.05	0.67	0.05	18.1	4.18
P17-33-6	1	11.2	0.08	0.03	14.0	0.46	0.79	0.05	0.71	0.05	18.0	4.51
P17-33-7	1	11.2	0.11	0.03	13.4	0.42	0.84	0.05	0.80	0.05	13.3	3.77
P17-33-9	1	11.2	0.18	0.03	13.5	0.45	0.89	0.05	0.87	0.05	18.8	3.58
LAB RESULT - GAMMA												
P17-33C-604181		10.3	0.25	0.07	16.0	1.30	1.00	0.11	1.20	0.14	11.8	2.27
P17-33C-620020		14.7	0.17	0.06	15.0	1.20	0.85	0.11	1.00	0.13	8.36	1.82
P17-33C-620020-D		12.0	0.19	0.06	12.0	1.20	0.90	0.14	0.57	0.09	5.45	1.76
P17-33C-634109		9.50	0.05	0.06	18.0	1.50	0.89	0.14	0.76	0.10	6.62	2.08
P17-33C-663037		9.20	0.04	0.07	18.0	1.30	0.79	0.79	1.00	0.12	9.73	2.44
P17-33C-684068		9.20	0.01	0.06	18.0	1.50	1.00	0.15	0.74	0.11	9.06	2.44
P17-33C-697110		10.3	0.06	0.08	18.0	1.30	0.91	0.13	1.10	0.13	9.38	2.41
P17-33C-720017		11.8	0.31	0.07	18.0	1.60	0.92	0.15	0.96	0.12	11.2	2.62
P17-33C-727116		16.2	0.00	0.12	18.0	1.60	1.40	0.17	1.30	0.15	8.67	2.72
P17-33C-736082		9.90	0.05	0.03	8.30	0.64	0.44	0.06	0.57	0.07	3.32	0.72

000469

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-33C-747174		12.5	0.12	0.05	19.0	1.70	0.94	0.16	0.97	0.12	8.08	2.18
P17-33C-764098		9.80	0.11	0.05	17.0	1.30	0.86	0.12	1.20	0.14	7.55	1.61
P17-33C-780141		12.5	0.17	0.07	20.0	1.60	1.20	0.14	0.94	0.12	6.06	1.73
LAB RESULT - ALPHA												
P17-33C-604181		10.3							0.74	0.30	15.9	5.65
P17-33C-620020		14.7							0.64	0.23	11.4	4.76
P17-33C-620020-D		12.0							0.53	0.21	9.06	2.92
P17-33C-634109		9.50							0.76	0.30	12.0	4.17
P17-33C-663037		9.20							0.83	0.32	12.4	4.17
P17-33C-684068		9.20							0.62	0.24	10.3	3.57
P17-33C-697110		10.3							0.88	0.35	12.7	3.87
P17-33C-720017		11.8							0.87	0.35	15.8	5.66
P17-33C-727116		16.2							1.20	0.44	14.2	4.76
P17-33C-736082		9.90							0.83	0.32	10.3	3.57
P17-33C-747174		12.5							0.74	0.28	8.24	3.27
P17-33C-764098		9.80							0.83	0.36	8.77	3.27
P17-33C-780141		12.5							0.72	0.28	9.86	3.57

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P17-40												
FIELD RESULT												
P17-40-1-G	.31	15.1	0.19	0.03	15.0	0.50	0.93	0.05	0.98	0.05	21.9	3.23
P17-40-10-G	.31	14.1	0.16	0.03	15.3	0.48	1.10	0.05	1.05	0.05	20.4	3.17
P17-40-11-G	.31	22.6	0.08	0.03	17.2	0.56	1.25	0.06	1.24	0.06	15.9	3.53
P17-40-11-G	.31	15.3	0.08	0.03	15.7	0.51	1.14	0.05	1.13	0.06	14.5	3.23
P17-40-12-G	.31	15.4	0.07	0.03	15.7	0.51	1.13	0.06	1.15	0.06	15.7	3.21
P17-40-13-G	.31	13.7	0.16	0.03	15.2	0.48	1.07	0.05	1.07	0.05	18.9	3.21
P17-40-14-G	.31	16.7	0.15	0.03	15.5	0.49	1.14	0.05	1.07	0.05	18.7	3.20
P17-40-14-G-D	.31	17.1	0.15	0.03	15.7	0.50	1.13	0.05	1.08	0.05	15.4	3.27
P17-40-15-G	.31	17.9	0.10	0.03	16.3	0.53	1.39	0.06	1.17	0.06	17.4	3.39
P17-40-15-G	.31	19.8	0.10	0.03	16.7	0.55	1.42	0.06	1.19	0.06	17.8	3.47
P17-40-16-G	.31	15.2	0.03	0.00	15.8	0.51	1.40	0.06	1.18	0.06	12.3	3.70
P17-40-16-G	.31	19.2	0.03	0.00	16.6	0.54	1.47	0.06	1.23	0.06	12.9	3.89
P17-40-2-G	.31	17.1	0.23	0.03	15.9	0.52	1.01	0.05	1.03	0.06	23.1	3.42
P17-40-3-G	.31	13.1	0.20	0.03	15.2	0.50	1.01	0.05	0.98	0.05	21.1	3.24
P17-40-8-G	.31	22.4	0.24	0.03	17.1	0.56	1.11	0.06	1.12	0.06	23.2	3.64
P17-40-8-G	.31	13.6	0.21	0.03	15.4	0.50	1.00	0.05	1.00	0.05	20.8	3.27
P17-40-9-G	.31	13.1	0.13	0.03	15.9	0.49	1.09	0.05	1.09	0.05	18.9	3.30

0003271

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-40-1-G	1	15.1	0.20	0.03	15.6	0.50	1.05	0.05	1.07	0.05	23.1	3.36
P17-40-10-G	1	14.1	0.15	0.03	14.9	0.48	1.03	0.05	0.95	0.05	13.8	3.67
P17-40-11-G	1	15.3	0.09	0.03	15.7	0.52	1.14	0.06	1.16	0.06	16.4	3.36
P17-40-11-G	1	22.6	0.10	0.03	17.2	0.57	1.24	0.06	1.27	0.06	17.9	3.67
P17-40-12-G	1	15.4	0.08	0.03	15.7	0.52	1.09	0.06	1.15	0.06	12.4	3.31
P17-40-13-G	1	13.7	0.14	0.03	14.7	0.48	1.04	0.05	0.95	0.05	15.6	6.15
P17-40-14-G	1	16.7	0.13	0.03	15.6	0.50	1.08	0.05	0.98	0.06	13.9	3.65
P17-40-14-G-D	1	17.1	0.13	0.03	15.9	0.51	1.05	0.05	1.06	0.06	16.9	3.41
P17-40-15-G	1	19.8	0.11	0.03	16.6	0.55	1.40	0.06	1.14	0.06	15.0	3.63
P17-40-15-G	1	17.9	0.11	0.03	16.2	0.54	1.36	0.06	1.11	0.06	14.7	3.54
P17-40-16-G	1	15.2	0.08	0.03	15.3	0.51	1.23	0.06	1.16	0.06	11.6	3.26
P17-40-16-G	1	19.2	0.08	0.03	16.1	0.54	1.29	0.06	1.22	0.06	12.2	3.42
P17-40-2-G	1	17.1	0.22	0.03	15.8	0.53	1.02	0.06	1.01	0.06	20.5	3.49
P17-40-3-G	1	13.1	0.20	0.03	15.4	0.50	0.98	0.05	0.97	0.05	20.6	3.39
P17-40-8-G	1	22.4	0.19	0.03	17.4	0.57	1.12	0.06	1.16	0.06	23.6	3.77
P17-40-8-G	1	13.6	0.17	0.03	15.6	0.51	1.00	0.05	1.04	0.06	21.2	3.39
P17-40-9-G	1	13.1	0.11	0.03	15.4	0.49	1.04	0.05	1.02	0.05	14.8	3.40
LAB RESULT - GAMMA												
P17-34C-964146		19.6	0.02	0.07	17.0	1.40	1.50	0.16	1.30	0.15	3.34	1.79
P17-34C-972199		18.4	0.08	0.14	18.0	1.60	1.60	0.21	1.30	0.15	8.99	2.48

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P17-40C-052114		22.4	0.22	0.05	18.0	1.60	1.40	0.17	1.40	0.15	13.6	3.28
P17-40C-145113		23.4	0.33	0.07	16.0	1.40	1.50	0.16	1.30	0.15	13.9	2.80
P17-40C-281110		17.3	0.14	0.14	19.0	1.70	1.50	0.18	1.40	0.15	8.42	2.33
P17-40C-289031		17.0	-0.02	0.16	17.0	1.60	1.60	0.20	1.40	0.15	2.54	2.09
P17-40C-292103		20.3	0.23	0.06	17.0	1.30	1.30	0.13	1.70	0.18	11.1	2.18
P17-40C-368105		18.6	0.10	0.05	17.0	1.50	1.40	0.16	1.40	0.16	6.43	1.82
P17-40C-397115		21.4	0.14	0.06	17.0	1.60	1.80	0.21	1.40	0.15	10.9	2.95
P17-40C-398021		19.4	0.03	0.05	18.0	1.40	1.30	0.13	1.60	0.17	7.59	2.09
P17-40C-398021-D		20.3	0.09	0.04	17.0	1.30	1.20	0.15	1.40	0.14	8.76	2.48
P17-40C2-R-1		16.6	0.09	0.05	20.0	1.50	1.60	0.16	1.60	0.17	9.08	2.08
P17-40C2-R-3		17.7	0.05	0.12	15.0	1.40	1.20	0.18	1.30	0.20	5.66	2.03
P17-40C2-R-3-D		17.9	0.06	0.07	19.0	1.50	1.40	0.16	1.30	0.15	7.22	1.99
P17-40C2-R-4		11.7	0.05	0.08	18.0	1.50	0.84	0.11	1.10	0.15	4.04	1.05
P17-40C2-R-5		15.7	0.06	0.13	18.0	1.60	1.20	0.18	1.30	0.20	7.62	3.28
LAB RESULT - ALPHA												
P17-34C-964146		19.6							1.10	0.41	3.98	1.46
P17-34C-972199		18.4							1.10	0.43	7.31	2.74
P17-40C-052114		22.4							1.20	0.54	13.9	5.65
P17-40C-145113		23.4							1.30	0.50	19.4	7.14
P17-40C-281110		17.3							1.30	0.49	10.6	3.87

001223

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P17-40C-289031		17.0							1.40	0.51	6.43	2.26
P17-40C-292103		20.3							1.10	0.42	14.8	5.35
P17-40C-368105		18.6							1.10	0.43	9.76	3.57
P17-40C-397115		21.4							1.30	0.49	14.7	5.35
P17-40C-398021		19.4							1.10	0.46	10.4	4.16
P17-40C-398021-D		20.3							1.00	0.40	11.0	3.87
P17-40C2-R-1		16.6							1.00	0.39		
P17-40C2-R-3		17.7							1.20	0.49		
P17-40C2-R-3-D		17.9							1.10	0.46		
P17-40C2-R-4		11.7							0.79	0.36		
P17-40C2-R-5		15.7							1.20	0.47		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P18												
FIELD RESULT												
P18-1	.31	20.5	0.05	0.03	15.5	0.52	1.20	0.06	1.03	0.06	6.49	0.08
P18-10	.31	20.5	0.53	0.04	11.6	0.45	0.91	0.05	0.84	0.05	33.7	3.67
P18-11	.31	20.5	0.51	0.04	12.2	0.46	0.90	0.05	0.78	0.05	34.2	3.67
P18-13	.31	20.5	0.48	0.04	10.3	0.42	0.88	0.05	0.72	0.05	28.9	3.60
P18-14	.31	20.5	0.53	0.04	12.3	0.47	0.80	0.05	0.84	0.05	33.0	3.65
P18-16	.31	20.5	0.49	0.04	12.3	0.46	0.95	0.05	0.91	0.05	29.6	3.55
P18-2	.31	20.5	0.00	0.00	15.8	0.51	0.99	0.05	0.73	0.05	6.15	0.08
P18-4B-G	.31	20.5	0.00	0.00	19.1	0.56	1.06	0.05	1.04	0.05	9.80	3.18
P18-5	.31	20.5	0.09	0.03	11.9	0.46	1.12	0.06	0.78	0.05	12.0	3.37
P18-7-G	.31	20.5	0.05	0.02	15.2	0.52	1.14	0.06	1.04	0.06	9.57	3.63
P18-8-G	.31	20.5	0.09	0.03	14.6	0.49	1.16	0.05	1.08	0.05	15.9	3.11
P18-9	.31	20.5	0.49	0.04	11.1	0.44	0.97	0.05	0.81	0.05	31.5	3.66
P18-1	1	20.5	0.04	0.02	15.0	0.48	1.19	0.06	1.05	0.06	11.5	4.95
P18-10	1	20.5	0.49	0.04	10.7	0.39	0.92	0.05	0.79	0.05	31.7	3.63
P18-11	1	20.5	0.50	0.04	12.1	0.42	0.90	0.05	0.83	0.05	34.2	3.63
P18-13	1	20.5	0.45	0.03	9.22	0.37	0.84	0.05	0.71	0.05	27.5	3.47
P18-14	1	20.5	0.54	0.04	11.4	0.41	0.84	0.05	0.78	0.05	32.0	3.68

001175

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-16	1	20.5	0.45	0.03	11.5	0.41	0.94	0.05	0.81	0.05	30.3	3.53
P18-2	1	20.5	0.02	0.00	13.8	0.45	0.91	0.05	0.73	0.05	0.04	0.02
P18-4B-G	1	20.5	0.05	0.02	17.9	0.55	1.05	0.06	1.07	0.06	8.20	4.49
P18-5	1	20.5	0.09	0.03	12.0	0.44	1.10	0.06	0.81	0.05	10.6	4.17
P18-7-G	1	20.5	0.06	0.02	15.0	0.53	1.11	0.06	1.06	0.06	11.3	3.97
P18-8-G	1	20.5	0.11	0.03	13.7	0.48	1.11	0.06	0.99	0.05	11.7	3.30
P18-9	1	20.5	0.48	0.03	9.65	0.38	0.93	0.05	0.77	0.05	27.7	3.58
LAB RESULT - GAMMA												
P18-31C-657677		18.8	0.08	0.08	18.7	3.90	0.90	0.31	1.13	0.71	11.6	8.33
P18-32C-816671		16.2	-0.03	0.07	15.9	3.40	1.04	0.35	1.97	0.76	15.0	10.4
P18C-634755		31.7	0.56	0.08	15.0	1.20	1.20	0.16	1.60	0.16	30.0	3.87
P18C-661706		14.7	0.46	0.07	16.0	1.80	1.00	0.15	1.10	0.15	24.7	6.25
P18C-670893		28.8	0.55	0.07	16.0	1.30	1.00	0.12	1.10	0.12	18.8	2.56
P18C-679450		18.6	0.00	0.08	22.0	1.60	1.10	0.16	1.40	0.16	3.92	1.38
P18C-750800		20.9	0.63	0.12	19.0	2.20	1.20	0.22	1.40	0.20	39.3	8.92
P18C-758813		24.4	0.74	0.08	19.0	1.50	1.60	0.17	1.40	0.16	30.2	5.06
P18C-761655		10.0	0.12	0.14	14.0	1.40	1.20	0.15	0.98	0.12	9.44	3.57
P18C-777911		21.9	0.45	0.06	17.0	2.00	1.10	0.15	1.20	0.15	22.1	5.95
P18C-781429		11.4	0.11	0.15	19.0	1.60	0.91	0.15	0.83	0.10	1.90	1.71
P18C-826521		20.4	0.05	0.07	20.0	1.60	1.40	0.14	1.30	0.15	5.18	2.02

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18C-830830		21.7	0.43	0.08	18.0	2.10	1.00	0.17	1.30	0.18	27.2	6.84
P18C-884947		18.4	0.36	0.06	18.0	1.90	0.95	0.14	1.20	0.16	20.6	4.46
P18C-987945		23.1	0.60	0.08	14.0	1.20	1.10	0.14	1.40	0.15	21.0	3.57
LAB RESULT - ALPHA												
P18-31C-657677		18.8							1.12	0.09		
P18-32C-816671		16.2							1.00	0.08		
P18C-634755		31.7							1.30	0.50	39.9	14.3
P18C-661706		14.7							0.99	0.21		
P18C-670893		28.8							1.10	0.43	30.9	11.0
P18C-679450		18.6							1.20	0.44	3.98	1.58
P18C-750800		20.9							1.20	0.25		
P18C-758813		24.4							1.40	0.55	43.1	17.6
P18C-761655		10.0							1.10	0.45	12.7	4.46
P18C-777911		21.9							1.20	0.25		
P18C-781429		11.4							0.80	0.31	2.40	0.89
P18C-826521		20.4							1.40	0.47	7.13	2.98
P18C-830830		21.7							0.99	0.23		
P18C-884947		18.4							1.00	0.20		
P18C-987945		23.1							1.10	0.40	29.0	11.3

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P18-11												
FIELD RESULT												
P18-11-1	.31	14.8	0.05	0.02	14.7	0.49	0.85	0.05	0.76	0.05	13.8	3.83
P18-11-10	.31	14.8	0.00	0.00	11.0	0.42	0.87	0.05	0.51	0.05	9.01	0.21
P18-11-11	.31	14.8	0.12	0.03	14.8	0.49	0.80	0.05	0.83	0.05	13.6	5.16
P18-11-13	.31	14.8	0.00	0.00	14.4	0.47	0.87	0.05	0.60	0.05	6.16	0.08
P18-11-13	.31	14.8	0.00	0.00	16.2	0.51	0.81	0.05	0.74	0.05	0.07	0.02
P18-11-14	.31	14.8	0.00	0.00	16.5	0.52	0.88	0.05	0.72	0.05	0.06	0.02
P18-11-14	.31	14.8	0.00	0.00	14.9	0.48	1.00	0.05	0.70	0.05	0.03	0.02
P18-11-15	.31	14.8	0.07	0.03	14.8	0.49	0.97	0.05	0.84	0.05	11.2	3.57
P18-11-4	.31	14.8	0.10	0.02	13.0	0.44	0.77	0.05	0.67	0.05	14.3	3.47
P18-11-4	.31	14.8	0.07	0.02	15.1	0.48	0.86	0.05	0.74	0.05	15.4	3.15
P18-11-5	.31	14.8	0.00	0.00	15.8	0.48	1.01	0.05	0.70	0.05	11.1	5.46
P18-11-6	.31	14.8	0.07	0.03	13.7	0.47	0.84	0.05	0.74	0.05	17.9	4.56
P18-11-7	.31	14.8	0.32	0.03	13.1	0.44	0.80	0.05	0.83	0.05	15.9	3.56
P18-11-8	.31	14.8	0.11	0.02	14.4	0.46	0.76	0.05	0.74	0.05	14.6	3.41
P18-11-9	.31	14.8	0.00	0.00	13.7	0.48	0.81	0.05	0.59	0.05	6.34	4.05
P18-11-9-D	.31	14.8	0.00	0.00	13.8	0.48	0.80	0.05	0.61	0.05	0.05	0.02
P18-11-1	1	14.8	0.06	0.02	13.3	0.43	0.89	0.05	0.72	0.05	14.7	3.78

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-11-10	1	14.8	0.00	0.00	10.3	0.39	0.83	0.05	0.53	0.04	0.00	0.00
P18-11-11	1	14.8	0.12	0.03	13.7	0.43	0.85	0.05	0.85	0.05	12.3	3.49
P18-11-13	1	14.8	0.00	0.00	15.4	0.51	0.83	0.05	0.70	0.05	8.54	4.25
P18-11-13	1	14.8	0.00	0.00	13.1	0.42	0.84	0.05	0.60	0.05	5.84	0.08
P18-11-14	1	14.8	0.00	0.00	16.4	0.53	0.89	0.05	0.74	0.05	7.80	3.43
P18-11-14	1	14.8	0.00	0.00	13.5	0.43	0.82	0.05	0.56	0.05	0.00	0.00
P18-11-15	1	14.8	0.06	0.02	13.8	0.45	0.95	0.05	0.82	0.05	12.0	3.36
P18-11-4	1	14.8	0.07	0.02	14.3	0.47	0.71	0.05	0.57	0.05	0.10	0.03
P18-11-4	1	14.8	0.07	0.02	16.1	0.50	0.82	0.05	0.74	0.05	15.7	3.31
P18-11-5	1	14.8	0.00	0.00	13.4	0.42	0.96	0.05	0.68	0.05	13.4	4.94
P18-11-6	1	14.8	0.07	0.02	13.1	0.42	0.82	0.05	0.73	0.05	12.0	3.78
P18-11-7	1	14.8	0.16	0.03	14.6	0.47	0.83	0.05	0.77	0.05	18.1	4.08
P18-11-8	1	14.8	0.07	0.02	14.4	0.47	0.79	0.05	0.66	0.05	11.4	5.14
P18-11-9	1	14.8	0.00	0.00	14.0	0.49	0.73	0.05	0.58	0.05	0.07	0.03
P18-11-9-D	1	14.8	0.00	0.00	13.5	0.48	0.82	0.05	0.62	0.05	0.05	0.02
LAB RESULT - GAMMA												
P18-11C-608400		12.9	0.05	0.08	18.0	1.30	0.76	0.11	1.00	0.13	2.08	1.47
P18-11C-627216		18.1	0.15	0.05	16.0	1.30	0.85	0.12	1.20	0.14	9.05	1.91
P18-11C-696228		11.9	0.09	0.15	18.0	1.50	0.85	0.14	0.75	0.10	4.30	1.96
P18-11C-711283		20.4	0.97	0.10	16.0	1.40	1.00	0.16	1.20	0.14	18.8	2.97

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-11C-712210		17.6	0.53	0.07	17.0	1.40	0.99	0.16	0.93	0.12	12.5	2.62
P18-11C-712303		13.4	0.07	0.13	19.0	1.70	0.91	0.14	1.10	0.13	6.83	1.80
P18-11C-721375		15.1	0.01	0.06	18.0	1.50	1.20	0.16	0.87	0.11	1.63	1.61
P18-11C-760289		13.8	0.14	0.06	18.0	1.30	0.85	0.11	1.20	0.13	10.1	2.36
P18-11C-783383		16.4	0.15	0.13	20.0	1.70	1.40	0.17	1.30	0.14	7.56	2.66
P18-11C-789320		13.8	0.07	0.07	20.0	1.60	1.00	0.16	0.95	0.12	2.36	1.73
P18-11C-798245		13.0	0.02	0.13	17.0	1.60	0.88	0.16	0.86	0.11	5.18	2.36
P18-11C2-1-R		13.9	-0.02	0.07	21.0	1.60	1.10	0.14	1.10	0.13	3.27	1.96
LAB RESULT - ALPHA												
P18-11C-608400		12.9							0.68	0.26	3.03	1.31
P18-11C-627216		18.1							0.99	0.42	12.7	4.46
P18-11C-696228		11.9							0.75	0.34	8.15	2.56
P18-11C-711283		20.4							1.20	0.47	30.9	11.0
P18-11C-712210		17.6							0.99	0.41	21.2	7.14
P18-11C-712303		13.4							0.99	0.34	10.4	4.16
P18-11C-721375		15.1							0.86	0.38	2.52	0.95
P18-11C-760289		13.8							1.40	0.52	12.7	5.06
P18-11C-783383		16.4							1.10	0.44	6.08	2.17
P18-11C-789320		13.8							0.88	0.32	3.64	1.52
P18-11C-798245		13.0							0.73	0.28	8.61	2.97

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-11C2-1-R		13.9							0.89	0.37		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P18-12												
FIELD RESULT												
P18-12-1-G	.31	17.9	0.07	0.03	18.4	0.56	0.99	0.06	1.12	0.06	14.6	3.54
P18-12-10-G	.31	20.7	0.04	0.03	14.3	0.49	1.01	0.05	1.20	0.06	14.1	4.03
P18-12-11-G	.31	17.4	0.05	0.02	13.4	0.48	0.97	0.05	1.10	0.06	14.5	3.31
P18-12-11-G	.31	17.4	0.06	0.02	13.8	0.49	0.97	0.05	1.08	0.06	12.7	3.93
P18-12-12-G	.31	17.9	0.04	0.02	14.5	0.48	1.03	0.05	1.15	0.06	11.4	3.93
P18-12-14-G	.31	18.7	0.05	0.02	15.0	0.49	1.00	0.05	1.15	0.06	10.2	3.58
P18-12-15-G	.31	17.8	0.04	0.02	16.6	0.52	0.97	0.05	1.13	0.06	11.0	3.58
P18-12-2-G	.31	19.4	0.07	0.03	18.8	0.58	0.98	0.06	1.16	0.06	17.7	3.57
P18-12-3-G	.31	18.7	0.05	0.03	17.4	0.55	1.01	0.06	1.14	0.06	18.0	3.58
P18-12-4-G	.31	14.5	0.04	0.02	15.6	0.51	0.84	0.05	0.86	0.05	13.4	3.29
P18-12-5-G	.31	10.2	0.00	0.00	14.9	0.47	0.71	0.04	0.66	0.04	10.4	3.16
P18-12-7-G	.31	16.3	0.05	0.02	15.5	0.51	0.93	0.05	1.12	0.06	12.2	3.33
P18-12-8-G	.31	14.3	0.07	0.02	14.1	0.47	0.96	0.05	1.04	0.05	16.6	3.22
P18-12-1-G	1	17.9	0.07	0.03	16.7	0.54	0.92	0.06	1.07	0.06	16.3	3.62
P18-12-10-G	1	20.7	0.05	0.02	14.4	0.50	0.96	0.05	1.16	0.06	14.7	3.55
P18-12-11-G	1	17.4	0.06	0.02	13.3	0.49	0.94	0.05	1.08	0.06	17.3	3.42
P18-12-11-G	1	17.4	0.07	0.03	13.7	0.49	0.98	0.05	1.12	0.06	12.8	3.43

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-12-12-G	1	17.9	0.06	0.02	13.4	0.47	0.98	0.05	1.11	0.06	12.9	3.74
P18-12-14-G	1	18.7	0.05	0.02	14.8	0.49	0.98	0.05	1.17	0.06	10.5	3.40
P18-12-15-G	1	17.8	0.06	0.02	15.9	0.51	0.98	0.05	1.05	0.06	12.4	3.39
P18-12-2-G	1	19.4	0.08	0.03	17.6	0.56	0.96	0.06	1.14	0.06	17.4	3.76
P18-12-3-G	1	18.7	0.06	0.03	16.4	0.54	0.97	0.06	1.11	0.06	19.2	3.65
P18-12-4-G	1	14.5	0.06	0.02	14.9	0.50	0.85	0.05	0.84	0.05	12.9	3.38
P18-12-5-G	1	10.2	0.03	0.02	14.7	0.47	0.72	0.05	0.67	0.05	11.9	3.00
P18-12-7-G	1	16.3	0.08	0.03	14.8	0.51	0.89	0.05	1.03	0.06	15.1	4.16
P18-12-8-G	1	14.3	0.06	0.02	14.1	0.47	0.94	0.05	0.89	0.05	14.2	3.33
LAB RESULT - GAMMA												
P17-34C-825010		15.0	0.27	0.06	16.0	1.20	0.92	0.14	1.30	0.15	9.93	2.15
P17-34C-825187		13.8	0.01	0.03	15.0	1.80	0.77	0.15	0.74	0.12	7.03	3.57
P17-34C-844094		21.0	0.00	0.08	21.0	1.70	1.70	0.17	1.50	0.17	8.53	2.14
P17-34C-848107		23.8	-0.02	0.05	18.8	2.70	1.33	0.30	1.51	0.59	9.71	9.22
P17-34C-868176		18.4	0.02	0.02	22.0	2.30	1.10	0.15	1.10	0.14	5.47	2.94
P17-34C-880001		16.0	0.13	0.13	15.0	1.50	1.20	0.18	1.20	0.14	7.77	2.77
P18-12C-806224		13.1	-0.02	0.02	19.0	2.10	0.92	0.15	0.81	0.12	8.14	3.57
P18-12C-814384		22.2	0.23	0.06	19.0	1.50	1.70	0.20	1.50	0.17	14.9	2.98
P18-12C-844336		28.8	0.06	0.15	16.0	1.40	1.60	0.19	1.50	0.16	7.38	2.98
P18-12C-863295		22.4	0.05	0.03	16.0	1.90	1.10	0.21	1.30	0.19	5.40	3.57

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-12C-868305		21.5	0.09	0.07	16.0	1.40	1.60	0.16	1.30	0.16	6.92	2.32
P18-12C-872219		22.8	0.10	0.07	26.0	2.00	2.00	0.19	1.60	0.18	6.07	2.23
P18-12C-890350		21.3	0.02	0.08	17.0	1.30	1.40	0.14	1.80	0.18	7.90	1.88
P18-12C-902358		22.6	0.07	0.08	15.0	1.20	1.30	0.13	1.60	0.16	4.94	1.56
P18-12C-903278		22.8	0.05	0.08	1.70	1.30	1.60	0.14	1.40	0.14	4.98	2.24
LAB RESULT - ALPHA												
P17-34C-825010		15.0							0.88	0.40	13.1	4.76
P17-34C-825187		13.8							0.76	0.19		
P17-34C-844094		21.0							1.50	0.56	10.1	3.57
P17-34C-848107		23.8							1.43	0.13		
P17-34C-868176		18.4							0.96	0.21		
P17-34C-880001		16.0							1.20	0.48	7.30	2.77
P18-12C-806224		13.1							0.79	0.18		
P18-12C-814384		22.2							1.30	0.46	25.3	9.52
P18-12C-844336		28.8							1.50	0.69	7.89	2.80
P18-12C-863295		22.4							1.20	0.23		
P18-12C-868305		21.5							1.40	0.55	6.07	2.23
P18-12C-872219		22.8							1.40	0.54	8.51	2.97
P18-12C-890350		21.3							1.20	0.52	6.68	2.41
P18-12C-902358		22.6							1.20	0.50	7.27	2.74

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-12C-903278		22.8							1.20	0.44	6.36	2.35

G001185

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P18-20												
FIELD RESULT												
P18-12-12	.31	18.8	0.03	0.00	15.0	0.49	1.05	0.05	0.99	0.05	13.2	3.37
P18-12-12	.31	18.8	0.04	0.00	14.8	0.50	1.07	0.06	1.00	0.06	13.4	3.89
P18-12-4	.31	18.8	0.08	0.03	15.1	0.51	1.06	0.06	1.06	0.06	16.5	3.67
P18-20-10	.31	18.8	0.08	0.02	15.5	0.50	0.95	0.05	0.99	0.05	11.7	3.25
P18-20-10	.31	18.8	0.08	0.03	15.4	0.49	1.11	0.05	0.84	0.05	13.4	3.35
P18-20-11	.31	18.8	0.12	0.03	15.6	0.50	1.21	0.06	1.05	0.06	12.9	3.44
P18-20-12	.31	18.8	0.08	0.03	14.7	0.50	1.17	0.06	1.11	0.06	13.4	3.94
P18-20-13	.31	18.8	0.05	0.03	14.9	0.51	1.13	0.06	1.10	0.06	12.6	3.43
P18-20-14	.31	18.8	0.04	0.02	15.1	0.49	1.14	0.05	0.92	0.05	12.1	4.46
P18-20-15	.31	18.8	0.10	0.03	15.5	0.52	1.13	0.06	1.01	0.06	13.3	3.33
P18-20-16	.31	18.8	0.11	0.03	14.0	0.49	1.24	0.06	1.14	0.06	16.1	3.36
P18-20-3	.31	18.8	0.10	0.03	13.9	0.49	1.16	0.06	1.14	0.06	14.3	3.45
P18-20-5	.31	18.8	0.05	0.03	16.4	0.53	1.10	0.06	0.98	0.06	15.2	3.49
P18-20-6	.31	18.8	0.00	0.00	16.1	0.51	1.11	0.06	0.91	0.05	12.4	6.59
P18-20-6	.31	18.8	0.00	0.00	16.4	0.52	0.83	0.05	0.83	0.05	13.0	4.94
P18-20-7	.31	18.8	0.04	0.02	16.1	0.51	1.04	0.05	1.12	0.06	13.6	3.40
P18-20-7	.31	18.8	0.08	0.03	14.3	0.49	1.22	0.06	1.10	0.06	13.6	3.78

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-20-8	.31	18.8	0.16	0.03	14.3	0.50	1.19	0.06	1.05	0.06	16.1	3.47
P18-4	.31	18.8	0.05	0.03	15.0	0.51	1.19	0.06	1.02	0.06	11.0	3.47
P18-12-12	1	18.8	0.05	0.03	14.9	0.50	1.01	0.05	0.90	0.05	13.3	5.15
P18-12-12	1	18.8	0.00	0.00	12.4	0.46	0.52	0.05	0.47	0.06	0.00	0.00
P18-12-4	1	18.8	0.06	0.03	13.5	0.44	0.93	0.05	0.86	0.06	11.3	5.95
P18-20-10	1	18.8	0.06	0.02	12.9	0.45	0.95	0.05	0.75	0.05	11.4	4.28
P18-20-10	1	18.8	0.06	0.02	14.4	0.46	0.89	0.05	0.84	0.05	10.9	3.47
P18-20-11	1	18.8	0.10	0.02	12.6	0.44	1.01	0.05	0.83	0.05	13.3	3.15
P18-20-11	1	18.8	0.10	0.03	16.0	0.51	1.05	0.06	0.98	0.06	12.3	3.41
P18-20-12	1	18.8	0.08	0.02	14.5	0.49	1.04	0.05	1.12	0.05	16.1	3.33
P18-20-12	1	18.8	0.08	0.02	14.2	0.45	1.19	0.05	1.10	0.05	12.9	3.35
P18-20-13	1	18.8	0.09	0.03	14.0	0.45	1.10	0.05	1.06	0.05	15.9	3.40
P18-20-14	1	18.8	0.00	0.00	11.0	0.47	0.57	0.05	0.51	0.07	0.00	0.00
P18-20-15	1	18.8	0.08	0.03	15.3	0.50	1.04	0.05	0.99	0.05	12.4	3.31
P18-20-15	1	18.8	0.11	0.03	14.5	0.46	1.15	0.05	0.98	0.05	16.9	3.27
P18-20-16	1	18.8	0.11	0.03	14.2	0.45	1.32	0.06	1.06	0.05	15.1	3.37
P18-20-16	1	18.8	0.07	0.03	14.4	0.49	1.13	0.06	1.05	0.05	12.7	3.31
P18-20-3	1	18.8	0.08	0.03	14.5	0.49	1.06	0.05	1.08	0.06	13.5	3.45
P18-20-3	1	18.8	0.07	0.03	13.2	0.43	1.10	0.05	1.04	0.05	10.8	3.53

0001287

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-20-5	1	18.8	0.06	0.02	15.1	0.47	1.09	0.05	0.99	0.05	14.0	4.87
P18-20-5	1	18.8	0.00	0.00	13.3	0.51	0.45	0.05	0.44	0.05	0.00	0.00
P18-20-6	1	18.8	0.04	0.02	15.3	0.47	0.95	0.05	0.95	0.05	11.1	3.35
P18-20-6	1	18.8	0.04	0.02	13.9	0.47	1.03	0.05	0.87	0.05	11.5	3.29
P18-20-7	1	18.8	0.07	0.02	14.4	0.45	1.26	0.06	1.12	0.06	13.8	4.20
P18-20-7	1	18.8	0.05	0.02	15.4	0.48	0.99	0.05	1.05	0.05	0.09	0.03
P18-20-8	1	18.8	0.11	0.03	14.9	0.50	1.05	0.05	1.08	0.06	16.1	3.36
P18-20-8	1	18.8	0.13	0.03	13.7	0.44	1.11	0.05	1.04	0.05	15.9	3.41
P18-4	1	18.8	0.07	0.03	14.0	0.45	1.10	0.05	1.03	0.05	13.9	3.38
LAB RESULT - GAMMA												
P18-12C-977297		18.9	0.40	0.08	17.0	1.40	1.50	0.17	1.30	0.15	19.2	3.57
P18-20C-006387		16.1	0.14	0.07	18.0	1.50	1.10	0.13	0.93	0.12	9.98	2.08
P18-20C-043443		14.9	0.01	0.07	19.0	1.50	1.30	0.15	0.93	0.12	5.72	1.88
P18-20C-103322		22.7	0.40	0.06	20.0	1.40	1.20	0.15	1.70	0.17	15.7	2.92
P18-20C-109583		17.0	0.07	0.08	18.0	1.40	1.50	0.16	1.40	0.16	5.70	2.20
P18-20C-232374		17.9	-0.02	0.07	14.6	2.10	0.88	0.20	1.40	0.43	7.55	5.65
P18-20C-232374-D		22.0	0.16	0.14	17.0	1.60	1.70	0.18	1.40	0.15	9.09	2.98
P18-20C-244287		19.6	0.06	0.08	16.0	1.30	1.20	0.12	1.60	0.16	6.88	1.97
P18-20C-267570		20.9	0.04	0.03	19.0	1.40	1.20	0.13	1.60	0.17	7.31	2.30
P18-20C-269488		17.5	0.10	0.08	17.0	1.30	1.10	0.12	1.60	0.16	10.6	2.68

008183

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-20C-306477		18.5	0.35	0.09	0.92	1.20	0.09	0.19	0.12	0.12	7.36	2.00
P18-20C-343361		16.9	0.10	0.13	17.0	1.70	1.40	0.17	1.30	0.14	3.39	1.86
P18-20C-366527		21.8	0.30	0.07	19.0	1.60	1.40	0.17	1.40	0.15	16.0	3.27
P18-20C-384287		19.7	0.14	0.06	18.0	1.60	1.40	0.18	1.30	0.14	13.1	2.98
P18C-998597		18.0	0.03	0.15	18.0	1.60	1.40	0.16	1.30	0.15	10.6	2.92
LAB RESULT - ALPHA												
P18-12C-977297		18.9							0.93	0.39	4.87	1.81
P18-20C-006387		16.1							0.93	0.37	13.1	4.48
P18-20C-043443		14.9							0.88	0.34	6.33	2.35
P18-20C-103322		22.7							1.10	0.42	26.2	9.52
P18-20C-109583		17.0							1.10	0.49	6.35	2.09
P18-20C-232374		17.9							1.27	0.10		
P18-20C-232374-D		22.0							1.10	0.43	3.69	1.37
P18-20C-244287		19.6							0.99	0.38	6.37	0.24
P18-20C-267570		20.9							1.20	0.49	7.73	2.67
P18-20C-269488		17.5							1.40	0.64	11.1	3.87
P18-20C-306477		18.5							0.96	0.40	10.9	3.28
P18-20C-343361		16.9							1.30	0.46	3.52	1.28
P18-20C-366527		21.8							1.20	0.45	21.2	8.33
P18-20C-384287		19.7							1.30	0.39	11.6	5.06

001189

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18C-998597		18.0							1.20	0.46	13.4	5.06

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P18-40												
FIELD RESULT												
P18-40-10	.31	19.2	0.20	0.03	11.9	0.45	0.99	0.05	0.92	0.05	17.6	3.22
P18-40-10	.31	19.2	0.18	0.03	13.0	0.46	0.90	0.05	0.87	0.05	15.6	3.08
P18-40-12	.31	19.2	0.15	0.03	12.0	0.42	0.97	0.05	0.93	0.05	15.4	3.09
P18-40-14	.31	19.2	0.35	0.03	12.5	0.46	1.05	0.05	0.84	0.05	21.0	3.35
P18-40-14	.31	19.2	0.32	0.03	12.9	0.45	0.85	0.05	0.90	0.05	21.9	3.01
P18-40-15	.31	19.2	0.12	0.03	14.2	0.48	0.96	0.05	0.94	0.05	14.9	3.08
P18-40-15	.31	19.2	0.12	0.03	14.0	0.48	1.14	0.05	0.86	0.05	12.3	6.22
P18-40-16	.31	19.2	0.14	0.03	16.6	0.54	1.01	0.05	0.98	0.05	15.6	3.20
P18-40-16	.31	19.2	0.11	0.03	14.9	0.49	0.99	0.05	0.82	0.05	0.08	0.03
P18-40-16-D	.31	19.2	0.16	0.03	16.5	0.54	1.01	0.05	0.97	0.05	14.2	3.18
P18-40-2	.31	19.2	0.05	0.02	16.2	0.51	1.16	0.06	0.96	0.05	11.6	3.49
P18-40-3	.31	19.2	0.11	0.03	14.7	0.48	1.24	0.06	1.09	0.05	16.2	3.35
P18-40-4	.31	19.2	0.09	0.02	14.7	0.48	1.26	0.06	1.06	0.05	14.1	3.94
P18-40-5	.31	19.2	0.14	0.03	13.2	0.48	1.07	0.05	0.99	0.06	14.5	3.25
P18-40-6	.31	19.2	0.13	0.03	12.7	0.48	1.03	0.05	0.91	0.05	16.1	3.26
P18-40-7	.31	19.2	0.12	0.03	13.7	0.47	1.20	0.06	1.06	0.05	15.4	3.31
P18-40-9	.31	19.2	0.13	0.03	14.2	0.49	1.16	0.06	0.98	0.05	14.4	3.26

001231

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-40-9	.31	19.2	0.12	0.03	15.1	0.50	0.96	0.05	0.96	0.05	16.9	3.19
P18-40-10	1	19.2	0.14	0.03	12.5	0.46	0.82	0.05	0.81	0.05	12.9	3.46
P18-40-10	1	19.2	0.18	0.03	11.2	0.40	1.00	0.05	0.83	0.05	18.5	3.12
P18-40-12	1	19.2	0.11	0.02	11.7	0.42	1.05	0.05	0.93	0.05	12.9	3.16
P18-40-14	1	19.2	0.27	0.03	13.0	0.46	0.86	0.05	0.88	0.05	21.5	3.21
P18-40-14	1	19.2	0.30	0.03	11.4	0.41	0.99	0.05	0.78	0.05	18.2	3.68
P18-40-15	1	19.2	0.14	0.03	13.5	0.46	1.11	0.05	0.91	0.05	13.6	3.30
P18-40-16	1	19.2	0.13	0.03	16.5	0.54	1.03	0.06	0.95	0.06	17.3	3.33
P18-40-16	1	19.2	0.10	0.03	14.1	0.47	1.05	0.05	0.88	0.05	13.0	3.59
P18-40-16-D	1	19.2	0.13	0.03	16.1	0.54	1.05	0.06	0.99	0.06	15.5	3.32
P18-40-2	1	19.2	0.00	0.00	14.1	0.47	1.02	0.05	0.85	0.05	9.35	3.75
P18-40-3	1	19.2	0.11	0.03	14.2	0.47	1.16	0.06	1.05	0.05	14.3	3.33
P18-40-4	1	19.2	0.09	0.03	13.7	0.47	1.23	0.06	1.03	0.05	15.8	3.35
P18-40-5	1	19.2	0.12	0.02	12.0	0.42	1.02	0.05	0.91	0.05	14.2	3.24
P18-40-6	1	19.2	0.14	0.03	12.6	0.48	0.99	0.05	0.93	0.06	15.1	3.70
P18-40-7	1	19.2	0.13	0.03	13.2	0.46	1.25	0.06	0.97	0.06	16.6	3.43
P18-40-9	1	19.2	0.12	0.03	14.5	0.49	0.93	0.05	0.89	0.05	13.6	3.56
P18-40-9	1	19.2	0.10	0.03	13.7	0.44	1.07	0.05	0.95	0.05	16.8	3.25

LAB RESULT - GAMMA

0001192

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P18-40C-057710		0.00	0.19	0.03	19.0	1.90	1.10	0.15	1.20	0.16	12.1	2.97
P18-40C-082930		20.0	0.08	0.08	13.8	2.10	0.91	0.21	1.18	0.42	8.71	6.25
P18-40C-097665		18.9	0.05	0.08	17.0	1.30	1.20	0.13	1.70	0.18	7.34	2.24
P18-40C-121992		11.8	0.04	0.09	19.0	1.10	1.30	0.14	1.30	0.14	2.76	1.37
P18-40C-133834		13.8	0.25	0.13	12.0	2.40	1.74	0.29	1.63	0.57	22.4	13.1
P18-40C-142613		19.9	0.15	0.07	19.0	1.50	1.30	0.15	1.10	0.14	2.64	1.73
P18-40C-217950		20.7	-0.07	0.08	17.1	2.40	1.04	0.23	1.39	0.38	4.78	6.84
P18-40C-233817		30.9	0.65	0.15	14.4	2.40	1.81	0.30	1.32	0.61	37.2	11.6
P18-40C-233817-D		15.3	0.74	0.18	11.0	2.10	1.45	0.27	0.88	0.54	31.1	11.9
P18-40C-238686		20.4	0.17	0.08	18.0	1.40	1.30	0.14	1.90	0.19	9.67	2.53
P18-40C-294716		23.6	0.74	0.18	14.7	2.50	1.79	0.28	1.62	0.53	41.6	11.3
P18-40C-333930		18.8	0.03	0.14	19.0	1.70	1.60	0.19	1.70	0.19	4.77	2.30
P18-40C-343874		19.1	0.07	0.07	14.7	2.20	1.06	0.20	1.03	0.40	6.73	5.95
P18-40C-345749		18.9	-0.09	0.10	14.7	2.30	1.38	0.29	1.04	0.53	7.78	6.54
P18-40C-399613		20.5	-0.09	0.15	19.0	1.60	1.30	0.17	1.40	0.16	6.91	2.75
LAB RESULT - ALPHA												
P18-40C-057710		0.00							1.00	0.22		
P18-40C-082930		20.0							0.98	0.08		
P18-40C-097665		18.9							1.00	0.47	6.83	2.53
P18-40C-121992		11.8							1.20	0.50		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P18-40C-133834		13.8							0.90	0.09		
P18-40C-142613		19.9							1.00	0.44	5.60	2.00
P18-40C-217950		20.7							0.99	0.12		
P18-40C-233817		30.9							1.18	0.10		
P18-40C-233817-D		15.3							1.17	0.09		
P18-40C-238686		20.4							1.40	0.52	10.1	3.57
P18-40C-294716		23.6							1.23	0.10		
P18-40C-333930		18.8							1.30	0.48		
P18-40C-343874		19.1							1.17	0.10		
P18-40C-345749		18.9							0.77	0.67		
P18-40C-399613		20.5							1.40	0.53		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P19												
FIELD RESULT												
P19-1	.31	24.5	0.56	0.04	11.3	0.44	0.76	0.05	0.74	0.05	30.0	3.64
P19-11	.31	24.5	0.31	0.03	10.0	0.42	0.90	0.05	0.48	0.04	13.7	3.12
P19-12	.31	24.5	0.51	0.04	13.1	0.48	0.81	0.05	0.86	0.05	25.7	3.54
P19-13	.31	24.5	0.44	0.04	15.6	0.52	0.87	0.05	0.76	0.05	16.4	3.48
P19-14	.31	24.5	0.41	0.03	12.8	0.44	0.77	0.05	0.59	0.05	16.5	3.32
P19-15	.31	24.5	0.44	0.04	15.2	0.53	0.90	0.05	0.72	0.05	17.9	3.54
P19-16	.31	24.5	0.46	0.04	14.4	0.50	0.65	0.05	0.74	0.05	17.6	3.39
P19-4	.31	24.5	0.48	0.04	12.6	0.49	0.79	0.05	0.85	0.05	24.9	3.44
P19-4	.31	24.5	0.19	0.04	9.39	0.45	0.35	0.05	0.37	0.05	0.00	0.00
P19-5	.31	24.5	0.53	0.04	13.0	0.47	0.96	0.05	0.82	0.05	28.1	3.59
P19-6	.31	24.5	0.52	0.04	12.6	0.46	0.68	0.05	0.77	0.05	21.9	3.50
P19-7	.31	24.5	0.55	0.04	13.8	0.49	0.75	0.05	0.83	0.05	27.0	3.58
P19-8	.31	24.5	0.50	0.04	10.8	0.45	0.81	0.05	0.75	0.05	24.4	3.50
P19-8	.31	24.5	0.64	0.04	13.6	0.48	0.90	0.05	0.95	0.05	29.4	3.63
P19-1	1	24.5	0.57	0.04	10.9	0.46	0.77	0.05	0.69	0.05	24.6	3.71
P19-11	1	24.5	0.37	0.03	10.2	0.43	0.92	0.05	0.50	0.05	16.8	3.32
P19-12	1	24.5	0.48	0.04	12.4	0.48	0.76	0.05	0.81	0.05	22.5	3.62

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-13	1	24.5	0.42	0.04	15.2	0.52	0.86	0.05	0.82	0.05	15.1	3.64
P19-14	1	24.5	0.38	0.04	13.6	0.51	0.77	0.05	0.61	0.05	16.8	3.64
P19-15	1	24.5	0.46	0.04	15.1	0.54	0.87	0.06	0.70	0.05	18.2	3.66
P19-16	1	24.5	0.49	0.04	14.7	0.51	0.77	0.05	0.75	0.05	19.3	3.56
P19-4	1	24.5	0.49	0.04	12.4	0.49	0.80	0.05	0.78	0.05	26.3	3.68
P19-4	1	24.5	0.43	0.04	10.4	0.45	0.78	0.05	0.77	0.05	22.9	3.57
P19-5	1	24.5	0.50	0.04	12.4	0.48	0.87	0.05	0.80	0.06	23.8	3.78
P19-6	1	24.5	0.48	0.04	13.5	0.50	0.70	0.05	0.77	0.05	20.4	3.66
P19-7	1	24.5	0.51	0.04	13.2	0.50	0.73	0.05	0.85	0.05	25.5	3.63
P19-8	1	24.5	0.58	0.04	12.6	0.48	0.85	0.05	0.94	0.06	27.1	3.74
P19-8	1	24.5	0.48	0.04	11.2	0.46	0.77	0.05	0.70	0.05	25.2	3.63
LAB RESULT - GAMMA												
P19C-653510		23.3	0.52	0.08	20.0	2.20	1.10	0.16	1.20	0.16	19.6	5.06
P19C-716011		23.6	0.43	0.08	17.0	1.90	1.00	0.16	1.10	0.16	18.2	6.25
P19C-734514		25.2	0.77	0.09	20.0	2.20	1.00	0.16	1.30	0.18	23.3	6.54
P19C-796728		26.6	0.63	0.09	20.0	2.30	1.10	0.18	1.30	0.20	23.9	6.84
P19C-804489		19.5	0.67	0.09	20.0	2.10	0.91	0.13	1.20	0.16	23.6	5.06
P19C-832239		27.2	0.89	0.12	18.0	2.00	1.10	0.16	1.30	0.17	39.0	7.73
P19C-871099		24.5	0.43	0.09	18.0	2.10	1.20	0.22	1.20	0.17	18.7	5.35
P19C-899672		26.1	0.63	0.09	25.0	2.60	0.96	0.14	1.30	0.17	21.2	4.76

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19C-902256		26.8	0.76	0.10	18.0	1.90	1.20	0.17	1.20	0.17	20.2	5.35
P19C-902785		20.5	0.53	0.08	24.0	2.70	0.98	0.16	1.30	0.19	18.1	5.65
P19C-923140		26.7	0.54	0.08	18.0	2.10	1.20	0.16	1.30	0.16	28.9	6.54
P19C-998543		23.7	0.70	0.13	18.0	2.10	1.10	0.20	1.20	0.17	24.3	5.95
LAB RESULT - ALPHA												
P19C-653510		23.3							1.10	0.21		
P19C-716011		23.6							1.20	0.24		
P19C-734514		25.2							1.00	0.22		
P19C-796728		26.6							1.60	0.32		
P19C-804489		19.5							0.84	0.23		
P19C-832239		27.2							0.92	0.20		
P19C-871099		24.5							1.10	0.22		
P19C-899672		26.1							1.10	0.23		
P19C-902256		26.8							1.10	0.24		
P19C-902785		20.5							1.20	0.27		
P19C-923140		26.7							0.96	0.22		
P19C-998543		23.7							1.00	0.30		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P19-20												
FIELD RESULT												
P19-20-1-G	.31	17.7	0.20	0.03	18.2	0.54	0.93	0.05	0.94	0.05	15.5	2.98
P19-20-1-G	.31	17.7	0.17	0.03	16.5	0.53	0.90	0.05	0.88	0.05	13.8	3.05
P19-20-1-G	.31	17.7	0.25	0.03	17.3	0.52	0.90	0.05	0.95	0.05	17.2	3.02
P19-20-1-G	.31	17.7	0.19	0.03	16.9	0.51	0.93	0.05	0.91	0.05	15.9	2.92
P19-20-10-G	.31	17.7	0.07	0.02	14.2	0.47	1.09	0.05	1.03	0.05	11.9	2.97
P19-20-11-G	.31	17.7	0.14	0.03	13.2	0.43	1.29	0.05	1.09	0.05	17.1	3.03
P19-20-11-G	.31	17.7	0.15	0.02	15.7	0.49	0.85	0.05	0.86	0.05	17.4	2.87
P19-20-14-G	.31	17.7	0.13	0.03	14.0	0.44	1.26	0.05	1.06	0.05	13.2	3.01
P19-20-16-G	.31	17.7	0.08	0.02	15.3	0.50	1.05	0.05	1.05	0.05	10.1	2.97
P19-20-16-G	.31	17.7	0.06	0.02	14.8	0.51	0.97	0.05	0.98	0.05	8.51	3.01
P19-20-2-G	.31	17.7	0.10	0.03	16.3	0.53	0.84	0.05	0.85	0.05	10.8	2.95
P19-20-3-G	.31	17.7	0.26	0.03	14.2	0.49	0.83	0.05	0.79	0.05	17.5	3.04
P19-20-3-G	.31	17.7	0.21	0.03	15.3	0.50	1.13	0.05	0.88	0.05	15.8	3.01
P19-20-4-G	.31	17.7	0.08	0.02	14.1	0.48	1.41	0.05	0.90	0.05	12.2	2.98
P19-20-4-G	.31	17.7	0.10	0.02	12.9	0.47	0.82	0.05	0.81	0.05	12.6	2.92
P19-20-6-G	.31	17.7	0.33	0.03	17.1	0.54	0.92	0.05	0.96	0.05	19.3	3.16
P19-20-7-G	.31	17.7	0.07	0.02	13.2	0.48	0.87	0.05	0.81	0.05	11.3	2.94

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P19-20-7-G	.31	17.7	0.19	0.03	14.6	0.49	1.09	0.05	1.07	0.05	16.6	3.04
P19-20-8-G	.31	17.7	0.22	0.03	11.2	0.44	0.80	0.05	0.73	0.05	16.0	2.95
P19-20-9-G	.31	17.7	0.47	0.03	10.5	0.39	0.69	0.04	0.74	0.04	23.0	3.05
P19-20-9-G	.31	17.7	0.20	0.02	7.90	0.37	0.67	0.04	0.55	0.04	13.2	2.75
P19-20-1-G	1	17.7	0.21	0.03	15.8	0.53	0.89	0.05	0.84	0.05	16.3	3.18
P19-20-1-G	1	17.7	0.21	0.03	17.1	0.53	0.90	0.05	0.88	0.05	17.4	3.09
P19-20-1-G	1	17.7	0.19	0.03	15.8	0.50	0.94	0.05	0.87	0.05	15.1	3.03
P19-20-1-G	1	17.7	0.22	0.03	17.3	0.53	0.88	0.05	0.89	0.05	16.2	3.08
P19-20-10-G	1	17.7	0.12	0.03	13.7	0.47	1.12	0.05	1.02	0.05	14.5	3.13
P19-20-11-G	1	17.7	0.17	0.03	13.2	0.44	1.30	0.05	1.04	0.05	16.4	3.15
P19-20-11-G	1	17.7	0.14	0.02	15.1	0.48	0.88	0.05	0.85	0.05	14.1	2.98
P19-20-14-G	1	17.7	0.14	0.03	13.0	0.43	1.18	0.05	1.08	0.05	15.7	3.11
P19-20-16-G	1	17.7	0.06	0.02	15.6	0.50	1.05	0.05	0.96	0.05	12.7	3.61
P19-20-16-G	1	17.7	0.07	0.02	13.9	0.49	0.91	0.05	0.96	0.05	9.62	3.66
P19-20-2-G	1	17.7	0.13	0.03	16.8	0.52	0.83	0.05	0.86	0.05	11.8	3.51
P19-20-3-G	1	17.7	0.18	0.03	15.8	0.51	1.17	0.05	0.90	0.05	19.2	3.16
P19-20-3-G	1	17.7	0.19	0.03	14.0	0.48	0.81	0.05	0.70	0.05	14.8	4.63
P19-20-4-G	1	17.7	0.07	0.02	11.4	0.45	0.46	0.05	0.40	0.05	14.2	7.43
P19-20-4-G	1	17.7	0.11	0.03	14.0	0.48	1.32	0.06	0.78	0.05	12.8	3.41

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P19-20-6-G	1	17.7	0.30	0.03	17.9	0.54	0.91	0.05	0.97	0.05	22.0	3.22
P19-20-7-G	1	17.7	0.17	0.03	14.0	0.48	1.09	0.05	1.03	0.05	15.4	3.15
P19-20-7-G	1	17.7	0.08	0.02	13.1	0.46	0.84	0.05	0.74	0.05	11.3	4.54
P19-20-8-G	1	17.7	0.18	0.03	11.2	0.43	0.78	0.05	0.69	0.05	11.4	3.00
P19-20-9-G	1	17.7	0.14	0.02	8.63	0.39	0.72	0.05	0.56	0.04	15.6	2.92
P19-20-9-G	1	17.7	0.48	0.04	10.7	0.44	0.66	0.05	0.76	0.05	23.1	3.33
LAB RESULT - GAMMA												
P19-20C-1-R		14.2	0.17	0.04	22.0	2.40	1.00	0.16	1.00	0.14	10.8	3.87
P19-20C-1-R-D		13.1	0.13	0.04	20.0	2.30	0.95	0.16	1.00	0.15	9.89	4.76
P19-20C-10-R		22.7	0.04	0.05	17.0	2.20	1.30	0.22	1.30	0.20	7.86	4.76
P19-20C-11-R		19.7	0.12	0.05	15.0	2.00	1.20	0.21	1.20	0.18	8.99	6.24
P19-20C-12-R		19.2	0.16	0.08	16.0	2.10	1.10	0.19	0.95	0.16	11.0	6.25
P19-20C-13-R		21.9	0.30	0.07	17.0	2.10	1.20	0.20	1.30	0.19	18.4	6.84
P19-20C-14-R		19.1	0.05	0.04	17.0	2.10	1.20	0.18	1.20	0.16	3.30	4.16
P19-20C-15-R		17.6	-0.01	0.02	19.0	2.10	1.10	0.17	1.20	0.16	4.54	3.27
P19-20C-151040		15.4	0.05	0.11	18.3	2.80	1.18	0.35	0.74	0.44	11.2	8.92
P19-20C-16-R		15.5	0.01	0.09	19.0	1.40	1.50	0.15	1.50	0.16	2.95	1.16
P19-20C-190103		18.1	0.09	0.13	24.6	3.40	1.44	0.37	1.30	0.64	13.4	10.7
P19-20C-213195		0.00	-0.06	0.11	16.6	2.60	1.30	0.28	1.06	0.47	9.67	7.73
P19-20C-297039		15.1	0.12	0.08	13.6	2.10	1.06	0.23	0.91	0.41	10.8	8.33

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-20C-367150		14.3	0.26	0.12	15.0	2.40	1.14	0.23	1.29	0.48	32.4	11.3
P19-20C-377016		20.3	0.07	0.08	16.7	2.40	1.18	0.25	1.40	0.52	8.24	6.84
P19-20C-4-R		15.8	0.13	0.06	18.0	2.20	0.98	0.19	1.10	0.17	9.41	6.25
P19-20C-5-R		16.7	0.02	0.03	21.0	2.30	1.10	0.17	1.20	0.16	4.50	2.56
P19-20C-6-R		17.8	0.21	0.08	20.0	2.60	1.30	0.22	1.30	0.21	11.3	5.65
P19-20C-8-R		14.9	0.11	0.04	16.0	2.10	1.10	0.18	1.10	0.16	9.59	5.65
P19-20C-9-R		14.7	0.14	0.05	17.0	2.10	1.00	0.17	0.85	0.13	17.4	6.84
LAB RESULT - ALPHA												
P19-20C-1-R		14.2							0.94	0.21		
P19-20C-1-R-D		13.1							1.20	0.25		
P19-20C-10-R		22.7							1.10	0.25		
P19-20C-11-R		19.7							1.10	0.26		
P19-20C-12-R		19.2							1.10	0.25		
P19-20C-13-R		21.9							0.92	0.21		
P19-20C-14-R		19.1							1.00	0.22		
P19-20C-15-R		17.6							1.10	0.22		
P19-20C-151040		15.4							1.05	0.09		
P19-20C-16-R		15.5							1.30	0.52	3.03	1.22
P19-20C-190103		18.1							1.25	0.11		
P19-20C-213195		0.00							1.12	0.10		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-20C-297039		15.1							1.03	0.10		
P19-20C-367150		14.3							1.31	0.10		
P19-20C-377016		20.3							1.14	0.12		
P19-20C-4-R		15.8							1.10	0.23		
P19-20C-5-R		16.7							1.10	0.26		
P19-20C-6-R		17.8							1.00	0.24		
P19-20C-8-R		14.9							0.86	0.22		
P19-20C-9-R		14.7							0.99	0.24		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: P19-23												
FIELD RESULT												
P19-20-13-G	.31	32.0	0.62	0.04	12.4	0.46	0.82	0.05	0.84	0.05	25.8	3.65
P19-23-10-G	.31	24.2	0.59	0.04	12.7	0.44	0.95	0.05	0.96	0.05	27.9	3.44
P19-23-11-G	.31	22.8	0.50	0.04	13.9	0.48	0.96	0.05	1.05	0.05	28.4	3.40
P19-23-12-G	.31	30.1	0.61	0.04	14.9	0.55	0.92	0.06	0.97	0.06	30.2	3.81
P19-23-13-G	.31	25.0	0.54	0.04	13.1	0.48	0.80	0.05	0.92	0.05	26.2	3.48
P19-23-15-G	.31	28.6	0.46	0.04	13.0	0.51	0.88	0.06	0.96	0.06	22.3	3.65
P19-23-16-G	.31	26.4	0.51	0.04	12.3	0.44	0.93	0.05	0.98	0.05	23.6	3.36
P19-23-2-G	.31	26.4	0.54	0.04	13.3	0.49	0.90	0.05	0.92	0.05	30.0	3.62
P19-23-2-G	.31	26.5	0.54	0.04	13.3	0.49	0.90	0.05	0.92	0.05	30.1	3.63
P19-23-3-G	.31	20.9	0.46	0.04	14.3	0.49	0.90	0.05	0.89	0.05	28.8	3.32
P19-23-4-G	.31	20.0	0.50	0.03	13.9	0.45	0.92	0.05	0.98	0.05	28.1	3.27
P19-23-5-G	.31	32.1	0.57	0.04	16.4	0.59	1.09	0.06	1.11	0.06	31.9	4.00
P19-23-7-G	.31	24.0	0.44	0.04	13.3	0.48	0.92	0.05	0.89	0.05	26.5	3.43
P19-23-9-G	.31	30.8	0.64	0.04	14.3	0.55	0.93	0.06	1.00	0.06	34.4	3.88
P19-20-13-G	1	32.0	0.61	0.04	12.5	0.51	0.81	0.06	0.77	0.06	27.3	3.91
P19-23-10-G	1	24.2	0.58	0.04	12.1	0.44	0.91	0.05	0.95	0.05	27.8	3.53
P19-23-11-G	1	22.8	0.49	0.04	13.6	0.49	0.93	0.05	0.93	0.05	25.8	3.50

000203

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-23-12-G	1	30.1	0.59	0.04	13.8	0.54	0.90	0.06	0.94	0.06	27.3	3.89
P19-23-13-G	1	25.0	0.47	0.04	13.2	0.48	0.86	0.05	0.88	0.05	24.5	3.55
P19-23-15-G	1	28.6	0.44	0.04	12.7	0.51	0.93	0.06	0.88	0.06	21.4	3.75
P19-23-16-G	1	26.4	0.47	0.04	11.8	0.43	0.93	0.05	0.90	0.05	23.6	3.50
P19-23-2-G	1	26.5	0.54	0.04	13.4	0.50	0.95	0.05	0.93	0.06	30.7	3.77
P19-23-2-G	1	26.4	0.54	0.04	13.4	0.50	0.94	0.05	0.93	0.06	30.6	3.76
P19-23-3-G	1	20.9	0.43	0.03	14.0	0.49	0.82	0.05	0.89	0.05	26.0	3.39
P19-23-4-G	1	20.0	0.55	0.04	12.9	0.44	0.89	0.05	0.97	0.05	30.6	3.41
P19-23-5-G	1	32.1	0.58	0.05	15.6	0.58	1.06	0.06	1.09	0.06	31.8	4.17
P19-23-7-G	1	24.0	0.36	0.03	13.3	0.48	0.95	0.05	0.96	0.05	24.2	3.50
P19-23-9-G	1	30.8	0.63	0.05	14.2	0.55	0.92	0.06	0.97	0.06	29.2	4:03
LAB RESULT - GAMMA												
P19-20C-010014		21.9	0.45	0.12	15.5	2.80	1.33	0.30	1.03	0.53	14.8	8.92
P19-20C-060180		34.1	0.70	0.17	15.6	2.60	0.83	0.24	1.57	0.53	40.8	11.9
P19-20C-094298		29.5	0.57	0.15	6.91	1.90	0.64	0.19	1.07	0.51	23.7	9.81
P19-20C-098322		27.2	0.64	0.12	11.7	1.70	0.69	0.17	0.96	0.38	22.6	7.43
P19-20C-163268		32.1	0.63	0.21	17.0	2.80	1.07	0.30	1.81	0.63	25.4	12.2
P19-20C-174397		33.3	0.87	0.19	17.5	3.40	1.37	0.33	1.61	0.60	38.6	12.8
P19-23C-1-R		18.8	0.47	0.08	21.0	1.60	1.60	0.18	1.40	0.15	12.2	2.65
P19-23C-10-R		20.7	0.22	0.06	18.0	1.60	1.60	0.18	1.40	0.15	11.0	2.54

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-23C-11-R		26.8	0.64	0.09	17.0	1.60	1.30	0.16	1.40	0.15	20.0	3.87
P19-23C-12-R		24.2	0.62	0.09	18.0	1.40	1.60	0.18	1.70	0.18	9.39	1.84
P19-23C-13-R		25.5	0.62	0.09	19.0	1.50	1.40	0.16	1.20	0.14	15.8	3.27
P19-23C-14-R		24.7	0.49	0.08	17.0	1.70	1.40	0.17	1.30	0.14	16.1	2.89
P19-23C-15-R		29.5	0.75	0.10	17.0	1.60	1.30	0.18	1.30	0.14	23.7	3.57
P19-23C-16-R		25.1	0.54	0.08	17.0	1.30	1.60	0.16	1.50	0.16	8.55	1.76
P19-23C-3-R		21.7	0.74	0.09	19.0	1.50	1.60	0.17	1.40	0.15	10.9	1.90
P19-23C-6-R		27.9	0.68	0.09	17.0	1.60	1.60	0.17	1.40	0.15	22.3	3.57
P19-23C-6-R-D		26.6	0.66	0.08	19.0	1.50	1.60	0.17	1.40	0.15	15.7	2.95
P19-23C-7-R		25.9	0.82	0.09	18.0	1.40	1.50	0.17	1.50	0.16	11.9	2.05
P19-23C-9-R		27.1	0.75	0.08	19.0	1.50	1.60	0.16	1.40	0.16	23.9	4.16
LAB RESULT - ALPHA												
P19-20C-010014		21.9							1.41	0.11		
P19-20C-060180		34.1							1.25	0.10		
P19-20C-094298		29.5							1.25	0.14		
P19-20C-098322		27.2							1.22	0.10		
P19-20C-163268		32.1							1.20	0.10		
P19-20C-174397		33.3							1.29	0.10		
P19-23C-1-R		18.8							0.94	0.34	17.0	6.25
P19-23C-10-R		20.7							1.10	0.38	14.0	5.06

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P19-23C-11-R		26.8							1.30	0.57	23.0	8.63
P19-23C-12-R		24.2							1.20	0.46	21.9	6.84
P19-23C-13-R		25.5							1.50	0.61	23.7	8.33
P19-23C-14-R		24.7							1.20	0.53	16.5	5.95
P19-23C-15-R		29.5							1.20	0.48	29.0	10.4
P19-23C-16-R		25.1							1.20	0.44	27.8	9.82
P19-23C-3-R		21.7							1.20	0.47	22.3	7.73
P19-23C-6-R		27.9							1.30	0.48	25.4	9.82
P19-23C-6-R-D		26.6							1.40	0.60	25.4	9.82
P19-23C-7-R		25.9							1.40	0.57	31.0	13.4
P19-23C-9-R		27.1							1.40	0.57	33.6	11.9

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: P19-40												
FIELD RESULT												
P19-40-11	.31	22.5	0.36	0.03	9.95	0.41	0.65	0.04	0.52	0.04	13.8	3.12
P19-40-13	.31	22.5	0.53	0.04	13.9	0.49	0.78	0.05	0.79	0.05	19.4	3.37
P19-40-14	.31	22.5	0.44	0.03	12.9	0.47	0.83	0.05	0.71	0.05	19.8	3.24
P19-40-15	.31	22.5	0.40	0.03	13.3	0.48	0.85	0.05	0.73	0.05	16.2	3.23
P19-40-16	.31	22.5	0.40	0.04	12.3	0.48	0.90	0.05	0.76	0.05	15.1	3.31
P19-40-2	.31	22.5	0.48	0.03	9.70	0.38	0.68	0.04	0.68	0.05	19.0	3.15
P19-40-3	.31	22.5	0.23	0.03	9.48	0.40	0.88	0.05	0.50	0.04	14.2	2.90
P19-40-4-G	.31	22.5	0.57	0.04	15.7	0.48	0.90	0.05	1.11	0.05	24.4	3.35
P19-40-5-G	.31	22.5	0.57	0.04	16.0	0.52	1.34	0.06	1.03	0.06	23.0	3.47
P19-40-5-G-D	.31	22.5	0.58	0.04	16.0	0.52	1.32	0.06	0.95	0.06	22.8	3.49
P19-40-6	.31	22.5	0.48	0.04	10.4	0.44	0.68	0.05	0.74	0.05	17.0	3.28
P19-40-7	.31	22.5	0.57	0.04	13.8	0.48	0.93	0.05	0.91	0.05	25.7	3.44
P19-40-7	.31	22.5	0.35	0.03	8.71	0.39	0.61	0.04	0.53	0.04	13.7	3.03
P19-40-9	.31	22.5	0.31	0.03	11.3	0.41	0.62	0.04	0.57	0.04	13.0	3.14
P19-40-11	1	22.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P19-40-13	1	22.5	0.53	0.04	14.3	0.50	0.77	0.05	0.80	0.05	21.5	3.56
P19-40-14	1	22.5	0.42	0.04	12.8	0.47	0.83	0.05	0.75	0.05	20.2	3.52

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-40-15	1	22.5	0.43	0.04	12.8	0.47	0.79	0.05	0.71	0.05	18.5	3.53
P19-40-16	1	22.5	0.40	0.04	12.5	0.48	0.89	0.05	0.77	0.05	16.0	3.47
P19-40-2	1	22.5	0.41	0.03	9.81	0.39	0.72	0.05	0.69	0.05	18.8	3.19
P19-40-3	1	22.5	0.39	0.03	8.70	0.36	0.65	0.04	0.62	0.04	15.6	3.42
P19-40-4-G	1	22.5	0.57	0.04	15.0	0.48	0.90	0.05	1.03	0.05	21.4	3.45
P19-40-5-G	1	22.5	0.51	0.04	15.2	0.52	1.34	0.06	0.98	0.06	24.1	3.56
P19-40-5-G-D	1	22.5	0.55	0.04	15.6	0.52	1.38	0.06	1.03	0.06	27.7	3.54
P19-40-6	1	22.5	0.45	0.04	10.6	0.45	0.73	0.05	0.73	0.05	20.6	3.46
P19-40-7	1	22.5	0.29	0.03	10.3	0.42	0.92	0.05	0.51	0.04	14.7	3.16
P19-40-7	1	22.5	0.53	0.04	13.8	0.49	0.87	0.05	0.81	0.05	24.0	3.46
P19-40-9	1	22.5	0.37	0.03	12.3	0.48	0.69	0.05	0.62	0.05	15.7	3.40
LAB RESULT - GAMMA												
P19-40C-001567		21.0	0.50	0.07	19.0	2.10	0.96	0.14	1.20	0.17	19.5	5.65
P19-40C-009494		16.9	0.54	0.07	17.0	1.80	1.00	0.15	1.10	0.16	17.4	4.16
P19-40C-018707		26.3	0.99	0.14	26.0	2.80	1.10	0.18	1.50	0.20	27.3	6.25
P19-40C-046680		19.7	0.43	0.06	20.0	2.30	0.89	0.13	1.20	0.15	16.3	5.06
P19-40C-131701		26.4	0.71	0.13	1.80	2.60	1.40	0.28	1.20	0.21	13.6	7.73
P19-40C-163578		16.1	0.16	0.04	19.0	2.10	0.92	0.13	1.20	0.14	6.99	3.57
P19-40C-176421		24.7	0.54	0.08	18.0	2.00	1.10	0.16	1.20	0.18	21.4	5.65
P19-40C-179603		19.4	0.63	0.12	14.0	1.80	0.91	0.19	0.95	0.14	17.2	5.06

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P19-40C-235537		27.2	0.71	0.09	18.0	2.00	1.10	0.16	1.20	0.16	24.4	5.95
P19-40C-237489		29.1	0.31	0.06	8.50	1.40	0.68	0.15	0.66	0.11	9.46	6.54
P19-40C-252690		29.2	0.64	0.09	19.0	2.10	1.00	0.16	1.20	0.17	22.6	6.54
P19-40C-297760		27.2	0.84	0.10	24.0	2.70	0.99	0.15	1.20	0.17	24.8	5.95
P19-40C-333523		22.7	0.58	0.12	16.0	2.00	1.20	0.23	1.10	0.16	22.6	5.65
P19-40C-336769		18.0	0.58	0.08	17.0	2.00	0.99	0.15	1.20	0.16	19.3	5.95
P19-40C-340632		25.3	0.62	0.09	19.0	2.30	1.20	0.18	1.20	0.16	18.8	5.35
LAB RESULT - ALPHA												
P19-40C-001567		21.0							1.20	0.22		
P19-40C-009494		16.9							0.89	0.18		
P19-40C-018707		26.3							1.10	0.22		
P19-40C-046680		19.7							0.91	0.21		
P19-40C-131701		26.4							1.10	0.24		
P19-40C-163578		16.1							0.91	0.21		
P19-40C-176421		24.7							1.10	0.22		
P19-40C-179603		19.4							1.00	0.22		
P19-40C-235537		27.2							1.30	0.24		
P19-40C-237489		29.1							1.20	0.24		
P19-40C-252690		29.2							1.00	0.29		
P19-40C-297760		27.2							0.72	0.17		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P19-40C-333523		22.7							0.99	0.22		
P19-40C-336769		18.0							1.10	0.25		
P19-40C-340632		25.3							1.10	0.22		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: P20-30												
FIELD RESULT												
P20-20-1-G	.31	30.0	0.48	0.04	17.3	0.59	1.03	0.06	0.85	0.06	17.3	3.81
P20-20-10-G	.31	30.0	0.54	0.04	17.3	0.54	0.96	0.06	0.92	0.06	20.4	3.57
P20-20-11-G	.31	30.0	0.59	0.04	17.7	0.54	0.88	0.05	0.99	0.06	16.3	3.64
P20-20-12-G	.31	30.0	0.54	0.04	18.0	0.55	0.87	0.05	0.92	0.06	21.1	3.62
P20-20-14-G	.31	30.0	0.46	0.04	20.0	0.64	0.83	0.06	0.95	0.06	17.8	4.19
P20-20-15-G	.31	30.0	0.56	0.04	18.3	0.55	1.07	0.06	1.10	0.06	22.6	3.65
P20-20-16-G	.31	30.0	0.49	0.04	18.4	0.55	1.04	0.06	1.00	0.06	20.0	3.65
P20-20-2-G	.31	30.0	0.60	0.04	17.3	0.53	0.98	0.06	0.98	0.06	24.5	3.68
P20-20-3-G	.31	30.0	0.51	0.04	17.4	0.59	0.85	0.06	0.91	0.06	22.6	3.80
P20-20-5-G	.31	30.0	0.53	0.04	18.1	0.54	0.93	0.05	0.97	0.06	19.4	3.64
P20-20-5-G	.31	30.0	0.46	0.04	16.6	0.52	0.83	0.05	0.86	0.05	18.2	3.56
P20-20-6-G	.31	30.0	0.46	0.04	16.9	0.58	0.90	0.06	0.87	0.06	19.0	3.67
P20-20-7-G	.31	30.0	0.54	0.04	18.1	0.60	0.99	0.06	1.01	0.06	22.6	3.83
P20-20-1-G	1	30.0	0.48	0.04	16.9	0.57	0.90	0.06	0.83	0.06	19.8	3.97
P20-20-10-G	1	30.0	0.56	0.04	17.1	0.54	1.01	0.06	0.98	0.06	19.7	3.76
P20-20-10-G	1	30.0	0.49	0.04	17.3	0.54	0.85	0.05	0.93	0.06	16.3	3.69
P20-20-11-G	1	30.0	0.48	0.04	17.6	0.58	1.06	0.06	0.95	0.06	20.4	3.91

0082211

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
P20-20-11-G	1	30.0	0.54	0.04	17.6	0.54	0.83	0.05	1.02	0.06	20.1	3.77
P20-20-12-G	1	30.0	0.53	0.04	17.7	0.55	0.89	0.05	0.96	0.06	21.1	3.80
P20-20-12-G	1	30.0	0.55	0.04	18.3	0.59	0.97	0.06	0.92	0.06	24.3	3.97
P20-20-14-G	1	30.0	0.55	0.04	20.0	0.64	0.81	0.06	1.02	0.06	17.1	3.89
P20-20-15-G	1	30.0	0.53	0.04	18.6	0.56	1.05	0.06	1.06	0.06	22.0	3.78
P20-20-15-G	1	30.0	0.50	0.04	18.3	0.55	0.85	0.05	1.04	0.06	21.4	3.75
P20-20-16-G	1	30.0	0.50	0.04	18.1	0.55	1.09	0.06	1.02	0.06	21.6	3.73
P20-20-2-G	1	30.0	0.53	0.04	17.1	0.54	0.95	0.06	0.93	0.06	23.2	3.78
P20-20-2-G	1	30.0	0.56	0.04	17.3	0.58	1.02	0.06	0.96	0.06	19.6	3.96
P20-20-3-G	1	30.0	0.49	0.04	16.1	0.56	1.02	0.06	0.88	0.06	22.3	3.90
P20-20-3-G	1	30.0	0.51	0.04	15.9	0.57	0.90	0.06	0.83	0.06	20.4	3.93
P20-20-5-G	1	30.0	0.55	0.04	18.0	0.55	0.92	0.06	0.95	0.06	21.1	3.79
P20-20-6-G	1	30.0	0.47	0.04	17.1	0.59	0.93	0.06	0.89	0.06	19.8	3.83
P20-20-7-G	1	30.0	0.53	0.04	17.4	0.60	0.90	0.06	0.96	0.06	22.3	3.93
LAB RESULT - GAMMA												
P20-20C-1-R		29.4	0.58	0.12	22.0	2.70	0.97	0.20	1.20	0.18	20.3	5.65
P20-20C-10-R		31.5	0.67	0.09	24.0	2.70	1.10	0.17	1.30	0.20	24.2	6.54
P20-20C-11-R		28.8	0.53	0.07	23.0	2.50	0.97	0.15	1.30	0.18	17.2	5.65
P20-20C-12-R		33.0	0.76	0.18	24.0	3.20	1.22	0.29	2.21	0.65	22.4	8.33
P20-20C-13-R		29.3	0.61	0.08	21.0	2.30	0.82	0.13	1.20	0.15	27.2	6.54

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
P20-20C-14-R		26.5	0.58	0.08	23.0	2.40	0.92	0.14	1.20	0.17	16.6	4.16
P20-20C-16-R		30.9	0.58	0.08	25.0	2.60	1.10	0.16	1.30	0.19	18.7	5.65
P20-20C-2-R		20.9	0.66	0.09	22.0	2.30	1.20	0.17	1.30	0.18	19.3	5.35
P20-20C-4-R		40.7	0.79	0.21	20.6	3.10	1.66	0.33	2.05	0.73	23.6	12.5
P20-20C-5-R		37.1	0.77	0.09	21.0	2.30	1.00	0.15	1.30	0.18	19.0	5.65
P20-20C-6-R		23.7	0.75	0.10	22.0	2.40	1.00	0.15	1.30	0.18	25.7	7.14
P20-20C-8-R		28.2	0.59	0.09	21.0	2.30	1.00	0.16	1.30	0.19	20.5	5.65
LAB RESULT - ALPHA												
P20-20C-1-R		29.4							1.00	0.22		
P20-20C-10-R		31.5							1.10	0.25		
P20-20C-11-R		28.8							1.10	0.23		
P20-20C-12-R		33.0							1.42	0.12		
P20-20C-13-R		29.3							1.10	0.22		
P20-20C-14-R		26.5							1.10	0.22		
P20-20C-16-R		30.9							1.10	0.25		
P20-20C-2-R		20.9							0.89	0.24		
P20-20C-4-R		40.7							1.32	0.10		
P20-20C-5-R		37.1							0.98	0.20		
P20-20C-6-R		23.7							0.97	0.21		
P20-20C-8-R		28.2							1.10	0.24		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: Q16-33												
FIELD RESULT												
Q16-33-1-G	.31	14.4	0.07	0.03	16.1	0.50	1.12	0.05	1.12	0.05	17.9	3.33
Q16-33-11-G	.31	19.6	0.30	0.03	14.9	0.50	1.18	0.06	1.14	0.06	28.3	3.56
Q16-33-13-G	.31	18.1	0.24	0.03	14.9	0.49	1.21	0.06	1.12	0.06	29.8	3.56
Q16-33-16-G	.31	17.2	0.14	0.03	15.2	0.49	1.19	0.05	1.14	0.05	20.8	3.26
Q16-33-2-G	.31	14.0	0.11	0.03	15.1	0.50	1.20	0.06	1.19	0.06	18.5	3.35
Q16-33-3-G	.31	15.4	0.11	0.02	15.4	0.48	1.08	0.05	1.10	0.05	18.6	3.26
Q16-33-4-G	.31	13.8	0.06	0.03	15.9	0.51	1.09	0.05	1.11	0.06	11.6	3.72
Q16-33-5-G	.31	15.4	0.00	0.00	19.8	0.58	1.15	0.06	1.10	0.06	12.6	3.85
Q16-33-6-G	.31	14.3	0.20	0.03	13.9	0.45	0.95	0.05	0.98	0.05	21.4	3.33
Q16-33-7-G	.31	13.7	0.23	0.03	14.0	0.48	1.06	0.05	1.05	0.05	26.8	3.38
Q16-33-8-G	.31	18.1	0.10	0.03	15.4	0.52	1.17	0.06	1.17	0.06	16.4	3.36
Q16-33-9-G	.31	21.6	0.31	0.04	15.5	0.53	1.17	0.06	1.13	0.06	35.7	3.92
Q16-33-1-G	1	14.4	0.09	0.03	15.9	0.50	1.12	0.05	1.13	0.06	22.4	3.47
Q16-33-11-G	1	19.6	0.29	0.03	15.3	0.51	1.12	0.06	1.12	0.06	33.5	3.72
Q16-33-13-G	1	18.1	0.26	0.03	14.7	0.49	1.22	0.06	1.14	0.06	27.7	3.70
Q16-33-16-G	1	17.2	0.14	0.03	15.1	0.49	1.09	0.05	1.10	0.06	21.4	3.44
Q16-33-2-G	1	14.0	0.10	0.03	14.8	0.50	1.14	0.06	1.13	0.06	18.8	3.51

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q16-33-3-G	1	15.4	0.08	0.02	15.1	0.48	1.05	0.05	1.12	0.05	16.3	3.39
Q16-33-4-G	1	13.8	0.09	0.03	14.9	0.50	1.05	0.05	1.07	0.06	13.1	3.91
Q16-33-5-G	1	15.4	0.04	0.00	18.3	0.56	1.09	0.06	1.05	0.06	12.7	4.66
Q16-33-6-G	1	14.3	0.23	0.03	14.1	0.46	1.05	0.05	1.04	0.05	25.1	3.48
Q16-33-7-G	1	13.7	0.19	0.03	14.3	0.49	1.06	0.05	1.14	0.06	26.5	3.49
Q16-33-8-G	1	18.1	0.11	0.03	15.3	0.52	1.11	0.06	1.16	0.06	17.3	3.49
Q16-33-9-G	1	21.6	0.29	0.04	15.2	0.54	1.25	0.06	1.15	0.06	32.4	4.04
LAB RESULT - GAMMA												
P17-22C-400417		24.8	0.44	0.07	17.0	1.60	1.40	0.16	1.40	0.16	30.3	4.76
Q16-33C-415297		20.3	0.08	0.17	23.6	3.00	1.35	0.30	1.40	0.59	1.10	8.03
Q16-33C-419394		22.0	0.35	0.14	13.0	2.70	1.03	0.36	1.14	0.57	24.2	6.84
Q16-33C-443311		20.8	-0.07	0.11	12.0	2.90	1.36	0.28	0.62	0.62	4.05	4.76
Q16-33C-476366		24.6	0.46	0.13	13.3	2.60	1.03	0.30	1.32	0.68	33.8	7.73
Q16-33C-478339		24.0	0.37	0.16	15.5	2.90	0.99	0.34	1.18	0.71	30.9	9.52
Q16-33C-495260		25.1	0.48	0.09	17.5	1.60	1.09	0.15	1.41	0.37	35.6	6.54
Q16-33C-532385		19.0	0.62	0.18	13.5	2.70	1.47	0.39	1.35	0.74	29.5	7.43
Q16-33C-534284		20.5	0.26	0.18	11.6	3.50	0.90	0.32	1.49	0.68	26.6	8.03
Q16-33C-540239		21.4	0.16	0.16	17.8	4.50	1.84	0.53	1.61	0.84	7.69	9.52
Q16-33C-546349		19.6	-0.08	0.12	9.41	3.00	1.44	0.39	1.71	0.71	3.87	5.35
Q16-33C-553248		18.9	0.23	0.14	16.9	2.80	1.34	0.32	1.75	0.74	20.9	11.6

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q16-33C-590295		17.9	0.10	0.09	15.3	2.80	0.69	0.32	0.92	0.49	4.76	5.65
LAB RESULT - ALPHA												
P17-22C-400417		24.8							1.30	0.49	34.0	14.6
Q16-33C-415297		20.3							1.25	0.13		
Q16-33C-419394		22.0							1.17	0.09		
Q16-33C-443311		20.8							1.24	0.09		
Q16-33C-476366		24.6							1.18	0.09		
Q16-33C-478339		24.0							1.22	0.09		
Q16-33C-495260		25.1							1.21	0.09		
Q16-33C-532385		19.0							1.32	0.10		
Q16-33C-534284		20.5							1.38	0.11		
Q16-33C-540239		21.4							1.34	0.16		
Q16-33C-546349		19.6							1.26	0.13		
Q16-33C-553248		18.9							1.37	0.16		
Q16-33C-590295		17.9							1.22	0.10		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q16-34												
FIELD RESULT												
Q16-34-1	.31	18.4	0.10	0.03	15.0	0.50	1.24	0.06	1.22	0.06	18.5	3.48
Q16-34-11	.31	18.4	0.09	0.03	14.5	0.47	1.21	0.06	1.13	0.06	15.9	3.55
Q16-34-12	.31	18.4	0.16	0.02	9.29	0.38	0.76	0.04	0.59	0.04	16.1	2.87
Q16-34-13	.31	18.4	0.07	0.03	14.0	0.49	1.23	0.06	1.14	0.06	14.3	3.38
Q16-34-15	.31	18.4	0.24	0.03	13.7	0.46	1.14	0.05	1.13	0.05	29.8	3.43
Q16-34-16	.31	18.4	0.10	0.03	13.4	0.45	1.08	0.05	0.99	0.05	15.5	3.19
Q16-34-2	.31	18.4	0.27	0.03	14.1	0.46	1.16	0.05	1.18	0.06	29.9	3.52
Q16-34-3	.31	18.4	0.25	0.03	13.0	0.45	1.12	0.05	1.07	0.05	29.8	3.38
Q16-34-5	.31	18.4	0.07	0.03	13.7	0.48	1.20	0.06	1.12	0.06	11.5	3.72
Q16-34-6	.31	18.4	0.08	0.02	9.67	0.38	0.84	0.05	0.80	0.05	14.4	3.32
Q16-34-8	.31	18.4	0.24	0.03	14.1	0.46	1.03	0.05	0.92	0.05	22.4	3.21
Q16-34-9	.31	18.4	0.19	0.03	13.6	0.48	1.21	0.06	1.13	0.06	21.3	3.53
Q16-34-1	1	18.4	0.11	0.03	13.8	0.47	1.16	0.06	1.14	0.06	18.8	3.60
Q16-34-11	1	18.4	0.08	0.03	14.5	0.49	1.23	0.06	1.11	0.06	13.5	3.87
Q16-34-12	1	18.4	0.20	0.03	10.4	0.41	0.86	0.05	0.59	0.04	14.8	3.14
Q16-34-13	1	18.4	0.10	0.03	12.9	0.43	1.10	0.05	1.15	0.06	15.7	3.63
Q16-34-15	1	18.4	0.19	0.03	13.4	0.47	1.13	0.06	1.16	0.06	25.0	3.55

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q16-34-16	1	18.4	0.06	0.03	12.1	0.47	0.55	0.06	0.50	0.06	0.06	0.03
Q16-34-2	1	18.4	0.22	0.03	13.0	0.46	1.12	0.05	1.04	0.05	25.0	3.61
Q16-34-3	1	18.4	0.28	0.03	12.7	0.46	1.11	0.05	1.06	0.05	29.8	3.53
Q16-34-5	1	18.4	0.06	0.02	13.4	0.43	1.20	0.05	1.06	0.05	17.4	4.15
Q16-34-6	1	18.4	0.10	0.03	13.5	0.47	1.11	0.06	1.09	0.06	17.2	3.48
Q16-34-8	1	18.4	0.31	0.03	12.9	0.46	1.00	0.05	0.93	0.05	24.9	3.40
Q16-34-9	1	18.4	0.14	0.03	13.6	0.44	1.18	0.05	1.10	0.05	21.6	3.47
LAB RESULT - GAMMA												
Q16-34C-641312		17.3	0.00	0.04	1.00	2.50	1.10	0.22	1.30	0.18	10.00	6.54
Q16-34C-649355		17.7	0.15	0.06	16.0	2.20	1.30	0.21	1.30	0.19	11.2	6.84
Q16-34C-690392		17.8	0.21	0.08	17.0	2.40	1.20	0.28	1.20	0.20	17.8	8.03
Q16-34C-709292		17.5	-0.01	0.04	17.0	2.30	1.10	0.21	1.20	0.20	8.14	6.25
Q16-34C-711328		17.0	0.00	0.04	17.0	2.30	1.10	0.19	1.30	0.20	6.93	5.65
Q16-34C-711328-D		20.4	0.63	0.12	15.0	2.10	1.40	0.23	1.30	0.22	45.4	12.8
Q16-34C-726243		16.3	0.22	0.09	16.0	2.20	1.20	0.20	1.30	0.19	23.8	8.92
Q16-34C-776325		17.3	0.16	0.12	12.0	2.00	1.10	0.26	1.00	0.21	11.4	7.44
Q16-34C-795356		19.3	0.30	0.11	14.8	2.50	1.45	0.30	1.57	0.63	22.0	11.3
Q16-34C-796258		18.4	0.01	0.04	18.0	2.30	1.20	0.23	1.20	0.19	15.0	6.84
Q16-34C-815206		19.4	0.43	0.08	17.0	2.30	1.20	0.20	1.30	0.19	33.1	11.3
Q16-34C-821347		23.0	0.70	0.17	13.6	2.30	1.08	0.25	1.36	0.45	21.3	10.4

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q16-34C3-R-1		16.6	0.10	0.44	18.0	1.50	1.50	0.18	1.40	0.16	10.8	2.44
LAB RESULT - ALPHA												
Q16-34C-795356		19.3							1.24	0.10		
Q16-34C-821347		23.0							1.33	0.11		
Q16-34C2-R-1		17.2							1.10	0.23		
Q16-34C2-R-10		17.1							1.30	0.27		
Q16-34C2-R-11		18.0							1.10	0.23		
Q16-34C2-R-2		20.5							1.10	0.23		
Q16-34C2-R-3		0.00							0.88	0.22		
Q16-34C2-R-4		15.6							0.96	0.21		
Q16-34C2-R-5		17.5							0.91	0.21		
Q16-34C2-R-6		17.9							1.00	0.21		
Q16-34C2-R-8		18.3							1.10	0.23		
Q16-34C2-R-9		16.0							1.00	0.22		
Q16-34C2-R-9-D		14.5							0.94	0.20		
Q16-34C3-R-1		16.6							1.10	0.40		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: Q17-10												
FIELD RESULT												
Q17-10-12-G	.31	18.6	0.06	0.02	16.1	0.53	0.94	0.05	1.06	0.06	9.42	3.73
Q17-10-14-G	.31	18.6	0.07	0.02	14.6	0.48	1.07	0.05	1.10	0.06	14.3	3.30
Q17-10-15-G	.31	18.6	0.04	0.02	14.9	0.51	0.94	0.05	1.06	0.06	8.93	4.21
Q17-10-16B-G	.31	18.6	0.10	0.03	16.0	0.51	1.07	0.05	1.10	0.05	18.0	3.22
Q17-10-1B-G	.31	18.6	0.40	0.03	15.5	0.50	1.09	0.05	1.23	0.06	37.5	3.68
Q17-10-2-G	.31	18.6	0.18	0.03	13.9	0.48	1.02	0.05	1.03	0.05	22.0	3.46
Q17-10-4-G	.31	18.6	0.08	0.02	12.9	0.46	0.97	0.05	0.84	0.05	14.2	3.16
Q17-10-5-G	.31	18.6	0.11	0.03	12.8	0.46	1.01	0.05	0.94	0.05	17.9	3.35
Q17-10-6-G	.31	18.6	0.08	0.02	13.8	0.47	1.00	0.05	0.99	0.05	15.4	3.37
Q17-10-7-G	.31	18.6	0.08	0.03	13.4	0.48	0.99	0.05	1.03	0.05	16.8	3.86
Q17-10-8-G	.31	18.6	0.06	0.02	13.6	0.49	0.97	0.05	0.86	0.05	12.4	3.14
Q17-10-9-G	.31	18.6	0.11	0.03	14.4	0.48	1.04	0.05	1.08	0.05	16.6	3.52
Q17-10-12-G	1	18.6	0.07	0.02	16.2	0.51	0.95	0.05	0.99	0.05	11.4	3.90
Q17-10-14-G	1	18.6	0.05	0.02	13.8	0.45	1.03	0.05	1.05	0.05	12.5	3.55
Q17-10-15-G	1	18.6	0.05	0.02	14.7	0.49	0.99	0.05	1.05	0.05	12.1	3.24
Q17-10-16B-G	1	18.6	0.12	0.03	15.4	0.50	1.10	0.05	1.13	0.05	18.8	3.33
Q17-10-1B-G	1	18.6	0.38	0.03	15.4	0.51	1.00	0.05	1.16	0.06	36.8	3.80

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q17-10-2-G	1	18.6	0.20	0.03	13.0	0.46	1.04	0.05	1.00	0.05	22.6	3.58
Q17-10-4-G	1	18.6	0.11	0.02	12.7	0.46	0.93	0.05	0.87	0.05	13.7	3.24
Q17-10-5-G	1	18.6	0.10	0.03	13.0	0.47	1.01	0.05	0.95	0.05	13.4	4.33
Q17-10-6-G	1	18.6	0.10	0.03	13.5	0.47	1.01	0.05	0.99	0.05	16.4	3.44
Q17-10-7-G	1	18.6	0.07	0.03	13.8	0.47	1.03	0.05	0.97	0.05	15.2	3.25
Q17-10-8-G	1	18.6	0.08	0.02	13.3	0.47	0.95	0.05	0.84	0.05	12.2	3.20
Q17-10-9-G	1	18.6	0.11	0.03	13.3	0.44	1.07	0.05	1.03	0.05	15.9	3.42
LAB RESULT - GAMMA												
Q17-10C-444513		27.3	0.22	0.10	18.1	2.30	1.28	0.29	1.58	0.54	25.7	11.3
Q17-10C-446405		20.3	0.45	0.14	14.7	2.50	1.14	0.32	1.33	0.49	37.7	11.6
Q17-10C-507678		16.7	0.02	0.07	16.3	2.50	0.96	0.26	1.43	0.48	10.0	7.43
Q17-10C-524504		29.3	0.46	0.16	16.2	2.40	1.18	0.26	1.27	0.67	38.0	14.0
Q17-10C-533635		21.5	0.00	0.07	14.1	2.10	1.04	0.23	1.28	0.53	9.25	7.73
Q17-10C-578761		17.6	0.19	0.06	18.0	2.30	1.30	0.25	1.30	0.22	30.3	9.52
Q17-10C-630774		17.3	-0.01	0.10	14.9	2.40	1.12	0.28	1.33	0.54	3.39	5.65
Q17-10C-685560		17.6	0.36	0.10	20.0	2.70	1.20	0.23	1.30	0.22	19.8	8.03
Q17-10C-717642		16.2	0.00	0.03	17.0	2.30	1.10	0.20	1.30	0.19	8.71	6.25
Q17-10C-743541		15.5	0.05	0.04	18.0	2.20	1.20	0.20	1.40	0.20	9.98	5.06
Q17-10C-823709		16.7	0.20	0.08	12.6	1.50	1.37	0.18	1.06	0.29	18.3	6.24
Q17-10C-831651		15.2	0.41	0.10	19.0	2.50	1.20	0.23	1.20	0.19	23.3	9.22

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
LAB RESULT - ALPHA												
Q17-10C-444513		27.3							1.26	0.15		
Q17-10C-446405		20.3							1.08	0.10		
Q17-10C-507678		16.7							1.12	0.10		
Q17-10C-524504		29.3							1.17	0.11		
Q17-10C-533635		21.5							1.15	0.13		
Q17-10C-630774		17.3							1.27	0.14		
Q17-10C-685560		17.6							1.10	0.17		
Q17-10C-717642		16.2							1.10	0.25		
Q17-10C-743541		15.5							1.20	0.20		
Q17-10C-823709		16.7							1.01	0.09		
Q17-10C-831651		15.2							0.98	0.14		
Q17-10C2-R-12		13.3							0.88	0.19		
Q17-10C2-R-13		16.3							1.20	0.25		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q17-30												
FIELD RESULT												
Q17-30-1-G	.31	18.8	0.32	0.03	12.0	0.46	0.96	0.05	0.94	0.05	31.8	3.61
Q17-30-10-G	.31	18.8	0.07	0.02	12.9	0.43	0.98	0.05	0.98	0.05	12.4	3.16
Q17-30-11-G	.31	18.8	0.06	0.02	11.9	0.42	0.98	0.05	0.79	0.05	9.90	3.70
Q17-30-12-G	.31	18.8	0.04	0.02	13.8	0.49	1.07	0.05	0.95	0.05	12.4	4.23
Q17-30-13-G	.31	18.8	0.06	0.02	12.6	0.42	0.99	0.05	1.05	0.05	9.11	3.76
Q17-30-2-G	.31	18.8	0.06	0.03	13.8	0.49	0.97	0.05	0.97	0.05	11.8	3.26
Q17-30-3-G	.31	18.8	0.00	0.00	14.5	0.51	1.01	0.05	1.06	0.06	12.1	3.79
Q17-30-4-G	.31	18.8	0.00	0.00	13.5	0.49	1.02	0.05	0.97	0.05	10.6	3.42
Q17-30-5-G	.31	18.8	0.07	0.03	13.9	0.50	0.99	0.05	1.04	0.06	13.7	3.32
Q17-30-6-G	.31	18.8	0.04	0.02	13.4	0.49	1.04	0.05	1.02	0.06	9.19	4.27
Q17-30-7-G	.31	18.8	0.10	0.03	13.5	0.49	0.96	0.05	1.01	0.05	14.2	3.24
Q17-30-8-G	.31	18.8	0.09	0.03	14.7	0.51	0.96	0.05	0.98	0.05	12.9	3.22
Q17-30-9-G	.31	18.8	0.07	0.02	12.9	0.43	0.98	0.05	0.98	0.05	12.4	3.16
Q17-30-1-G	1	18.8	0.24	0.03	12.4	0.46	1.05	0.05	1.01	0.05	25.6	3.57
Q17-30-10-G	1	18.8	0.07	0.02	13.9	0.48	1.02	0.05	1.06	0.05	13.0	3.62
Q17-30-11-G	1	18.8	0.05	0.02	12.2	0.42	1.01	0.05	0.83	0.05	12.7	3.15
Q17-30-12-G	1	18.8	0.00	0.00	13.5	0.49	1.06	0.06	0.92	0.06	0.09	0.03

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q17-30-13-G	1	18.8	0.06	0.02	12.8	0.43	1.00	0.05	1.03	0.05	12.2	3.47
Q17-30-2-G	1	18.8	0.05	0.02	13.5	0.48	1.04	0.05	1.01	0.05	14.9	3.35
Q17-30-3-G	1	18.8	0.04	0.02	15.0	0.50	1.04	0.05	1.07	0.05	12.7	3.90
Q17-30-4-G	1	18.8	0.00	0.00	13.5	0.48	0.98	0.05	0.94	0.05	9.59	3.51
Q17-30-5-G	1	18.8	0.10	0.03	14.3	0.49	0.99	0.05	1.02	0.05	15.8	3.42
Q17-30-6-G	1	18.8	0.05	0.02	13.5	0.48	1.09	0.05	0.98	0.05	13.1	3.28
Q17-30-7-G	1	18.8	0.06	0.03	13.8	0.48	1.06	0.05	1.01	0.05	17.0	3.34
Q17-30-8-G	1	18.8	0.05	0.03	15.3	0.50	0.95	0.05	1.03	0.05	14.9	3.87
Q17-30-9-G	1	18.8	0.06	0.02	13.8	0.48	1.00	0.05	0.97	0.05	13.1	3.34
LAB RESULT - GAMMA												
Q17-30C-457860		15.8	0.17	0.11	13.3	2.70	1.16	0.34	1.25	0.53	15.9	7.14
Q17-30C-465922		18.3	0.08	0.09	14.3	3.20	1.33	0.39	1.52	0.71	10.1	6.84
Q17-30C-477106		22.8	0.19	0.14	14.0	3.00	0.95	0.35	1.14	0.57	13.8	6.25
Q17-30C-571997		20.9	0.00	0.04	18.0	2.50	1.50	0.24	1.30	0.18	7.90	6.54
Q17-30C-573853		18.6	0.18	0.07	16.0	2.20	1.10	0.20	1.20	0.18	21.1	9.52
Q17-30C-621146		18.7	0.04	0.04	19.0	2.60	1.30	0.21	1.40	0.20	10.3	6.54
Q17-30C-631819		17.1	0.02	0.03	17.0	2.10	1.20	0.22	1.20	0.18	9.44	6.54
Q17-30C-653173		24.2	0.43	0.08	17.0	2.30	1.30	0.24	1.30	0.20	22.5	8.63
Q17-30C-693998		18.0	0.02	0.03	21.0	2.40	1.20	0.20	1.30	0.19	9.71	5.06
Q17-30C-715029		18.9	0.05	0.10	23.0	4.50	1.40	0.45	1.30	0.30	10.3	17.0

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q17-30C-753114		16.5	0.01	0.06	16.0	2.60	1.30	0.31	0.84	0.21	4.45	6.54
Q17-30C-781023		16.8	-0.02	0.04	19.0	2.40	1.30	0.21	1.30	0.20	6.90	7.73
LAB RESULT - ALPHA												
Q17-30C-457860		15.8							1.23	0.10		
Q17-30C-465922		18.3							1.26	0.11		
Q17-30C-477106		22.8							1.28	0.10		
Q17-30C-571997		20.9							1.10	0.18		
Q17-30C-573853		18.6							1.10	0.18		
Q17-30C-621146		18.7							1.00	0.17		
Q17-30C-631819		17.1							2.10	0.48		
Q17-30C-653173		24.2							1.30	0.22		
Q17-30C-693998		18.0							0.96	0.20		
Q17-30C-715029		18.9							1.10	0.16		
Q17-30C-753114		16.5							1.30	0.24		
Q17-30C2-R-14		18.4							0.96	0.22		
Q17-30C2-R-15		18.1							1.20	0.26		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q18-10												
FIELD RESULT												
Q18-10-1	.31	18.3	0.05	0.02	14.8	0.47	1.17	0.05	1.09	0.05	12.2	3.24
Q18-10-11	.31	18.3	0.05	0.02	13.8	0.49	1.10	0.05	1.13	0.06	11.6	3.20
Q18-10-12	.31	18.3	0.04	0.02	13.7	0.48	1.08	0.05	1.11	0.06	10.6	4.22
Q18-10-13	.31	18.3	0.09	0.03	13.7	0.48	1.22	0.06	1.11	0.06	13.5	3.27
Q18-10-14	.31	18.3	0.07	0.03	14.7	0.50	1.02	0.05	1.08	0.06	12.3	3.23
Q18-10-15	.31	18.3	0.04	0.00	14.4	0.49	1.06	0.06	1.09	0.06	10.7	3.72
Q18-10-16	.31	18.3	0.17	0.03	12.6	0.46	1.11	0.06	1.06	0.05	17.1	3.23
Q18-10-2	.31	18.3	0.08	0.02	15.4	0.50	1.08	0.05	1.01	0.05	13.8	3.33
Q18-10-3	.31	18.3	0.12	0.03	13.5	0.48	1.10	0.05	1.03	0.06	15.7	3.30
Q18-10-5	.31	18.3	0.00	0.00	14.0	0.49	1.07	0.06	1.03	0.06	10.5	3.28
Q18-10-6	.31	18.3	0.06	0.02	13.7	0.47	0.96	0.05	0.96	0.05	10.5	3.41
Q18-10-8	.31	18.3	0.05	0.02	13.2	0.47	1.15	0.06	1.13	0.06	14.2	3.18
Q18-10-1	1	18.3	0.05	0.02	14.3	0.47	1.15	0.06	1.07	0.05	10.7	3.37
Q18-10-11	1	18.3	0.05	0.02	13.6	0.44	0.99	0.05	1.06	0.05	9.82	4.40
Q18-10-12	1	18.3	0.03	0.00	12.9	0.43	1.03	0.05	1.13	0.05	10.1	3.12
Q18-10-13	1	18.3	0.16	0.03	13.6	0.44	1.21	0.05	1.07	0.05	21.2	3.37
Q18-10-14	1	18.3	0.08	0.02	13.6	0.44	1.08	0.05	1.06	0.05	10.4	3.91

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q18-10-15	1	18.3	0.05	0.02	13.6	0.44	1.09	0.05	1.09	0.05	14.2	3.87
Q18-10-16	1	18.3	0.15	0.03	12.4	0.42	1.11	0.05	1.03	0.05	12.8	3.23
Q18-10-2	1	18.3	0.09	0.03	15.8	0.51	1.04	0.05	1.02	0.05	15.2	3.47
Q18-10-3	1	18.3	0.09	0.02	13.2	0.43	1.11	0.05	1.04	0.05	14.4	3.94
Q18-10-5	1	18.3	0.04	0.02	13.6	0.44	1.13	0.05	1.05	0.05	9.65	3.52
Q18-10-6	1	18.3	0.07	0.02	13.3	0.47	1.01	0.05	0.98	0.05	12.8	4.00
Q18-10-8	1	18.3	0.05	0.02	12.9	0.43	1.12	0.05	1.09	0.05	10.1	3.39
LAB RESULT - GAMMA												
Q18-10C-422483		18.5	0.14	0.07	13.6	2.20	1.40	0.27	1.96	0.55	10.0	5.65
Q18-10C-485247		17.0	0.32	0.16	12.8	3.30	1.49	0.39	1.43	0.81	9.92	8.33
Q18-10C-487528		18.4	0.05	0.08	20.0	1.40	1.50	0.13	1.90	0.19	18.7	2.95
Q18-10C-509599		19.9	0.09	0.08	17.0	1.40	1.50	0.16	1.40	0.16	6.59	2.11
Q18-10C-517303		12.7	0.65	0.28	16.4	3.20	0.90	0.35	1.20	0.64	22.0	8.03
Q18-10C-542232		20.8	-0.05	0.15	16.7	3.10	1.19	0.35	1.56	0.83	6.56	5.06
Q18-10C-588407		17.7	0.07	0.06	20.0	2.60	1.20	0.22	1.30	0.22	8.45	5.35
Q18-10C-638515		21.8	0.03	0.04	19.0	2.50	1.40	0.24	1.40	0.21	3.65	5.06
Q18-10C-679345		17.4	0.01	0.04	17.0	2.20	1.10	0.21	1.40	0.20	4.50	4.46
Q18-10C-725517		17.0	0.08	0.05	15.0	2.10	1.20	0.25	1.20	0.19	4.46	5.95
Q18-10C-734434		20.7	0.01	0.07	16.0	2.70	1.30	0.35	1.20	0.23	11.6	11.9
Q18-10C-747320		17.7	0.01	0.04	15.0	2.10	1.30	0.21	1.30	0.18	7.20	6.54

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
LAB RESULT - ALPHA												
Q18-10C-422483		18.5							1.08	0.17		
Q18-10C-485247		17.0							1.12	0.10		
Q18-10C-487528		18.4							1.10	0.44	24.8	8.63
Q18-10C-509599		19.9							1.20	0.49	5.19	1.90
Q18-10C-517303		12.7							1.10	0.10		
Q18-10C-542232		20.8							1.14	0.18		
Q18-10C-638515		21.8							1.10	0.24		
Q18-10C2-R-16		16.3							1.10	0.23		
Q18-10C2-R-17		19.6							1.40	0.29		
Q18-10C2-R-18		14.2							1.00	0.21		
Q18-10C2-R-19		19.9							0.95	0.22		
Q18-10C2-R-20		19.5							1.10	0.21		
Q18-10C2-R-21		16.4							1.00	0.25		

0002229

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
CU Name: Q18-30												
FIELD RESULT												
Q18-30-1	.31	19.1	0.09	0.03	13.8	0.49	1.23	0.06	1.12	0.06	13.6	3.30
Q18-30-10	.31	19.1	0.13	0.03	13.5	0.48	1.17	0.06	1.04	0.05	13.7	3.83
Q18-30-11	.31	19.1	0.05	0.02	12.7	0.47	1.19	0.06	1.01	0.05	11.2	3.22
Q18-30-12	.31	19.1	0.11	0.03	12.9	0.47	1.14	0.06	0.96	0.05	13.9	3.22
Q18-30-13	.31	19.1	0.20	0.03	14.3	0.50	1.01	0.05	0.99	0.05	17.7	3.30
Q18-30-15	.31	19.1	0.13	0.03	11.8	0.45	1.29	0.06	1.02	0.06	14.3	3.24
Q18-30-16	.31	19.1	0.06	0.03	13.2	0.48	1.25	0.06	1.09	0.06	10.9	3.76
Q18-30-5	.31	19.1	0.05	0.03	13.1	0.48	1.30	0.06	1.08	0.06	9.37	4.36
Q18-30-6	.31	19.1	0.16	0.03	12.6	0.46	1.20	0.06	0.99	0.06	15.7	3.35
Q18-30-7	.31	19.1	0.04	0.02	12.0	0.46	1.18	0.06	0.96	0.06	8.83	4.22
Q18-30-8	.31	19.1	0.12	0.03	12.6	0.47	1.10	0.06	1.04	0.06	13.8	3.32
Q18-30-9	.31	19.1	0.17	0.03	12.9	0.47	1.20	0.06	0.96	0.06	16.5	3.35
Q18-30-1	1	19.1	0.10	0.03	13.1	0.44	1.27	0.05	1.08	0.05	14.0	3.38
Q18-30-10	1	19.1	0.11	0.03	12.6	0.43	1.18	0.05	0.98	0.05	14.0	4.01
Q18-30-11	1	19.1	0.05	0.02	12.4	0.42	1.16	0.05	0.96	0.05	9.99	3.36
Q18-30-12	1	19.1	0.10	0.02	12.5	0.42	1.23	0.05	0.99	0.05	14.4	3.18
Q18-30-13	1	19.1	0.15	0.03	14.1	0.51	0.96	0.06	0.96	0.06	18.3	3.46

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q18-30-15	1	19.1	0.13	0.03	11.8	0.41	1.26	0.05	1.03	0.05	9.03	3.25
Q18-30-16	1	19.1	0.07	0.02	12.4	0.42	1.30	0.05	1.07	0.05	11.1	3.95
Q18-30-5	1	19.1	0.07	0.02	12.7	0.43	1.33	0.06	1.08	0.05	11.4	3.99
Q18-30-6	1	19.1	0.15	0.03	11.5	0.41	1.20	0.05	1.02	0.05	16.6	3.28
Q18-30-7	1	19.1	0.04	0.02	11.8	0.41	1.22	0.05	0.98	0.05	11.6	3.91
Q18-30-8	1	19.1	0.10	0.02	12.6	0.43	1.17	0.05	1.02	0.05	14.6	3.21
Q18-30-9	1	19.1	0.13	0.03	12.1	0.41	1.23	0.05	0.97	0.05	12.7	3.25
LAB RESULT - GAMMA												
Q18-30C-404861		20.7	0.09	0.08	17.0	1.40	1.40	0.17	1.20	0.15	6.38	1.79
Q18-30C-440916		20.2	0.18	0.14	16.0	1.50	1.30	0.17	1.20	0.13	5.13	2.06
Q18-30C-479618		17.8	0.20	0.13	17.0	1.60	1.30	0.16	1.30	0.15	5.92	2.98
Q18-30C-538810		21.3	0.11	0.07	16.0	1.20	1.30	0.16	1.40	0.14	7.15	2.56
Q18-30C-563663		17.9	-0.01	0.04	16.0	2.20	1.40	0.30	1.20	0.19	4.23	4.76
Q18-30C-587936		17.2	-0.04	0.07	14.1	2.40	1.25	0.31	1.48	0.89	1.43	3.27
Q18-30C-616928		18.9	0.05	0.07	14.4	2.20	1.28	0.33	1.13	0.46	5.49	5.65
Q18-30C-640877		20.1	0.05	0.07	12.7	2.20	1.30	0.32	1.34	0.54	2.82	3.57
Q18-30C-704635		17.7	0.11	0.05	18.0	2.30	1.10	0.20	1.30	0.19	10.3	6.25
Q18-30C-753949		18.3	0.09	0.08	13.8	2.20	1.09	0.28	0.74	0.61	13.4	7.43
Q18-30C-772773		19.4	0.03	0.07	14.5	2.40	1.13	0.30	1.21	0.46	8.19	4.76
Q18-30C-774831		19.8	0.02	0.07	14.6	2.20	1.53	0.29	1.05	0.51	1.91	3.27

002231

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
LAB RESULT - ALPHA												
Q18-30C-404861		20.7							1.10	0.41	10.9	3.27
Q18-30C-440916		20.2							1.10	0.45	8.00	2.98
Q18-30C-479618		17.8							1.00	0.42	7.10	2.53
Q18-30C-538810		21.3							1.20	0.41	5.11	1.82
Q18-30C-587936		17.2							1.07	0.09		
Q18-30C-616928		18.9							1.10	0.09		
Q18-30C-640877		20.1							1.09	0.10		
Q18-30C-753949		18.3							1.12	0.10		
Q18-30C-772773		19.4							1.26	0.10		
Q18-30C-774831		19.8							1.23	0.10		
Q18-30C2-R-22		15.5							1.20	0.26		
Q18-30C2-R-23		18.7							0.98	0.23		
Q18-30C2-R-23-D		15.0							1.00	0.23		

000232

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
CU Name: Q18-40												
FIELD RESULT												
Q18-40-1	.31	20.5	0.06	0.03	12.4	0.47	1.09	0.06	1.08	0.06	11.3	3.76
Q18-40-10	.31	20.5	0.08	0.03	13.1	0.49	1.17	0.06	1.00	0.05	9.30	3.74
Q18-40-11	.31	20.5	0.05	0.03	13.1	0.48	1.33	0.06	1.03	0.06	8.27	4.28
Q18-40-12	.31	20.5	0.05	0.03	12.4	0.46	1.36	0.06	1.05	0.06	8.82	3.80
Q18-40-14	.31	20.5	0.06	0.02	15.0	0.46	1.17	0.05	1.13	0.05	14.2	3.80
Q18-40-16	.31	20.5	0.05	0.02	14.4	0.46	1.23	0.05	1.17	0.05	11.3	3.13
Q18-40-2	.31	20.5	0.19	0.03	11.1	0.45	1.01	0.05	0.97	0.06	15.1	3.27
Q18-40-3	.31	20.5	0.11	0.03	12.7	0.47	1.04	0.05	0.99	0.05	13.0	3.25
Q18-40-4	.31	20.5	0.06	0.03	12.7	0.47	1.08	0.05	1.04	0.05	0.09	0.03
Q18-40-5	.31	20.5	0.08	0.03	12.2	0.47	1.16	0.06	1.04	0.06	12.9	3.53
Q18-40-6	.31	20.5	0.09	0.03	12.4	0.47	1.09	0.06	0.91	0.05	11.2	3.19
Q18-40-9	.31	20.5	0.09	0.03	12.2	0.46	1.27	0.06	0.94	0.06	12.6	3.25
Q18-40-1	1	20.5	0.07	0.02	12.0	0.42	1.09	0.05	1.04	0.05	10.5	3.16
Q18-40-10	1	20.5	0.09	0.02	12.2	0.42	1.19	0.05	0.88	0.05	10.3	4.45
Q18-40-11	1	20.5	0.04	0.02	12.4	0.43	1.31	0.05	1.01	0.05	11.1	4.46
Q18-40-12	1	20.5	0.05	0.02	11.9	0.42	1.30	0.05	1.01	0.05	11.6	4.43
Q18-40-14	1	20.5	0.04	0.03	15.5	0.53	1.08	0.06	0.93	0.06	12.7	6.69

003233

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q18-40-16	1	20.5	0.06	0.03	14.7	0.52	1.21	0.06	1.10	0.06	10.4	3.97
Q18-40-2	1	20.5	0.15	0.03	10.9	0.40	1.03	0.05	0.93	0.05	13.3	3.22
Q18-40-3	1	20.5	0.10	0.02	12.1	0.42	1.05	0.05	0.98	0.05	13.1	3.23
Q18-40-4	1	20.5	0.05	0.02	12.2	0.43	1.04	0.05	0.99	0.05	9.37	4.44
Q18-40-5	1	20.5	0.10	0.03	11.0	0.40	1.17	0.05	1.02	0.05	13.4	3.19
Q18-40-6	1	20.5	0.09	0.02	12.4	0.42	1.06	0.05	0.93	0.05	13.7	3.19
Q18-40-9	1	20.5	0.13	0.03	11.9	0.42	1.18	0.05	0.99	0.05	11.1	3.26
LAB RESULT - GAMMA												
Q18-40C-811654		20.2	0.16	0.08	11.9	1.90	1.29	0.22	1.38	0.43	7.80	7.43
Q18-40C-870874		21.2	0.20	0.10	15.4	2.60	1.57	0.30	1.13	0.54	9.01	8.92
Q18-40C-872764		22.4	0.07	0.06	13.5	1.90	1.25	0.21	11.1	0.41	1.66	5.35
Q18-40C-891658		18.9	0.03	0.07	11.4	1.70	1.25	0.23	1.14	0.42	8.49	5.65
Q18-40C-898975		21.7	0.03	0.10	16.0	2.60	1.94	0.33	1.58	0.59	9.86	8.03
Q18-40C-914679		21.3	0.13	0.14	11.4	2.20	2.61	0.40	1.40	0.60	22.8	12.8
Q18-40C-920785		17.8	-0.02	0.06	12.7	1.80	1.04	0.20	1.49	0.39	-4.77	4.46
Q18-40C-926871		20.8	0.02	0.05	15.0	2.00	1.07	0.22	1.43	0.39	1.80	5.95
Q18-40C-977977		21.7	0.21	0.12	14.7	2.50	1.40	0.31	1.74	0.58	7.24	6.84
Q18-40C-977977-D		22.2	0.04	0.08	17.6	2.70	1.64	0.31	1.66	0.57	7.01	10.1
Q18-40C-981808		20.6	0.01	0.05	11.5	1.80	1.06	0.23	1.25	0.40	-0.64	4.76
Q18-40C-986850		18.6	0.03	0.06	13.2	1.90	1.25	0.22	1.39	0.59	1.32	5.65

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q18-40C-987728		22.2	-0.04	0.09	16.2	2.70	2.42	0.42	2.10	0.58	4.83	8.03
LAB RESULT - ALPHA												
Q18-40C-811654		20.2							1.07	0.09		
Q18-40C-870874		21.2							1.24	0.10		
Q18-40C-872764		22.4							1.10	0.09		
Q18-40C-891658		18.9							1.10	0.10		
Q18-40C-898975		21.7							1.31	0.11		
Q18-40C-914679		21.3							1.20	0.10		
Q18-40C-920785		17.8							1.08	0.09		
Q18-40C-926871		20.8							1.15	0.10		
Q18-40C-977977		21.7							1.27	0.19		
Q18-40C-977977-D		22.2							1.36	0.18		
Q18-40C-981808		20.6							1.11	0.09		
Q18-40C-986850		18.6							1.06	0.10		
Q18-40C-987728		22.2							1.16	0.10		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q19-10												
FIELD RESULT												
Q19-10-10	.31	20.6	0.27	0.03	12.3	0.46	1.00	0.05	0.87	0.05	14.6	3.20
Q19-10-10	.31	20.6	0.20	0.03	15.2	0.52	1.42	0.06	1.04	0.06	17.6	3.25
Q19-10-13	.31	20.6	0.04	0.00	14.9	0.51	1.20	0.06	1.08	0.06	11.3	4.29
Q19-10-14	.31	20.6	0.23	0.03	15.1	0.50	1.54	0.06	1.09	0.05	16.1	3.23
Q19-10-14	.31	20.6	0.26	0.03	12.4	0.46	1.07	0.06	0.94	0.05	18.0	3.28
Q19-10-15	.31	20.6	0.16	0.03	9.21	0.40	0.86	0.05	0.58	0.05	11.6	3.00
Q19-10-16	.31	20.6	0.08	0.02	13.9	0.44	1.16	0.05	1.05	0.05	12.0	3.69
Q19-10-2	.31	20.6	0.24	0.03	13.5	0.44	1.22	0.05	1.07	0.05	20.3	3.27
Q19-10-4	.31	20.6	0.03	0.00	13.5	0.44	1.19	0.05	1.10	0.05	9.82	3.73
Q19-10-5	.31	20.6	0.11	0.03	13.1	0.48	1.10	0.06	0.89	0.05	13.6	3.14
Q19-10-6	.31	20.6	0.26	0.03	13.0	0.48	1.11	0.06	0.93	0.05	22.7	3.36
Q19-10-7	.31	20.6	0.27	0.03	12.5	0.42	1.12	0.05	1.05	0.05	19.9	3.21
Q19-10-8	.31	20.6	0.10	0.03	13.4	0.44	1.12	0.05	1.10	0.05	13.1	3.15
Q19-10-9	.31	20.6	0.03	0.00	15.7	0.52	1.13	0.06	1.09	0.06	8.68	3.55
Q19-10-10	1	20.6	0.20	0.03	15.1	0.52	1.34	0.06	1.03	0.06	16.0	3.40
Q19-10-10	1	20.6	0.17	0.03	11.5	0.41	0.87	0.05	0.74	0.05	10.4	3.36
Q19-10-13	1	20.6	0.00	0.00	14.7	0.46	1.12	0.05	1.02	0.05	0.05	0.02

0002336

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q19-10-14	1	20.6	0.20	0.03	15.1	0.51	1.40	0.06	0.98	0.06	16.4	3.36
Q19-10-14	1	20.6	0.20	0.03	11.8	0.42	1.03	0.05	0.79	0.05	12.0	3.54
Q19-10-15	1	20.6	0.15	0.03	9.72	0.38	0.93	0.05	0.65	0.05	11.7	2.97
Q19-10-16	1	20.6	0.10	0.03	13.9	0.50	1.09	0.06	1.03	0.06	13.5	3.37
Q19-10-2	1	20.6	0.21	0.03	14.2	0.50	1.23	0.06	1.07	0.06	16.8	3.50
Q19-10-4	1	20.6	0.08	0.03	13.0	0.49	1.15	0.06	1.02	0.06	11.6	3.37
Q19-10-5	1	20.6	0.11	0.02	12.7	0.43	1.12	0.05	0.89	0.05	12.4	3.20
Q19-10-6	1	20.6	0.26	0.03	12.0	0.42	1.17	0.05	0.96	0.05	19.0	3.35
Q19-10-7	1	20.6	0.28	0.03	12.3	0.46	1.01	0.06	1.01	0.06	17.3	3.44
Q19-10-8	1	20.6	0.07	0.03	13.9	0.50	1.13	0.06	1.09	0.06	11.7	3.70
Q19-10-9	1	20.6	0.00	0.00	14.9	0.47	1.14	0.05	1.04	0.05	8.37	4.41
LAB RESULT - GAMMA												
Q19-10C-403377		19.4	0.01	0.08	17.0	1.40	1.40	0.16	1.30	0.15	2.62	1.58
Q19-10C-407286		18.8	0.10	0.14	17.0	1.50	1.30	0.18	1.20	0.14	1.87	1.47
Q19-10C-424101		20.2	0.01	0.80	17.0	1.50	1.40	0.15	1.20	0.15	2.73	1.99
Q19-10C-466170		21.4	0.12	0.05	16.0	1.30	1.20	0.12	1.50	0.15	0.17	1.17
Q19-10C-640364		18.3	0.11	0.11	14.7	2.40	1.12	0.26	1.11	0.52	12.2	7.14
Q19-10C-644025		22.1	0.24	0.12	13.2	2.40	1.55	0.36	1.01	0.65	7.80	5.35
Q19-10C-655190		20.1	0.24	0.10	13.4	2.30	0.84	0.28	0.83	0.46	11.0	5.95
Q19-10C-673281		25.8	0.31	0.17	14.8	3.30	1.67	0.39	1.71	0.89	17.0	7.14

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q19-10C-683145		22.4	0.16	0.11	17.0	3.10	1.47	0.36	1.68	0.59	5.98	4.76
Q19-10C-707234		19.3	0.22	0.11	18.3	3.50	1.66	0.47	1.72	0.65	8.72	7.14
Q19-10C-755391		20.4	0.42	0.20	12.2	3.00	1.64	0.43	1.86	0.71	15.9	8.92
Q19-10C-765036		19.5	0.01	0.10	17.8	3.30	1.21	0.34	1.36	0.71	1.29	5.95
LAB RESULT - ALPHA												
Q19-10C-403377		19.4							0.98	0.42	4.02	1.44
Q19-10C-407286		18.8							0.96	0.36	4.27	2.20
Q19-10C-424101		20.2							1.10	0.38	3.40	1.31
Q19-10C-466170		21.4							1.00	0.39	9.43	3.28
Q19-10C-640364		18.3							1.13	0.09		
Q19-10C-644025		22.1							1.31	0.10		
Q19-10C-655190		20.1							1.16	0.14		
Q19-10C-673281		25.8							1.03	0.09		
Q19-10C-683145		22.4							1.14	0.19		
Q19-10C-707234		19.3							1.19	0.10		
Q19-10C-755391		20.4							1.12	0.17		
Q19-10C-765036		19.5							1.24	0.10		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q19-20												
FIELD RESULT												
Q19-20-10	.31	16.5	0.05	0.02	13.5	0.43	1.10	0.05	1.00	0.05	0.07	0.02
Q19-20-11	.31	16.5	0.06	0.02	13.7	0.43	1.21	0.05	1.11	0.05	9.17	3.02
Q19-20-12	.31	16.5	0.14	0.03	13.4	0.43	1.32	0.05	1.10	0.05	14.2	2.99
Q19-20-15	.31	16.5	0.08	0.02	14.1	0.44	1.33	0.05	1.09	0.05	14.1	3.24
Q19-20-2	.31	16.5	0.07	0.02	13.9	0.43	1.27	0.05	1.10	0.05	12.1	3.02
Q19-20-3	.31	16.5	0.05	0.02	14.4	0.44	1.15	0.05	1.07	0.05	10.2	3.58
Q19-20-4	.31	16.5	0.05	0.02	14.1	0.43	1.16	0.05	1.12	0.05	11.0	2.97
Q19-20-6	.31	16.5	0.07	0.02	14.0	0.44	1.18	0.05	1.11	0.05	10.0	3.02
Q19-20-8	.31	16.5	0.07	0.02	13.5	0.43	1.32	0.05	1.11	0.05	12.3	2.97
Q19-20-9	.31	16.5	0.04	0.02	15.4	0.46	1.10	0.05	1.14	0.05	3.94	0.05
Q19-20-10	1	16.5	0.07	0.02	13.9	0.48	1.07	0.05	0.97	0.05	8.62	3.46
Q19-20-11	1	16.5	0.06	0.03	14.1	0.49	1.28	0.06	1.06	0.06	12.0	4.33
Q19-20-12	1	16.5	0.14	0.03	13.5	0.48	1.29	0.06	1.04	0.06	14.1	3.28
Q19-20-15	1	16.5	0.06	0.03	14.5	0.50	1.29	0.06	1.07	0.06	11.3	3.29
Q19-20-2	1	16.5	0.09	0.02	14.6	0.50	1.19	0.06	1.06	0.06	12.4	3.32
Q19-20-3	1	16.5	0.08	0.03	15.0	0.50	1.16	0.06	1.13	0.06	11.3	3.31
Q19-20-4	1	16.5	0.09	0.03	14.4	0.49	1.13	0.06	1.08	0.06	11.5	3.23

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q19-20-6	1	16.5	0.07	0.02	14.3	0.49	1.17	0.06	1.09	0.06	9.87	3.28
Q19-20-8	1	16.5	0.06	0.03	14.5	0.49	1.33	0.06	1.04	0.06	11.8	3.56
Q19-20-9	1	16.5	0.04	0.02	15.8	0.52	1.12	0.05	1.09	0.06	12.6	3.52
LAB RESULT - GAMMA												
Q19-20C-817138		14.8	0.03	0.04	14.0	1.90	1.10	0.23	1.10	0.18	4.95	5.35
Q19-20C-832024		14.5	0.42	0.09	18.0	2.20	1.10	0.19	1.10	0.16	12.4	4.76
Q19-20C-853266		15.7	0.00	0.02	1.00	2.00	1.20	0.19	1.20	0.18	6.34	4.76
Q19-20C-863173		13.4	-0.01	0.02	16.0	1.80	0.98	0.15	1.10	0.15	4.55	2.53
Q19-20C-890340		11.7	-0.01	0.04	15.0	2.10	1.10	0.21	1.20	0.18	2.77	5.06
Q19-20C-897327		15.7	0.12	0.08	16.0	2.30	1.10	0.21	1.30	0.18	10.9	6.84
Q19-20C-927271		16.8	0.14	0.07	19.0	2.20	1.20	0.20	1.20	0.17	7.23	4.76
Q19-20C-961179		14.4	0.04	0.03	20.0	2.30	1.20	0.21	1.10	0.16	3.30	3.87
Q19-20C-967389		17.7	0.09	0.05	18.0	2.20	1.20	0.20	1.20	0.18	4.80	4.16
Q19-20C-969016		18.0	-0.01	0.04	16.0	2.10	0.86	0.19	1.20	0.19	7.03	5.65
Q19-20C-995288		13.9	0.02	0.04	15.0	1.60	1.20	0.19	1.20	0.11	2.37	5.35
Q19-20C-998104		13.7	0.15	0.08	16.0	2.50	1.10	0.24	1.20	0.20	14.1	6.84
LAB RESULT - ALPHA												
Q19-20C2-R-24		15.8							1.20	0.26		
Q19-20C2-R-25		16.3							0.98	0.22		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q19-20C2-R-26		18.6							1.30	0.29		
Q19-20C2-R-27		13.4							0.87	0.20		
Q19-20C2-R-28		16.9							0.83	0.20		
Q19-20C2-R-29		14.4							1.10	0.24		
Q19-20C2-R-30		17.7							1.30	0.24		
Q19-20C2-R-31		12.6							1.20	0.25		
Q19-20C2-R-32		15.0							1.10	0.24		
Q19-20C2-R-33		20.4							1.00	0.24		
Q19-20C2-R-34		17.6							1.00	0.20		
Q19-20C2-R-34-D		14.7							1.00	0.22		
Q19-20C2-R-35		20.3							1.20	0.27		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q19-30												
FIELD RESULT												
Q19-30-10	.31	15.2	0.00	0.00	16.4	0.51	1.05	0.05	1.12	0.05	5.66	3.44
Q19-30-11	.31	15.2	0.04	0.00	15.3	0.50	1.19	0.05	1.08	0.05	0.08	0.02
Q19-30-12	.31	15.2	0.05	0.02	15.6	0.48	1.13	0.05	1.10	0.05	9.87	2.99
Q19-30-14B	.31	15.2	0.00	0.00	13.0	0.45	1.07	0.05	0.89	0.05	0.06	0.02
Q19-30-16	.31	15.2	0.04	0.02	16.2	0.48	1.00	0.05	1.07	0.05	10.4	3.22
Q19-30-3	.31	15.2	0.25	0.03	13.7	0.47	1.05	0.05	0.98	0.05	16.0	3.14
Q19-30-4	.31	15.2	0.06	0.02	14.9	0.46	1.16	0.05	1.07	0.05	11.3	3.49
Q19-30-4B	.31	15.2	0.17	0.03	12.4	0.44	1.07	0.05	0.90	0.05	12.9	3.00
Q19-30-6	.31	15.2	0.28	0.03	14.3	0.48	1.21	0.05	0.99	0.05	20.2	3.17
Q19-30-6B	.31	15.2	0.04	0.02	13.8	0.47	1.02	0.05	0.94	0.05	9.89	3.42
Q19-30-7	.31	15.2	0.24	0.03	13.7	0.45	1.13	0.05	1.02	0.05	18.7	3.08
Q19-30-8	.31	15.2	0.05	0.02	15.8	0.48	1.19	0.05	1.10	0.05	10.7	3.98
Q19-30-10	1	15.2	0.00	0.00	15.3	0.45	1.07	0.05	1.00	0.05	10.6	3.23
Q19-30-11	1	15.2	0.05	0.02	14.6	0.45	1.15	0.05	0.98	0.05	17.4	7.73
Q19-30-12	1	15.2	0.00	0.00	14.9	0.47	0.93	0.05	0.81	0.05	0.00	0.00
Q19-30-14B	1	15.2	0.00	0.00	10.6	0.46	0.46	0.05	0.38	0.05	0.00	0.00
Q19-30-16	1	15.2	0.05	0.02	15.6	0.48	0.85	0.05	0.91	0.05	0.05	0.02

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q19-30-3	1	15.2	0.20	0.03	13.7	0.48	1.21	0.06	1.05	0.06	13.6	3.25
Q19-30-4	1	15.2	0.06	0.02	14.6	0.47	1.11	0.05	0.96	0.05	0.09	0.02
Q19-30-4B	1	15.2	0.16	0.03	13.8	0.47	1.13	0.05	0.98	0.05	11.7	3.12
Q19-30-6	1	15.2	0.28	0.03	13.3	0.43	1.39	0.06	1.08	0.05	18.1	3.23
Q19-30-6B	1	15.2	0.04	0.02	14.0	0.47	1.07	0.05	0.91	0.05	10.9	4.10
Q19-30-7	1	15.2	0.25	0.03	12.7	0.45	1.10	0.05	0.91	0.05	13.9	3.08
Q19-30-8	1	15.2	0.05	0.02	15.0	0.47	1.09	0.05	0.97	0.05	11.9	3.42
LAB RESULT - GAMMA												
Q19-30C-434472		13.7	0.08	0.05	16.0	1.50	1.20	0.14	1.10	0.10	6.59	5.95
Q19-30C-487610		15.7	0.12	0.05	19.0	2.40	1.20	0.21	1.20	0.18	6.12	5.95
Q19-30C-552565		20.1	0.56	0.10	19.0	2.20	1.20	0.21	1.20	0.18	18.9	5.95
Q19-30C-562718		14.5	-0.03	0.04	19.0	2.40	1.10	0.23	1.20	0.19	6.29	5.35
Q19-30C-570659		10.6	0.01	0.04	16.0	2.10	1.10	0.20	1.10	0.18	4.58	5.95
Q19-30C-573492		14.7	0.10	0.06	17.0	2.20	1.10	0.20	1.30	0.19	9.71	5.35
Q19-30C-602626		13.1	0.16	0.05	15.0	1.30	1.30	0.15	1.20	0.10	9.03	5.65
Q19-30C-657409		20.7	0.39	0.08	14.0	2.00	0.90	0.17	1.00	0.18	19.5	8.03
Q19-30C-695738		12.2	0.16	0.05	16.0	2.10	1.20	0.19	1.20	0.17	8.15	5.35
Q19-30C-718516		11.6	0.13	0.06	16.0	2.20	1.30	0.22	1.10	0.19	9.68	7.14
Q19-30C-777429		13.4	0.04	0.04	16.0	2.10	1.00	0.20	1.40	0.19	4.27	5.35
Q19-30C2-R-1		15.8	0.03	0.03	16.0	1.90	1.10	0.16	1.10	0.16	2.46	3.27

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q19-30C2-R-2		19.3	0.05	0.04	18.0	2.20	1.20	0.18	1.30	0.17	5.46	4.16
LAB RESULT - ALPHA												
Q19-30C2-R-1		15.8							0.94	0.20		
Q19-30C2-R-2		19.3							1.20	0.24		
Q19-30C2-R-36		14.9							1.20	0.24		
Q19-30C2-R-37		17.9							1.10	0.23		
Q19-30C2-R-38		15.1							0.99	0.20		
Q19-30C2-R-39		11.8							1.00	0.21		
Q19-30C2-R-40		18.6							1.00	0.22		
Q19-30C2-R-41		11.9							0.94	0.21		
Q19-30C2-R-42		13.5							1.10	0.20		
Q19-30C2-R-43		18.6							1.30	0.28		
Q19-30C2-R-44		13.9							1.10	0.23		
Q19-30C2-R-45		20.2							1.10	0.24		
Q19-30C2-R-46		16.4							0.99	0.21		
Q19-30C2-R-47		15.6							0.79	0.19		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q19-40												
FIELD RESULT												
Q19-40-10	.31	16.8	0.06	0.02	19.4	0.54	1.13	0.05	1.18	0.05	9.31	3.09
Q19-40-13	.31	16.8	0.06	0.03	15.9	0.51	1.38	0.06	1.15	0.06	10.7	3.67
Q19-40-13	.31	16.8	0.06	0.02	15.9	0.48	1.20	0.05	1.12	0.05	10.8	4.02
Q19-40-2	.31	16.8	0.08	0.03	18.8	0.56	1.29	0.06	1.15	0.06	6.51	3.74
Q19-40-3	.31	16.8	0.18	0.03	14.9	0.45	1.24	0.05	1.05	0.05	14.1	3.07
Q19-40-4	.31	16.8	0.31	0.03	14.9	0.45	1.23	0.05	1.05	0.05	15.6	3.13
Q19-40-6	.31	16.8	0.10	0.03	15.3	0.51	1.12	0.05	0.96	0.05	11.3	3.13
Q19-40-6	.31	16.8	0.09	0.02	15.5	0.48	1.02	0.05	0.97	0.05	11.9	3.27
Q19-40-9	.31	16.8	0.05	0.02	16.2	0.49	1.18	0.05	1.11	0.05	10.2	3.08
Q19-40-10	1	16.8	0.03	0.00	19.2	0.54	1.14	0.06	1.14	0.06	9.83	4.22
Q19-40-13	1	16.8	0.00	0.00	15.6	0.52	1.34	0.06	0.97	0.06	17.1	8.14
Q19-40-2	1	16.8	0.11	0.03	18.0	0.50	1.27	0.05	1.10	0.05	13.3	3.80
Q19-40-3	1	16.8	0.14	0.03	15.3	0.51	1.29	0.06	1.04	0.06	13.4	3.35
Q19-40-4	1	16.8	0.26	0.03	15.9	0.52	1.29	0.06	1.04	0.06	14.4	3.38
Q19-40-6	1	16.8	0.08	0.02	14.2	0.47	1.01	0.05	0.92	0.05	13.0	3.68
Q19-40-6	1	16.8	0.08	0.03	14.4	0.45	1.32	0.05	0.84	0.05	10.3	3.44
Q19-40-9	1	16.8	0.08	0.02	15.6	0.49	1.14	0.05	1.09	0.06	13.0	4.28

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
LAB RESULT - GAMMA												
Q19-40C-041550		18.1	0.20	0.07	20.0	2.60	1.20	0.23	1.40	0.22	17.1	8.92
Q19-40C-079740		17.2	0.02	0.04	23.0	2.70	1.30	0.23	1.30	0.19	7.88	5.06
Q19-40C-835755		17.5	0.00	0.02	19.0	2.20	1.20	0.19	1.30	0.19	3.97	2.80
Q19-40C-849480		16.3	0.04	0.06	19.0	2.60	1.20	0.25	1.20	0.19	9.38	8.03
Q19-40C-882465		16.4	0.25	0.10	18.0	2.60	1.20	0.21	1.20	0.20	11.2	6.84
Q19-40C-882465-D		17.6	0.24	0.06	18.0	2.50	1.10	0.23	1.30	0.18	10.9	6.84
Q19-40C-904775		16.8	0.02	0.04	20.0	2.60	1.30	0.24	1.40	0.22	7.37	6.84
Q19-40C-927651		16.4	-0.01	0.04	24.0	3.00	1.40	0.23	1.40	0.19	5.71	5.65
Q19-40C-999438		17.0	0.11	0.06	19.0	1.60	1.20	0.20	1.20	0.11	1.25	5.95
Q19-40C2-R-1		17.4	0.32	0.06	17.0	2.00	1.10	0.16	1.10	0.15	14.3	5.06
Q19-40C2-R-2		22.2	0.00	0.03	2.00	2.40	1.30	0.21	1.30	0.18	3.97	2.97
Q19-40C2-R-3		22.4	0.10	0.07	20.0	2.50	1.50	0.24	1.20	0.20	2.13	5.35
Q19-40C2-R-4		14.7	0.02	0.03	16.0	2.00	1.20	0.23	1.20	0.17	3.90	3.57
Q19-40C2-R-5		15.0	0.06	0.04	17.0	1.90	1.20	0.19	1.20	0.17	6.29	4.16
Q19-40C2-R-6		17.8	-0.01	0.03	23.0	2.60	1.30	0.19	1.30	0.19	7.90	4.46
LAB RESULT - ALPHA												
Q19-40C-041550		18.1							1.00	0.23		
Q19-40C2-R-1		17.4							1.10	0.22		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q19-40C2-R-2		22.2							0.84	0.18		
Q19-40C2-R-3		22.4							1.10	0.22		
Q19-40C2-R-4		14.7							1.20	0.24		
Q19-40C2-R-48		16.9							1.00	0.22		
Q19-40C2-R-49		18.0							0.93	0.18		
Q19-40C2-R-5		15.0							1.00	0.20		
Q19-40C2-R-50		20.0							1.00	0.19		
Q19-40C2-R-50-D		20.1							0.99	0.22		
Q19-40C2-R-51		18.3							0.98	0.24		
Q19-40C2-R-52		17.3							1.00	0.23		
Q19-40C2-R-53		18.8							1.10	0.23		
Q19-40C2-R-54		14.1							1.00	0.22		
Q19-40C2-R-6		17.8							1.10	0.23		

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q20-20												
FIELD RESULT												
Q20-10-12	.31	19.9	0.28	0.03	16.7	0.54	0.96	0.05	1.03	0.06	12.3	3.17
Q20-10-4	.31	19.9	0.00	0.00	16.6	0.53	1.09	0.06	1.08	0.06	10.3	4.11
Q20-20-1	.31	19.9	0.05	0.02	17.0	0.51	1.13	0.05	1.14	0.06	10.5	3.16
Q20-20-10	.31	19.9	0.52	0.04	15.4	0.48	0.84	0.05	0.91	0.05	19.5	3.18
Q20-20-11	.31	19.9	0.42	0.04	14.5	0.50	0.86	0.05	0.89	0.05	11.7	3.23
Q20-20-12	.31	19.9	0.46	0.04	14.0	0.49	0.83	0.05	0.83	0.05	17.6	3.24
Q20-20-14	.31	19.9	0.55	0.04	15.6	0.49	0.81	0.05	0.93	0.05	23.7	3.21
Q20-20-4	.31	19.9	0.45	0.03	15.0	0.48	1.04	0.05	0.91	0.05	21.1	3.26
Q20-20-5	.31	19.9	0.37	0.04	17.5	0.55	1.19	0.06	1.11	0.06	18.5	3.34
Q20-20-7	.31	19.9	0.39	0.03	15.7	0.49	0.89	0.05	0.94	0.05	16.4	3.17
Q20-20-8	.31	19.9	0.38	0.03	13.1	0.45	1.01	0.05	0.88	0.05	16.6	3.20
Q20-20-9	.31	19.9	0.13	0.03	17.7	0.55	1.11	0.06	1.06	0.06	13.0	3.28
Q20-10-12	1	19.9	0.26	0.03	15.4	0.47	0.85	0.05	0.86	0.05	11.9	5.77
Q20-10-3	1	19.9	0.00	0.00	16.2	0.48	1.10	0.05	1.08	0.05	6.50	0.08
Q20-10-4	1	19.9	0.00	0.00	15.2	0.47	0.97	0.05	1.00	0.05	0.07	0.02
Q20-20-1	1	19.9	0.06	0.03	16.7	0.51	1.03	0.05	1.04	0.06	8.67	4.12
Q20-20-10	1	19.9	0.49	0.04	14.9	0.49	0.90	0.05	0.89	0.05	19.4	3.29

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q20-20-11	1	19.9	0.43	0.03	14.7	0.46	0.90	0.05	0.89	0.05	16.2	3.22
Q20-20-12	1	19.9	0.46	0.03	13.5	0.44	0.82	0.05	0.83	0.05	19.0	3.17
Q20-20-14	1	19.9	0.42	0.04	16.1	0.51	0.80	0.05	0.92	0.05	19.3	3.32
Q20-20-4	1	19.9	0.36	0.03	14.1	0.47	1.03	0.05	0.86	0.05	17.6	3.14
Q20-20-5	1	19.9	0.36	0.03	16.1	0.48	1.16	0.05	1.06	0.05	17.6	3.28
Q20-20-7	1	19.9	0.38	0.03	14.4	0.48	0.82	0.05	0.86	0.05	16.5	3.17
Q20-20-8	1	19.9	0.35	0.03	13.0	0.45	0.95	0.05	0.81	0.05	13.9	3.09
Q20-20-9	1	19.9	0.25	0.03	15.7	0.47	1.07	0.05	0.99	0.05	12.3	3.58
LAB RESULT - GAMMA												
Q20-10C-714896		19.7	-0.02	0.06	17.0	2.60	1.20	0.32	1.20	0.22	6.42	8.03
Q20-20C-008111		31.7	0.52	0.09	22.0	2.60	1.00	0.19	1.30	0.20	12.4	5.35
Q20-20C-064950		11.3	0.16	0.05	20.0	2.40	1.10	0.19	1.30	0.20	7.03	5.65
Q20-20C-074915		19.7	0.48	0.09	16.0	2.10	0.91	0.17	1.10	0.17	21.9	8.63
Q20-20C-815917		13.5	0.04	0.07	20.0	2.60	1.10	0.18	1.30	0.18	5.75	5.06
Q20-20C-847132		28.4	0.70	0.09	19.0	2.30	0.90	0.15	1.20	0.16	23.3	7.14
Q20-20C-859980		12.8	0.00	0.03	20.0	2.50	0.79	0.17	0.96	0.15	4.52	4.76
Q20-20C-875821		12.2	0.07	0.05	19.0	1.60	1.30	0.15	1.10	0.10	6.57	5.35
Q20-20C-902959		14.4	0.06	0.03	20.0	2.30	1.10	0.19	1.30	0.19	6.07	3.87
Q20-20C-947192		28.6	0.68	0.11	26.0	2.80	1.10	0.17	1.30	0.18	15.5	4.76
Q20-20C-964100		26.4	0.47	0.07	17.0	1.40	1.10	0.17	1.20	0.18	12.2	2.77

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q20-20C2-R-1		40.9	0.50	0.07	18.0	1.50	1.10	0.12	1.30	0.18	3.36	0.81
Q20-20C2-R-2		29.0	0.59	0.09	19.0	1.50	1.20	0.14	0.96	0.13	10.7	2.14
Q20-20C2-R-3		23.0	-0.03	0.08	18.0	1.50	1.50	0.17	1.70	0.22	1.51	0.75
LAB RESULT - ALPHA												
Q20-10C-714896		19.7							1.20	0.25		
Q20-20C-008111		31.7							1.20	0.26		
Q20-20C-847132		28.4							1.30	0.28		
Q20-20C-947192		28.6							1.40	0.29		
Q20-20C-964100		26.4							1.20	0.46		
Q20-20C2-R-1		40.9							1.10	0.41		
Q20-20C2-R-2		29.0							0.95	0.37		
Q20-20C2-R-3		23.0							1.10	0.42		
Q20-20C2-R-55		24.0							1.30	0.26		
Q20-20C2-R-56		22.4							1.00	0.24		
Q20-20C2-R-58		20.7							1.30	0.25		
Q20-20C2-R-59		22.7							1.20	0.25		
Q20-20C2-R-60		20.5							1.30	0.25		
Q20-20C2-R-61		17.6							0.96	0.22		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q20-30												
FIELD RESULT												
Q20-10-13-G	.31	25.1	0.45	0.04	16.2	0.55	0.83	0.05	0.84	0.06	15.6	3.55
Q20-30-10-G	.31	25.1	0.40	0.04	16.3	0.56	0.70	0.05	0.81	0.05	11.3	3.43
Q20-30-11-G	.31	25.1	0.42	0.03	14.8	0.49	0.60	0.05	0.68	0.05	9.91	3.35
Q20-30-11-G	.31	25.1	0.47	0.03	15.2	0.48	0.71	0.05	0.74	0.05	13.1	3.09
Q20-30-11-G	.31	25.1	0.45	0.04	15.8	0.52	0.70	0.05	0.71	0.05	11.5	3.69
Q20-30-12-G	.31	25.1	0.50	0.04	19.2	0.54	0.85	0.05	0.94	0.05	15.9	3.31
Q20-30-12-G	.31	25.1	0.44	0.04	19.6	0.59	0.72	0.05	0.82	0.05	18.0	3.38
Q20-30-13-G	.31	25.1	0.45	0.04	19.2	0.54	0.80	0.05	0.97	0.05	19.3	3.43
Q20-30-16-G	.31	25.1	0.51	0.04	18.2	0.57	0.95	0.05	0.91	0.06	17.4	3.49
Q20-30-4-G	.31	25.1			17.9	0.59	0.84	0.06	0.87	0.06	15.3	3.51
Q20-30-6-G	.31	25.1	0.39	0.04	17.9	0.58	0.77	0.05	0.85	0.06	16.1	3.51
Q20-30-8-G	.31	25.1	0.22	0.04	16.4	0.60	0.42	0.06	0.47	0.06	0.00	0.00
Q20-30-9-G	.31	25.1	0.50	0.04	20.7	0.56	0.84	0.05	0.97	0.05	14.0	3.69
Q20-40-10-G	.31	25.1	0.41	0.03	17.0	0.51	0.73	0.05	0.81	0.05	17.5	3.36
Q20-40-13-G	.31	25.1	0.46	0.04	18.2	0.57	0.86	0.05	0.87	0.06	12.9	3.65
Q20-40-5-G	.31	25.1	0.44	0.04	18.0	0.53	0.83	0.05	0.95	0.05	16.2	3.29
Q20-40-9-G	.31	25.1	0.40	0.03	18.3	0.53	0.73	0.05	0.90	0.05	16.5	3.34

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q20-10-13-G	1	25.1	0.46	0.04	16.0	0.56	0.84	0.06	0.80	0.06	16.6	3.69
Q20-30-10-G	1	25.1	0.38	0.04	16.6	0.56	0.82	0.05	0.79	0.06	14.0	3.94
Q20-30-11-G	1	25.1	0.44	0.04	16.3	0.54	0.73	0.05	0.78	0.05	17.2	3.30
Q20-30-12-G	1	25.1	0.46	0.04	19.0	0.58	0.82	0.05	0.90	0.05	19.4	3.51
Q20-30-16-G	1	25.1	0.53	0.04	17.5	0.56	0.95	0.06	0.94	0.06	16.7	4.25
Q20-30-4-G	1	25.1	0.43	0.04	18.7	0.60	0.84	0.06	0.94	0.06	17.0	3.67
Q20-30-6-G	1	25.1	0.42	0.04	17.2	0.58	0.81	0.06	0.86	0.06	15.2	3.66
Q20-30-8-G	1	25.1	0.50	0.04	17.9	0.59	0.83	0.06	0.97	0.06	19.4	4.23
Q20-30-9-G	1	25.1	0.46	0.04	19.9	0.56	0.82	0.05	0.98	0.06	12.6	3.53
Q20-40-10-G	1	25.1	0.40	0.04	17.2	0.52	0.74	0.05	0.82	0.05	19.1	3.51
Q20-40-13-G	1	25.1	0.23	0.04	13.2	0.58	0.38	0.05	0.44	0.05	0.00	0.00
Q20-40-5-G	1	25.1	0.41	0.04	17.9	0.53	0.75	0.05	0.85	0.05	16.1	3.45
Q20-40-9-G	1	25.1	0.41	0.04	17.9	0.53	0.75	0.05	0.89	0.05	14.0	3.77
LAB RESULT - GAMMA												
Q20-30C-1-R		31.0	0.63	0.07	25.0	1.80	1.20	0.16	0.91	0.12	9.97	2.56
Q20-30C-1-R-D		29.6	0.72	0.09	25.0	1.70	1.20	0.16	1.40	0.15	6.41	2.20
Q20-30C-10-R		20.3	0.53	0.10	21.0	2.40	1.10	0.19	1.20	0.17	13.3	5.06
Q20-30C-11-R		24.4	0.59	0.07	21.0	1.50	1.10	0.14	1.30	0.14	5.42	1.34
Q20-30C-12-R		24.0	0.61	0.10	25.0	3.00	1.20	0.20	1.30	0.20	16.1	5.65
Q20-30C-13-R		18.4	0.66	0.14	18.0	2.40	0.88	0.19	0.92	0.15	13.9	6.25

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APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q20-30C-14-R		22.9	0.53	0.09	24.0	2.80	0.80	0.16	1.10	0.16	10.2	5.35
Q20-30C-15-R		21.0	0.55	0.09	24.0	2.70	1.10	0.18	1.20	0.18	15.7	5.65
Q20-30C-3-R		27.3	0.56	0.09	22.0	1.90	1.20	0.18	1.20	0.14	11.2	2.71
Q20-30C-4-R		28.1	0.70	0.08	24.0	1.70	1.30	0.17	1.20	0.08	7.05	1.46
Q20-30C-5-R		29.1	0.66	0.09	26.0	2.10	1.30	0.18	1.30	0.15	13.0	2.48
Q20-30C-8-R		29.5	0.39	0.05	18.0	1.30	0.89	0.11	1.00	0.11	8.46	2.83
Q20-30C-9-R		25.7	0.60	0.09	27.0	3.10	1.10	0.19	1.30	0.19	13.0	5.35
Q20-40C-1-R		26.7	0.60	0.07	24.0	1.70	1.40	0.18	1.60	0.16	7.31	1.40
Q20-40C-10-R		29.1	0.54	0.08	24.0	2.00	1.10	0.17	1.25	0.14	12.0	2.86
Q20-40C-10-R-D		29.0	0.47	0.08	25.0	1.80	1.10	0.15	1.30	0.15	9.69	2.44
Q20-40C-13-R		27.1	0.61	0.09	25.0	1.80	1.30	0.19	1.30	0.15	10.3	2.53
Q20-40C-14-R		28.4	0.54	0.08	20.0	1.80	1.00	0.17	1.25	0.14	7.60	2.89
Q20-40C-9-R		28.6	0.54	0.07	24.0	1.70	1.20	0.14	1.60	0.17	6.75	1.52
LAB RESULT - ALPHA												
Q20-30C-1-R		31.0							1.20	0.46	13.8	5.65
Q20-30C-1-R-D		29.6							1.40	0.60	14.7	1.55
Q20-30C-10-R		20.3							1.00	0.22		
Q20-30C-11-R		24.4							0.96	0.36	10.7	4.46
Q20-30C-12-R		24.0							1.30	0.29		
Q20-30C-13-R		18.4							0.85	0.19		

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q20-30C-14-R		22.9							1.10	0.24		
Q20-30C-15-R		21.0							1.10	0.24		
Q20-30C-3-R		27.3							1.30	0.48	16.6	5.95
Q20-30C-4-R		28.1							1.40	0.50	18.5	6.55
Q20-30C-5-R		29.1							1.30	0.46	16.5	5.95
Q20-30C-8-R		29.5							1.40	0.47	16.6	5.65
Q20-30C-9-R		25.7							0.95	0.22		
Q20-40C-1-R		26.7							1.30	0.51	15.6	5.95
Q20-40C-10-R		29.1							1.50	0.58	14.3	5.06
Q20-40C-10-R-D		29.0							1.30	0.49	13.2	4.76
Q20-40C-13-R		27.1							1.30	0.46	13.6	5.65
Q20-40C-14-R		28.4							1.30	0.51	9.19	3.27
Q20-40C-9-R		28.6							1.30	0.48	13.8	5.06

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
CU Name: Q20-40												
FIELD RESULT												
Q20-40-16-G	.31	27.2	0.52	0.04	16.6	0.56	0.94	0.06	0.93	0.06	17.0	3.36
Q20-40-16-G	.31	27.2	0.49	0.04	15.8	0.50	0.91	0.05	0.83	0.05	14.8	3.26
Q20-40-3-G	.31	27.2	0.51	0.04	16.1	0.52	0.98	0.05	0.95	0.06	13.7	3.40
Q20-40-3-G	.31	27.2	0.38	0.04	14.0	0.52	0.98	0.06	0.78	0.05	16.7	3.46
Q20-40-4-G	.31	27.2	0.33	0.03	13.3	0.49	1.07	0.06	0.66	0.05	9.18	4.46
Q20-40-4-G	.31	27.2	0.36	0.04	17.2	0.54	1.01	0.06	0.95	0.06	10.9	3.93
Q20-40-7-G	.31	27.2	0.31	0.03	13.5	0.47	0.94	0.05	0.80	0.05	9.55	3.22
Q20-40-7-G	.31	27.2	0.24	0.03	15.9	0.52	1.00	0.06	0.94	0.05	11.7	3.33
Q20-40-8-G	.31	27.2	0.41	0.04	17.3	0.56	0.98	0.06	1.01	0.06	16.6	3.53
Q20-40-8-G	.31	27.2	0.46	0.04	17.6	0.58	0.92	0.06	1.07	0.06	15.8	3.59
Q20-402-1-G	.31	27.2	0.46	0.04	16.3	0.56	0.82	0.05	0.86	0.06	17.0	3.55
Q20-402-12-G	.31	27.2	0.52	0.04	11.2	0.45	0.80	0.05	0.69	0.05	15.3	3.10
Q20-402-15-G	.31	27.2	0.36	0.04	14.3	0.53	0.89	0.05	0.86	0.05	12.6	3.41
Q20-402-2-G	.31	27.2	0.37	0.03	17.0	0.55	0.86	0.05	0.85	0.05	19.0	3.45
Q20-402-3-G	.31	27.2	0.38	0.03	14.1	0.48	0.97	0.05	0.76	0.05	12.0	3.62
Q20-402-5-G	.31	27.2	0.33	0.03	14.3	0.51	0.73	0.05	0.72	0.05	12.6	3.42
Q20-402-5-G-D	.31	27.2	0.36	0.03	14.3	0.51	0.79	0.05	0.67	0.05	14.2	3.37

000253

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	Det Ht (m)	Moisture (%)	Result	TPU/Err	Result	TPU/Er	Result	TPU/Er	Result	TPU/Er	Result	TPU/Err
Q20-402-9-G	.31	27.2	0.39	0.04	16.6	0.57	0.96	0.06	0.90	0.06	18.0	3.59
Q20-40-16-G	1	27.2	0.43	0.04	15.4	0.51	0.95	0.05	0.83	0.05	12.2	3.39
Q20-40-16-G	1	27.2	0.52	0.04	15.4	0.49	0.95	0.05	0.87	0.05	15.2	3.37
Q20-40-3-G	1	27.2	0.40	0.04	13.5	0.52	0.98	0.06	0.77	0.06	12.1	3.57
Q20-40-3-G	1	27.2	0.43	0.04	15.5	0.50	0.83	0.05	0.84	0.06	14.0	9.06
Q20-40-4-G	1	27.2	0.38	0.03	16.1	0.50	0.93	0.05	0.93	0.06	10.4	4.68
Q20-40-4-G	1	27.2	0.34	0.03	13.9	0.50	1.16	0.06	0.71	0.05	8.20	4.64
Q20-40-7-G	1	27.2	0.31	0.03	13.9	0.47	0.98	0.05	0.75	0.05	11.9	4.68
Q20-40-7-G	1	27.2	0.32	0.04	16.6	0.54	0.93	0.06	0.92	0.06	12.0	3.52
Q20-40-8-G	1	27.2	0.41	0.04	16.9	0.56	0.99	0.06	0.95	0.06	18.8	3.55
Q20-40-8-G	1	27.2	0.46	0.04	16.8	0.51	0.97	0.05	1.04	0.06	18.0	3.65
Q20-402-1-G	1	27.2	0.44	0.04	16.2	0.57	0.84	0.06	0.81	0.06	16.5	3.59
Q20-402-12-G	1	27.2	0.51	0.04	11.6	0.47	0.77	0.05	0.70	0.05	14.2	3.19
Q20-402-15-G	1	27.2	0.33	0.04	14.3	0.54	0.94	0.06	0.75	0.06	13.4	3.57
Q20-402-2-G	1	27.2	0.40	0.04	16.5	0.55	0.83	0.05	0.80	0.05	16.5	3.55
Q20-402-3-G	1	27.2	0.42	0.03	14.3	0.48	0.96	0.05	0.82	0.05	14.1	4.72
Q20-402-5-G	1	27.2	0.31	0.03	13.4	0.50	0.74	0.05	0.66	0.05	11.4	4.74
Q20-402-5-G-D	1	27.2	0.33	0.03	13.7	0.50	0.75	0.05	0.70	0.05	11.3	4.25
Q20-402-9-G	1	27.2	0.39	0.04	16.5	0.57	0.97	0.06	0.86	0.06	13.8	3.69

LAB RESULT - GAMMA

000256

924

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

Sample Id	Det Ht (m)	Moisture (%)	Cesium-137 pCi/g Result	Cesium-137 pCi/g TPU/Err	Potassium-40 pCi/g Result	Potassium-40 pCi/g TPU/Er	Radium-226 pCi/g Result	Radium-226 pCi/g TPU/Er	Thorium-232 pCi/g Result	Thorium-232 pCi/g TPU/Er	Calculated Uranium,Total ppm Result	Calculated Uranium,Total ppm TPU/Err
Q20-40C-11-R		27.0	0.63	0.09	21.0	1.80	1.40	0.18	1.20	0.14	11.8	2.92
Q20-40C-12-R		27.8	0.38	0.05	16.0	1.20	0.74	0.09	0.89	0.10	9.59	2.14
Q20-40C-2-R		27.0	0.51	0.07	20.0	1.60	1.20	0.15	1.10	0.13	7.32	1.91
Q20-40C-4-R		33.5	0.57	0.07	22.0	1.60	1.30	0.16	1.50	0.16	5.45	1.61
Q20-40C-7-R		26.0	0.45	0.08	20.0	1.80	1.30	0.18	1.30	0.15	10.9	3.27
Q20-40C2-11-R		26.7	0.52	0.08	21.0	1.50	1.50	0.18	1.60	0.18	5.47	1.61
Q20-40C2-12-R		27.1	0.55	0.10	21.0	1.50	1.60	0.17	1.60	0.17	4.83	1.02
Q20-40C2-12-R-D		28.3	0.46	0.08	20.0	1.60	1.40	0.17	1.40	0.15	12.4	2.98
Q20-40C2-15-RV		26.7	0.58	0.08	18.0	1.50	1.20	0.16	1.00	0.13	13.4	2.50
Q20-40C2-16-R		25.5	0.51	0.07	19.0	1.50	1.50	0.17	1.30	0.15	6.60	1.88
Q20-40C2-2-R		29.8	0.49	0.08	23.0	1.80	1.42	0.17	1.02	0.12	5.73	1.13
Q20-40C2-3-R		28.5	0.37	0.07	22.0	1.80	1.20	0.16	1.30	0.15	8.98	2.60
Q20-40C2-6-R		30.8	0.55	0.09	21.0	1.50	1.60	0.16	1.50	0.16	1.32	1.37
Q20-40C2-7-RV		28.6	0.57	0.09	18.0	1.70	1.30	0.16	1.10	0.14	10.3	2.80
Q20-40C2-8-R		30.5	0.43	0.06	21.0	1.70	1.30	0.19	1.20	0.14	6.91	2.29
LAB RESULT - ALPHA												
Q20-40C-11-R		27.0							1.30	0.53	12.9	4.76
Q20-40C-12-R		27.8							1.30	0.56	13.9	5.95
Q20-40C-2-R		27.0							1.10	0.52	12.2	4.16

APPENDIX B - ANALYTICAL RESULTS FOR PART A COMPARABILITY STUDY

			Cesium-137 pCi/g		Potassium-40 pCi/g		Radium-226 pCi/g		Thorium-232 pCi/g		Calculated Uranium,Total ppm	
Sample Id	**Det Ht (m)**	**Moisture (%)**	**Result**	**TPU/Err**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Er**	**Result**	**TPU/Err**
Q20-40C-4-R		33.5							1.20	0.51	9.44	3.57
Q20-40C-7-R		26.0							1.40	0.52	13.5	4.76
Q20-40C2-11-R		26.7							1.40	0.51	13.7	4.76
Q20-40C2-12-R		27.1							1.10	0.40	13.4	4.76
Q20-40C2-12-R-D		28.3							1.20	0.46	13.1	4.76
Q20-40C2-15-RV		26.7							0.98	0.37	19.1	6.55
Q20-40C2-16-R		25.5							1.30	0.54	10.6	3.87
Q20-40C2-2-R		29.8							1.40	0.58	15.2	5.35
Q20-40C2-3-R		28.5							1.20	0.56	11.5	3.87
Q20-40C2-6-R		30.8							1.40	0.52	6.21	2.08
Q20-40C2-7-RV		28.6							1.30	0.50	14.9	5.06
Q20-40C2-8-R		30.5							1.30	0.51	10.4	3.57

APPENDIX C

STATISTICAL EVALUATION OF DATA IN APPENDIX B TO ASSESS IF 95% UPPER CONFIDENCE LIMITS EXCEED FRLs

APPENDIX C
STATISTICAL EVALUATION OF DATA IN APPENDIX B

This appendix contains a statistical evaluation of data in Appendix B to assess if the 95% upper confidence limits (90% for cesium-137) exceed FRLs. Data are presented for cesium-137, potassium-40, radium-226, thorium-232, and total uranium. Further, all data are shown whether by gamma spectrometry, alpha spectrometry, or HPGe.

- "Max" refers to the largest value of a measurement for a given data set.
- "Mean" is the average value of the data set.
- "Std Dev" is the standard deviation of the data set.
- "UCL" is the upper confidence limit calculated for the standard deviation.
- "t-stat" is the calculated "t" value.
- "prob" is the calculated probability of a Type I error.
- "Pass/fail" indicates whether the UCL is greater than the FRL (whether the calculated probability of a Type I error is greater than 5.0%).
- "2 x FRL" indicates that if one or more samples have data greater than 2 times the FRL, the certification unit fails the hot spot criteria.

Certification Unit: N19 03:38 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	12
Max	**0.964**	**28.73**	**1.654**	**1.465**	**1.51**	**--**	**1.51**	**23.81**
Mean	0.63	20.5	1.42	1.30	1.33	--	1.33	12.9
St.Dev.	0.12	3.1	0.11	0.13	0.11	--	0.11	5.2
UCL	**0.68**	**22.1**	**1.48**	**1.37**	**1.39**	**--**	**1.39**	**15.6**
t-Stat	22.209	--	8.393	12.994	11.514	--	5.264	45.670
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**Pass**	**Pass**	**--**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**Pass**	**Pass**	**--**	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	12
Hits	0	0	0	0	12	12	12	12
Max	**--**	**--**	**--**	**--**	**2.125**	**2.067**	**1.71**	**24.29**
Mean	--	--	--	--	1.48	1.75	1.20	18.6
St.Dev.	--	--	--	--	0.25	0.19	0.19	3.9
UCL	**--**	**--**	**--**	**--**	**1.61**	**1.83**	**1.30**	**20.6**
t-Stat	--	--	--	--	3.040	5200.454	5.357	56.753
Prob.	--	--	--	--	0.6%	0.0%	0.0%	0.0%
Pass/Fail	**--**	**--**	**--**	**--**	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	**--**	**--**	**--**	**--**	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.51**	**22.07**	**0.98**	**--**	**--**	**--**	**1.02**	**29.38**
Mean	0.48	16.0	0.82	--	--	--	0.89	21.4
St.Dev.	0.03	3.2	0.09	--	--	--	0.09	5.5
UCL	**0.49**	**17.6**	**0.87**	**--**	**--**	**--**	**0.93**	**24.3**
t-Stat	101.090	--	33.595	--	--	--	24.998	38.015
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**--**	**--**	**--**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**--**	**--**	**--**	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.51**	**20.55**	**0.95**	**--**	**--**	**--**	**0.92**	**26.70**
Mean	0.46	15.5	0.83	--	--	--	0.84	20.0
St.Dev.	0.03	2.9	0.09	--	--	--	0.05	4.6
UCL	**0.47**	**16.9**	**0.88**	**--**	**--**	**--**	**0.87**	**22.4**
t-Stat	99.012	--	32.256	--	--	--	49.564	46.340
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**--**	**--**	**--**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**--**	**--**	**--**	**Pass**	**Pass**

Certification Unit: O18 04:17 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	12
Max	**0.98**	**24**	**1.2**	**1.5**	**1.356**	--	**1.336**	**40.48**
Mean	0.69	19.4	1.09	1.24	1.22	--	1.21	29.9
St.Dev.	0.12	2.1	0.06	0.12	0.10	--	0.10	5.8
UCL	**0.74**	**20.5**	**1.12**	**1.30**	**1.28**	--	**1.26**	**32.9**
t-Stat	20.964	--	34.914	16.382	16.638	--	10.420	31.217
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.44**	**2.07**	**1.34**	--
Mean	--	--	--	--	1.18	1.78	1.15	--
St.Dev.	--	--	--	--	0.17	0.17	0.12	--
UCL	--	--	--	--	**1.27**	**1.85**	**1.21**	--
t-Stat	--	--	--	--	10.283	5594.737	10.086	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.53**	**16.43**	**1.03**	--	--	--	**0.99**	**36.77**
Mean	0.48	13.7	0.90	--	--	--	0.87	29.2
St.Dev.	0.05	1.6	0.07	--	--	--	0.07	3.4
UCL	**0.50**	**14.6**	**0.93**	--	--	--	**0.91**	**31.0**
t-Stat	62.719	--	39.051	--	--	--	31.135	53.825
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.50**	**16.28**	**1.02**	--	--	--	**1.02**	**35.16**
Mean	0.46	13.4	0.89	--	--	--	0.87	29.7
St.Dev.	0.04	1.7	0.07	--	--	--	0.07	3.5
UCL	**0.47**	**14.3**	**0.93**	--	--	--	**0.90**	**31.5**
t-Stat	88.737	--	39.021	--	--	--	31.090	52.287
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	--	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	10
Max	0.982	31.6	1.42	2.05	1.95	--	2.05	35.98
Mean	0.64	20.3	1.15	1.33	1.32	--	1.36	23.6
St.Dev.	0.19	4.0	0.18	0.33	0.24	--	0.32	8.4
UCL	0.72	22.4	1.25	1.50	1.44	--	1.53	28.0
t-Stat	13.546	--	10.454	4.990	5.545	--	1.490	24.007
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	8.2%	0.0%
Pass/Fail	Pass	--	Pass	Pass	Pass	--	Fail	Pass
2 x (P/F)	Pass	--	Pass	Pass	Pass	--	Pass	Pass

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	--	1.7	1.8	1.7	280	1.5	82
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	1.47	1.94	1.32	--
Mean	--	--	--	--	1.30	1.61	1.18	--
St.Dev.	--	--	--	--	0.10	0.15	0.07	--
UCL	--	--	--	--	1.35	1.67	1.22	--
t-Stat	--	--	--	--	13.994	6354.739	15.798	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	Pass	Pass	Pass	--
2 x (P/F)	--	--	--	--	Pass	Pass	Pass	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	--	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	0.62	20.77	1.06	--	--	--	1.05	28.03
Mean	0.50	15.8	0.86	--	--	--	0.82	22.5
St.Dev.	0.06	2.2	0.10	--	--	--	0.11	3.5
UCL	0.52	16.9	0.91	--	--	--	0.88	24.4
t-Stat	50.908	--	30.081	--	--	--	21.337	58.694
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	Pass	--	Pass	--	--	--	Pass	Pass
2 x (P/F)	Pass	--	Pass	--	--	--	Pass	Pass

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	--	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	0.55	20.84	0.99	--	--	--	1.02	27.03
Mean	0.47	15.3	0.85	--	--	--	0.80	21.5
St.Dev.	0.05	2.1	0.08	--	--	--	0.09	3.3
UCL	0.49	16.4	0.89	--	--	--	0.85	23.2
t-Stat	62.859	--	37.946	--	--	--	28.001	62.598
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	Pass	--	Pass	--	--	--	Pass	Pass
2 x (P/F)	Pass	--	Pass	--	--	--	Pass	Pass

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GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	7
Max	**0.9075**	**34**	**1.38**	**2.46**	**2.13**	**--**	**2.46**	**205.4**
Mean	0.59	24.8	1.07	1.65	1.44	--	1.65	39.2
St.Dev.	0.19	7.6	0.26	0.42	0.40	--	0.42	54.8
UCL	**0.67**	**28.7**	**1.20**	**1.86**	**1.65**	**--**	**1.86**	**67.6**
t-Stat	14.617	--	8.418	1.263	2.251	--	-1.239	2.705
Prob.	0.0%	--	0.0%	11.6%	2.3%	--	87.9%	1.0%
Pass/Fail	**Pass**	**--**	**Pass**	**Fail**	**Pass**	**--**	**Fail**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**Pass**	**Pass**	**--**	**Pass**	**Fail**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.66**	**1.81**	**1.61**	--
Mean	--	--	--	--	1.32	1.46	1.27	--
St.Dev.	--	--	--	--	0.23	0.17	0.18	--
UCL	--	--	--	--	**1.44**	**1.53**	**1.37**	--
t-Stat	--	--	--	--	5.723	5795.627	4.286	--
Prob.	--	--	--	--	0.0%	0.0%	0.1%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.60**	**20.43**	**1.39**	--	--	--	**1.29**	**68.18**
Mean	0.31	16.6	0.89	--	--	--	0.89	24.0
St.Dev.	0.23	4.7	0.39	--	--	--	0.36	14.8
UCL	**0.39**	**19.0**	**1.09**	--	--	--	**1.07**	**31.4**
t-Stat	17.113	--	7.396	--	--	--	6.142	14.123
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.58**	**20.86**	**1.31**	--	--	--	**1.16**	**59.64**
Mean	0.38	18.5	1.02	--	--	--	1.00	26.1
St.Dev.	0.17	1.3	0.19	--	--	--	0.09	11.7
UCL	**0.45**	**19.2**	**1.12**	--	--	--	**1.05**	**31.9**
t-Stat	21.194	--	12.804	--	--	--	18.829	17.222
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	8	13	13	13	13	0	13	12
Max	**0.4035**	**20.2**	**1.615**	**1.647**	**1.685**	--	**1.685**	**22.6**
Mean	0.13	18.1	1.35	1.33	1.44	--	1.44	9.5
St.Dev.	0.13	1.6	0.14	0.16	0.16	--	0.16	7.1
UCL	**0.18**	**18.9**	**1.42**	**1.41**	**1.51**	--	**1.51**	**13.0**
t-Stat	35.458	--	8.992	10.851	5.934	--	1.452	36.807
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	8.6%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Fail**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	13	13	13	0
Hits	0	0	0	0	13	13	13	0
Max	--	--	--	--	**1.57**	**1.99**	**1.368**	--
Mean	--	--	--	--	1.40	1.72	1.23	--
St.Dev.	--	--	--	--	0.10	0.16	0.07	--
UCL	--	--	--	--	**1.45**	**1.78**	**1.26**	--
t-Stat	--	--	--	--	10.492	6342.397	13.573	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.31**	**19.23**	**1.35**	--	--	--	**1.15**	**34.84**
Mean	0.18	16.1	1.20	--	--	--	1.11	24.3
St.Dev.	0.08	1.6	0.08	--	--	--	0.04	6.6
UCL	**0.21**	**16.9**	**1.24**	--	--	--	**1.13**	**27.8**
t-Stat	53.445	--	22.377	--	--	--	37.381	30.228
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.32**	**18.04**	**1.37**	--	--	--	**1.18**	**35.63**
Mean	0.17	15.9	1.20	--	--	--	1.09	24.0
St.Dev.	0.08	1.2	0.09	--	--	--	0.05	6.4
UCL	**0.20**	**16.5**	**1.25**	--	--	--	**1.12**	**27.3**
t-Stat	53.461	--	19.402	--	--	--	29.294	31.397
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

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GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	4	12	12	12	12	0	12	12
Max	**0.382**	**24**	**1.6**	**1.6**	**1.4**	- -	**1.4**	**25.00**
Mean	0.09	20.2	1.29	1.16	1.20	- -	1.20	9.2
St.Dev.	0.10	1.7	0.30	0.22	0.15	- -	0.15	5.9
UCL	**0.13**	**21.1**	**1.44**	**1.27**	**1.28**	- -	**1.27**	**12.2**
t-Stat	47.201	–	4.799	10.303	11.675	- -	7.001	42.431
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	11
Hits	0	0	0	0	12	12	12	11
Max	- -	- -	- -	- -	**1.44**	**3.08**	**1.3**	**22.16**
Mean	- -	- -	- -	- -	1.11	1.65	1.06	10.9
St.Dev.	- -	- -	- -	- -	0.21	0.52	0.19	5.7
UCL	- -	- -	- -	- -	**1.22**	**1.85**	**1.15**	**14.0**
t-Stat	- -	–	- -	- -	9.609	1842.582	8.321	41.280
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	11	13	13	0	0	0	13	13
Max	**0.32**	**15.29**	**1.02**	- -	- -	- -	**1.03**	**37.04**
Mean	0.12	13.5	0.87	- -	- -	- -	0.84	20.3
St.Dev.	0.10	1.5	0.11	- -	- -	- -	0.15	6.8
UCL	**0.16**	**14.2**	**0.92**	- -	- -	- -	**0.92**	**23.7**
t-Stat	46.922	–	28.546	- -	- -	- -	15.692	32.535
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.30**	**14.82**	**1.10**	- -	- -	- -	**1.11**	**33.97**
Mean	0.13	13.8	0.93	- -	- -	- -	0.89	21.6
St.Dev.	0.08	1.2	0.09	- -	- -	- -	0.15	5.3
UCL	**0.16**	**14.4**	**0.98**	- -	- -	- -	**0.97**	**24.3**
t-Stat	53.965	–	31.061	- -	- -	- -	14.313	39.710
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	8	12	12	12	12	0	12	11
Max	**0.69**	**22.89**	**1.4**	**1.525**	**1.8**	- -	**1.8**	**25.49**
Mean	0.14	19.1	1.27	1.36	1.47	- -	1.45	11.8
St.Dev.	0.18	2.1	0.13	0.11	0.19	- -	0.19	6.9
UCL	**0.21**	**20.2**	**1.33**	**1.42**	**1.56**	- -	**1.55**	**15.4**
t-Stat	24.480	–	11.920	14.029	4.396	- -	0.852	35.238
Prob.	0.0%	–	0.0%	0.0%	0.1%	- -	20.6%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Fail**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	7
Hits	0	0	0	0	12	12	12	7
Max	- -	- -	- -	- -	**1.52**	**2.2**	**1.6**	**33.43**
Mean	- -	- -	- -	- -	1.33	1.66	1.28	13.8
St.Dev.	- -	- -	- -	- -	0.12	0.21	0.19	11.3
UCL	- -	- -	- -	- -	**1.39**	**1.74**	**1.38**	**22.1**
t-Stat	- -	–	- -	- -	10.940	4535.654	4.042	15.929
Prob.	- -	–	- -	- -	0.0%	0.0%	0.1%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.37**	**18.35**	**1.20**	- -	- -	- -	**1.24**	**39.57**
Mean	0.18	15.3	1.05	- -	- -	- -	1.11	24.3
St.Dev.	0.10	1.9	0.09	- -	- -	- -	0.11	8.2
UCL	**0.22**	**16.3**	**1.09**	- -	- -	- -	**1.17**	**28.6**
t-Stat	41.876	–	26.245	- -	- -	- -	11.885	24.283
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.28**	**17.86**	**1.19**	- -	- -	- -	**1.19**	**38.76**
Mean	0.15	15.1	1.03	- -	- -	- -	1.06	24.6
St.Dev.	0.07	1.9	0.07	- -	- -	- -	0.09	6.3
UCL	**0.18**	**16.1**	**1.07**	- -	- -	- -	**1.11**	**27.9**
t-Stat	59.473	–	31.595	- -	- -	- -	16.184	31.694
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

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GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	6	12	12	12	12	0	12	12
Max	**0.31**	**20**	**1.4**	**1.4**	**1.3**	--	**1.3**	**11.69**
Mean	0.12	17.6	0.98	0.94	0.99	--	0.99	8.5
St.Dev.	0.09	1.6	0.17	0.19	0.18	--	0.18	1.8
UCL	**0.15**	**18.5**	**1.07**	**1.03**	**1.08**	--	**1.08**	**9.4**
t-Stat	48.259	--	14.977	15.817	13.527	--	9.728	144.983
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	12
Hits	0	0	0	0	12	12	12	12
Max	--	--	--	--	**1.2**	**1.8**	**1.2**	**15.84**
Mean	--	--	--	--	0.83	1.32	0.80	11.7
St.Dev.	--	--	--	--	0.16	0.21	0.16	2.5
UCL	--	--	--	--	**0.92**	**1.40**	**0.88**	**13.0**
t-Stat	--	--	--	--	18.910	4543.238	15.531	95.578
Prob.	--	--	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.21**	**14.86**	**0.89**	--	--	--	**0.94**	**21.29**
Mean	0.13	13.5	0.81	--	--	--	0.75	16.4
St.Dev.	0.05	0.9	0.05	--	--	--	0.10	2.7
UCL	**0.15**	**14.0**	**0.83**	--	--	--	**0.80**	**17.9**
t-Stat	84.837	--	61.479	--	--	--	25.860	83.177
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.18**	**14.86**	**0.90**	--	--	--	**0.87**	**20.79**
Mean	0.12	13.3	0.84	--	--	--	0.75	16.7
St.Dev.	0.04	0.7	0.04	--	--	--	0.07	2.9
UCL	**0.14**	**13.7**	**0.86**	--	--	--	**0.79**	**18.3**
t-Stat	104.322	--	72.572	--	--	--	39.275	76.824
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	14	14	14	14	14	0	14	14
Hits	8	14	14	14	14	0	14	13
Max	**0.33**	**19.69**	**1.8**	**1.667**	**1.7**	--	**1.7**	**13.79**
Mean	0.12	17.6	1.41	1.28	1.38	--	1.38	8.0
St.Dev.	0.09	1.0	0.23	0.21	0.14	--	0.14	3.6
UCL	**0.15**	**18.1**	**1.52**	**1.38**	**1.45**	--	**1.45**	**9.7**
t-Stat	54.549	–	4.681	9.039	8.291	--	3.074	75.897
Prob.	0.0%	–	0.0%	0.0%	0.0%	--	0.4%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	10
Hits	0	0	0	0	14	14	14	10
Max	--	--	--	--	**1.5**	**2**	**1.4**	**19.26**
Mean	--	--	--	--	1.24	1.55	1.14	11.1
St.Dev.	--	--	--	--	0.15	0.22	0.15	4.6
UCL	--	--	--	--	**1.31**	**1.63**	**1.22**	**13.8**
t-Stat	--	–	--	--	11.639	4755.673	8.709	48.809
Prob.	--	–	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	–	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	–	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.23**	**16.52**	**1.44**	--	--	--	**1.20**	**22.88**
Mean	0.14	15.8	1.13	--	--	--	1.09	18.5
St.Dev.	0.06	0.5	0.15	--	--	--	0.08	3.2
UCL	**0.17**	**16.0**	**1.21**	--	--	--	**1.13**	**20.2**
t-Stat	67.584	–	12.935	--	--	--	18.541	69.688
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.22**	**16.52**	**1.38**	--	--	--	**1.22**	**22.96**
Mean	0.14	15.7	1.10	--	--	--	1.06	16.7
St.Dev.	0.05	0.6	0.12	--	--	--	0.09	3.8
UCL	**0.16**	**16.0**	**1.16**	--	--	--	**1.11**	**18.7**
t-Stat	89.812	–	17.855	--	--	--	16.646	59.083
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P18 02:50 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	15	15	15	15	15	0	15	15
Hits	11	15	15	15	15	0	15	12
Max	**0.74**	**22**	**1.6**	**1.97**	**1.6**	--	**1.97**	**38.92**
Mean	0.35	17.5	1.11	1.16	1.22	--	1.29	17.7
St.Dev.	0.25	2.3	0.19	0.27	0.23	--	0.27	11.4
UCL	**0.43**	**18.5**	**1.20**	**1.28**	**1.32**	--	**1.41**	**22.9**
t-Stat	16.299	--	12.112	9.250	8.163	--	3.043	21.780
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.4%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	15	15	15	8
Hits	0	0	0	0	15	15	15	8
Max	--	--	--	--	**1.59**	**2.6**	**1.4**	**42.78**
Mean	--	--	--	--	1.22	1.66	1.13	21.0
St.Dev.	--	--	--	--	0.22	0.42	0.16	16.4
UCL	--	--	--	--	**1.32**	**1.81**	**1.20**	**32.0**
t-Stat	--	--	--	--	8.407	2557.246	8.834	10.532
Prob.	--	--	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	10	12	12	0	0	0	12	12
Max	**0.53**	**19.12**	**1.20**	--	--	--	**1.08**	**33.92**
Mean	0.28	13.5	1.01	--	--	--	0.88	20.7
St.Dev.	0.24	2.6	0.13	--	--	--	0.13	11.7
UCL	**0.37**	**14.8**	**1.07**	--	--	--	**0.95**	**26.8**
t-Stat	16.268	--	18.872	--	--	--	16.118	18.198
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	11
Max	**0.54**	**17.86**	**1.19**	--	--	--	**1.07**	**33.92**
Mean	0.27	12.6	0.99	--	--	--	0.87	19.8
St.Dev.	0.22	2.5	0.12	--	--	--	0.13	11.4
UCL	**0.36**	**13.9**	**1.05**	--	--	--	**0.94**	**25.7**
t-Stat	17.430	--	20.836	--	--	--	16.411	18.940
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P18-11 05:41 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	5	12	12	12	12	0	12	9
Max	**0.97**	**21**	**1.4**	**1.2**	**1.3**	--	**1.3**	**18.59**
Mean	0.19	18.2	0.98	0.98	1.04	--	1.04	6.7
St.Dev.	0.28	1.6	0.18	0.15	0.17	--	0.17	5.2
UCL	**0.30**	**19.0**	**1.08**	**1.06**	**1.13**	--	**1.13**	**9.4**
t-Stat	14.869	–	13.855	18.492	13.464	--	9.395	50.316
Prob.	0.0%	–	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	11
Hits	0	0	0	0	12	12	12	11
Max	--	--	--	--	**1.6**	**2.9**	**1.4**	**30.64**
Mean	--	--	--	--	0.97	1.55	0.96	10.8
St.Dev.	--	--	--	--	0.24	0.54	0.21	8.5
UCL	--	--	--	--	**1.10**	**1.76**	**1.06**	**15.5**
t-Stat	--	–	--	--	10.381	1780.053	9.134	27.781
Prob.	--	–	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	–	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	–	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	7	12	12	0	0	0	12	9
Max	**0.32**	**16.20**	**1.01**	--	--	--	**0.84**	**17.72**
Mean	0.08	14.4	0.86	--	--	--	0.73	10.7
St.Dev.	0.08	1.4	0.08	--	--	--	0.10	5.4
UCL	**0.11**	**15.1**	**0.90**	--	--	--	**0.78**	**13.5**
t-Stat	53.983	–	37.894	--	--	--	28.088	45.845
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	7	12	12	0	0	0	12	10
Max	**0.16**	**16.08**	**0.96**	--	--	--	**0.85**	**17.94**
Mean	0.06	13.8	0.85	--	--	--	0.70	10.5
St.Dev.	0.05	1.4	0.06	--	--	--	0.09	5.0
UCL	**0.08**	**14.5**	**0.88**	--	--	--	**0.75**	**13.1**
t-Stat	99.422	–	51.286	--	--	--	30.713	49.267
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P18-12 03:45 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	15	15	15	15	15	0	15	15
Hits	7	15	15	15	15	0	15	14
Max	**0.27**	**26**	**2**	**1.6**	**1.8**	--	**1.8**	**14.69**
Mean	0.07	17.9	1.35	1.22	1.34	--	1.34	7.4
St.Dev.	0.09	3.1	0.35	0.30	0.28	--	0.29	2.4
UCL	**0.10**	**19.3**	**1.51**	**1.35**	**1.47**	--	**1.48**	**8.5**
t-Stat	60.432	--	3.873	7.593	5.024	--	2.071	118.382
Prob.	0.0%	--	0.1%	0.0%	0.0%	--	2.9%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	10
Hits	0	0	0	0	14	14	14	10
Max	--	--	--	--	**1.6**	**2**	**1.5**	**25.12**
Mean	--	--	--	--	1.24	1.52	1.19	9.8
St.Dev.	--	--	--	--	0.21	0.32	0.26	5.8
UCL	--	--	--	--	**1.34**	**1.63**	**1.31**	**13.1**
t-Stat	--	--	--	--	8.012	3262.632	4.480	39.531
Prob.	--	--	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	7	12	12	0	0	0	12	12
Max	**0.07**	**18.75**	**1.03**	--	--	--	**1.20**	**17.84**
Mean	0.04	15.7	0.95	--	--	--	1.07	13.5
St.Dev.	0.02	1.7	0.09	--	--	--	0.15	2.7
UCL	**0.05**	**16.6**	**1.00**	--	--	--	**1.15**	**14.9**
t-Stat	219.186	--	28.960	--	--	--	9.681	88.079
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.08**	**17.64**	**0.98**	--	--	--	**1.17**	**19.01**
Mean	0.06	15.1	0.93	--	--	--	1.03	14.3
St.Dev.	0.02	1.3	0.08	--	--	--	0.15	2.4
UCL	**0.07**	**15.8**	**0.97**	--	--	--	**1.11**	**15.5**
t-Stat	282.534	--	35.150	--	--	--	10.788	96.191
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P18-20 11:29 AM 07-Jul-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	7	13	13	13	13	0	13	13
Max	**0.4**	**20**	**1.5**	**1.5**	**1.7**	--	**1.7**	**19.19**
Mean	0.14	17.8	1.31	1.25	1.36	--	1.37	10.0
St.Dev.	0.13	1.2	0.14	0.16	0.24	--	0.24	4.8
UCL	**0.19**	**18.4**	**1.38**	**1.32**	**1.48**	--	**1.48**	**12.3**
t-Stat	33.617	--	10.251	12.797	5.182	--	2.033	54.616
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	3.2%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	0
Hits	0	0	0	0	14	14	14	0
Max	--	--	--	--	**1.4**	**2.5**	**1.4**	--
Mean	--	--	--	--	1.11	1.55	1.12	--
St.Dev.	--	--	--	--	0.17	0.33	0.16	--
UCL	--	--	--	--	**1.19**	**1.67**	**1.20**	--
t-Stat	--	--	--	--	12.996	3132.720	8.810	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	14	14	14	0	0	0	14	14
Hits	14	14	14	0	0	0	14	14
Max	**0.16**	**16.38**	**1.24**	--	--	--	**1.14**	**16.36**
Mean	0.08	15.0	1.14	--	--	--	1.04	13.7
St.Dev.	0.03	0.7	0.06	--	--	--	0.07	1.6
UCL	**0.09**	**15.3**	**1.17**	--	--	--	**1.08**	**14.4**
t-Stat	141.846	--	34.027	--	--	--	23.255	156.664
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.12**	**15.15**	**1.22**	--	--	--	**1.11**	**15.91**
Mean	0.08	14.4	1.07	--	--	--	1.00	13.1
St.Dev.	0.02	0.5	0.07	--	--	--	0.09	2.1
UCL	**0.08**	**14.6**	**1.11**	--	--	--	**1.04**	**14.2**
t-Stat	206.483	--	30.558	--	--	--	19.633	117.540
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P18-40 08:53 AM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	14	14	14	14	13	0	14	14
Hits	6	14	14	14	13	0	14	9
Max	**0.739**	**19.29**	**1.79**	**1.63**	**1.724**	- -	**1.9**	**41.38**
Mean	0.19	16.5	1.32	1.23	1.28	- -	1.38	11.6
St.Dev.	0.23	2.5	0.27	0.19	0.26	- -	0.29	12.2
UCL	**0.27**	**17.7**	**1.45**	**1.32**	**1.41**	- -	**1.52**	**17.4**
t-Stat	19.468	–	5.225	10.961	5.810	- -	1.501	21.557
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	7.9%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Fail**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	3
Hits	0	0	0	0	14	14	14	3
Max	- -	- -	- -	- -	**1.81**	**2.5**	**1.4**	**9.98**
Mean	- -	- -	- -	- -	1.25	1.51	1.10	7.5
St.Dev.	- -	- -	- -	- -	0.28	0.40	0.19	2.3
UCL	- -	- -	- -	- -	**1.38**	**1.65**	**1.19**	**11.3**
t-Stat	- -	–	- -	- -	6.053	2598.594	8.011	56.544
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.33**	**16.58**	**1.26**	- -	- -	- -	**1.09**	**21.27**
Mean	0.14	14.2	1.07	- -	- -	- -	0.97	15.4
St.Dev.	0.07	1.6	0.11	- -	- -	- -	0.07	2.2
UCL	**0.17**	**15.0**	**1.12**	- -	- -	- -	**1.00**	**16.5**
t-Stat	68.262	–	20.281	- -	- -	- -	28.627	110.194
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	12	13	13	0	0	0	13	13
Max	**0.27**	**16.09**	**1.25**	- -	- -	- -	**1.05**	**21.34**
Mean	0.13	13.5	1.05	- -	- -	- -	0.93	14.9
St.Dev.	0.06	1.3	0.11	- -	- -	- -	0.06	2.7
UCL	**0.15**	**14.1**	**1.11**	- -	- -	- -	**0.96**	**16.2**
t-Stat	81.780	–	20.764	- -	- -	- -	31.889	91.294
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

Certification Unit: P19

02:59 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	12
Max	**0.894**	**25.37**	**1.211**	**1.334**	**1.361**	--	**1.334**	**38.11**
Mean	0.63	19.8	1.07	1.22	1.26	--	1.24	23.0
St.Dev.	0.14	2.7	0.09	0.10	0.07	--	0.07	5.7
UCL	**0.68**	**21.2**	**1.11**	**1.27**	**1.30**	--	**1.27**	**26.0**
t-Stat	18.869	--	24.536	21.139	22.594	--	13.710	35.582
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.58**	**1.75**	**1.62**	--
Mean	--	--	--	--	1.35	1.52	1.12	--
St.Dev.	--	--	--	--	0.18	0.17	0.19	--
UCL	--	--	--	--	**1.45**	**1.59**	**1.21**	--
t-Stat	--	--	--	--	6.664	5656.896	7.134	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**1.14**	**24.41**	**1.70**	--	--	--	**1.70**	**53.44**
Mean	0.50	14.4	0.92	--	--	--	0.87	24.0
St.Dev.	0.25	3.6	0.30	--	--	--	0.30	10.9
UCL	**0.60**	**16.2**	**1.08**	--	--	--	**1.03**	**29.6**
t-Stat	12.450	--	9.110	--	--	--	7.225	18.505
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**1.07**	**23.85**	**1.62**	--	--	--	**1.63**	**51.95**
Mean	0.55	14.8	0.94	--	--	--	0.87	25.2
St.Dev.	0.22	4.3	0.32	--	--	--	0.35	12.2
UCL	**0.64**	**17.0**	**1.10**	--	--	--	**1.05**	**31.5**
t-Stat	13.609	--	8.359	--	--	--	6.229	16.086
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P19-20 02:09 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	19	19	19	19	19	0	19	19
Hits	10	19	19	19	19	0	19	14
Max	**0.3**	**24.6**	**1.463**	**1.4**	**1.62**	--	**1.489**	**32.08**
Mean	0.11	17.8	1.17	1.12	1.22	--	1.15	9.7
St.Dev.	0.08	2.6	0.14	0.18	0.24	--	0.19	6.8
UCL	**0.14**	**18.8**	**1.23**	**1.19**	**1.31**	--	**1.23**	**12.4**
t-Stat	70.427	--	16.480	16.030	8.623	--	7.776	46.314
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	19	19	19	0
Hits	0	0	0	0	19	19	19	0
Max	--	--	--	--	**1.628**	**18.902**	**1.295**	--
Mean	--	--	--	--	1.16	2.45	1.09	--
St.Dev.	--	--	--	--	0.19	4.03	0.10	--
UCL	--	--	--	--	**1.24**	**3.68**	**1.14**	--
t-Stat	--	--	--	--	12.115	299.965	16.928	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	0	12	0	0	0	12	12
Hits	12	0	12	0	0	0	12	12
Max	**0.33**	--	**1.26**	--	--	--	**1.06**	**19.15**
Mean	0.16	--	0.97	--	--	--	0.89	14.0
St.Dev.	0.08	--	0.16	--	--	--	0.14	2.9
UCL	**0.19**	--	**1.05**	--	--	--	**0.97**	**15.5**
t-Stat	54.486	--	16.050	--	--	--	14.599	81.912
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	0	12	0	0	0	12	12
Hits	12	0	12	0	0	0	12	12
Max	**0.30**	--	**1.32**	--	--	--	**1.08**	**21.82**
Mean	0.16	--	1.01	--	--	--	0.89	15.0
St.Dev.	0.06	--	0.18	--	--	--	0.15	3.2
UCL	**0.18**	--	**1.10**	--	--	--	**0.97**	**16.6**
t-Stat	72.743	--	13.080	--	--	--	14.119	73.405
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P19-23 04:21 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	18	18	18	18	18	0	18	18
Hits	18	18	18	18	18	0	18	17
Max	**0.873**	**21**	**1.6**	**1.809**	**1.7**	- -	**1.809**	**40.54**
Mean	0.62	16.8	1.34	1.36	1.38	- -	1.39	18.3
St.Dev.	0.15	3.1	0.32	0.22	0.19	- -	0.22	9.3
UCL	**0.67**	**18.0**	**1.47**	**1.45**	**1.46**	- -	**1.48**	**22.1**
t-Stat	21.528	–	4.817	8.718	7.111	- -	2.163	29.012
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	2.3%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	18	18	18	12
Hits	0	0	0	0	18	18	18	12
Max	- -	- -	- -	- -	**1.6**	**2.3**	**1.5**	**33.34**
Mean	- -	- -	- -	- -	1.34	1.78	1.26	23.6
St.Dev.	- -	- -	- -	- -	0.12	0.18	0.13	5.9
UCL	- -	- -	- -	- -	**1.39**	**1.84**	**1.31**	**26.7**
t-Stat	- -	–	- -	- -	13.029	6740.494	8.055	34.026
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.64**	**16.35**	**1.09**	- -	- -	- -	**1.11**	**34.08**
Mean	0.54	13.7	0.92	- -	- -	- -	0.96	27.8
St.Dev.	0.07	1.1	0.07	- -	- -	- -	0.07	3.2
UCL	**0.56**	**14.2**	**0.95**	- -	- -	- -	**0.99**	**29.4**
t-Stat	46.288	–	39.749	- -	- -	- -	27.812	60.341
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	13	13	13	0	0	0	13	13
Max	**0.63**	**15.61**	**1.06**	- -	- -	- -	**1.09**	**31.53**
Mean	0.52	13.3	0.91	- -	- -	- -	0.93	26.7
St.Dev.	0.08	1.0	0.06	- -	- -	- -	0.07	3.1
UCL	**0.55**	**13.8**	**0.94**	- -	- -	- -	**0.96**	**28.2**
t-Stat	39.253	–	45.698	- -	- -	- -	28.543	65.336
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

Certification Unit: P19-40 01:28 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	15	15	15	15	15	0	15	15
Hits	15	15	15	15	15	0	15	15
Max	**0.991**	**25.83**	**1.392**	**1.495**	**1.503**	--	**1.463**	**27.33**
Mean	0.59	18.2	1.03	1.17	1.18	--	1.14	18.6
St.Dev.	0.20	4.0	0.16	0.19	0.18	--	0.18	5.6
UCL	**0.65**	**20.0**	**1.10**	**1.26**	**1.26**	--	**1.22**	**21.2**
t-Stat	15.804	--	16.230	12.812	11.389	--	7.905	43.863
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	15	15	15	0
Hits	0	0	0	0	15	15	15	0
Max	--	--	--	--	**1.54**	**1.72**	**1.28**	--
Mean	--	--	--	--	1.21	1.35	1.06	--
St.Dev.	--	--	--	--	0.20	0.19	0.13	--
UCL	--	--	--	--	**1.30**	**1.42**	**1.12**	--
t-Stat	--	--	--	--	9.319	5578.077	12.598	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.58**	**16.00**	**1.34**	--	--	--	**1.11**	**25.48**
Mean	0.47	12.8	0.89	--	--	--	0.79	19.1
St.Dev.	0.11	2.5	0.22	--	--	--	0.19	4.0
UCL	**0.51**	**14.1**	**1.01**	--	--	--	**0.88**	**21.1**
t-Stat	30.126	--	12.447	--	--	--	13.228	54.240
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.57**	**15.61**	**1.38**	--	--	--	**1.03**	**27.51**
Mean	0.45	12.6	0.88	--	--	--	0.78	19.8
St.Dev.	0.07	2.2	0.24	--	--	--	0.15	3.5
UCL	**0.48**	**13.8**	**1.01**	--	--	--	**0.86**	**21.6**
t-Stat	48.297	--	11.873	--	--	--	16.524	61.150
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: P20-30 10:57 AM 07-Jul-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	12	12	12	12	12	0	12	12
Max	**0.788**	**24.62**	**1.664**	**2.214**	**1.793**	--	**2.214**	**26.88**
Mean	0.66	22.2	1.08	1.36	1.36	--	1.41	21.0
St.Dev.	0.09	1.3	0.21	0.37	0.19	--	0.34	3.3
UCL	**0.69**	**22.9**	**1.19**	**1.55**	**1.46**	--	**1.59**	**22.7**
t-Stat	28.403	--	10.110	4.157	6.273	--	0.864	64.143
Prob.	0.0%	--	0.0%	0.1%	0.0%	--	20.3%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Fail**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.85**	**1.885**	**1.424**	--
Mean	--	--	--	--	1.30	1.51	1.16	--
St.Dev.	--	--	--	--	0.24	0.17	0.14	--
UCL	--	--	--	--	**1.43**	**1.57**	**1.23**	--
t-Stat	--	--	--	--	5.627	5670.592	8.757	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.60**	**20.00**	**1.07**	--	--	--	**1.10**	**24.28**
Mean	0.52	17.8	0.94	--	--	--	0.95	20.1
St.Dev.	0.05	0.8	0.08	--	--	--	0.07	2.5
UCL	**0.54**	**18.3**	**0.98**	--	--	--	**0.99**	**21.4**
t-Stat	65.108	--	32.073	--	--	--	27.365	86.086
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.55**	**20.00**	**1.09**	--	--	--	**1.05**	**22.52**
Mean	0.52	17.7	0.94	--	--	--	0.95	20.4
St.Dev.	0.03	1.0	0.06	--	--	--	0.07	1.7
UCL	**0.53**	**18.2**	**0.97**	--	--	--	**0.99**	**21.3**
t-Stat	114.605	--	40.592	--	--	--	28.336	128.184
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q16-33 05:28 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	8	13	13	12	13	0	12	8
Max	**0.615**	**23.55**	**1.84**	**1.751**	**1.74**	--	**1.751**	**35.23**
Mean	0.25	15.2	1.23	1.30	1.37	--	1.31	19.7
St.Dev.	0.22	3.6	0.30	0.38	0.27	--	0.38	12.4
UCL	**0.34**	**16.9**	**1.38**	**1.48**	**1.50**	--	**1.49**	**25.9**
t-Stat	18.959	–	5.647	4.811	4.405	--	1.853	18.097
Prob.	0.0%	–	0.0%	0.0%	0.0%	--	4.4%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	13	13	13	1
Hits	0	0	0	0	13	13	13	1
Max	--	--	--	--	**1.642**	**1.719**	**1.377**	**33.73**
Mean	--	--	--	--	1.30	1.54	1.26	33.7
St.Dev.	--	--	--	--	0.15	0.13	0.07	--
UCL	--	--	--	--	**1.38**	**1.59**	**1.30**	--
t-Stat	--	–	--	--	9.786	7537.337	12.059	--
Prob.	--	–	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	–	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	–	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.31**	**19.76**	**1.21**	--	--	--	**1.19**	**35.44**
Mean	0.16	15.5	1.13	--	--	--	1.11	21.4
St.Dev.	0.10	1.5	0.07	--	--	--	0.05	7.2
UCL	**0.19**	**16.3**	**1.17**	--	--	--	**1.14**	**25.1**
t-Stat	44.832	–	26.504	--	--	--	25.111	29.164
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.29**	**18.34**	**1.25**	--	--	--	**1.16**	**33.25**
Mean	0.16	15.2	1.11	--	--	--	1.11	22.1
St.Dev.	0.09	1.1	0.07	--	--	--	0.04	6.9
UCL	**0.20**	**15.8**	**1.15**	--	--	--	**1.13**	**25.7**
t-Stat	48.318	–	31.085	--	--	--	34.118	30.005
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q16-34 04:30 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	9	12	12	12	12	0	12	12
Max	**0.697**	**18.56**	**1.474**	**1.57**	**1.408**	--	**1.57**	**32.98**
Mean	0.22	16.1	1.21	1.27	1.25	--	1.29	17.5
St.Dev.	0.20	1.9	0.13	0.19	0.12	--	0.14	7.7
UCL	**0.30**	**17.1**	**1.28**	**1.37**	**1.32**	--	**1.36**	**21.5**
t-Stat	20.799	--	12.618	9.616	13.290	--	5.398	28.873
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.445**	**2.114**	**1.318**	--
Mean	--	--	--	--	1.20	1.43	1.10	--
St.Dev.	--	--	--	--	0.15	0.25	0.14	--
UCL	--	--	--	--	**1.28**	**1.53**	**1.17**	--
t-Stat	--	--	--	--	11.500	3825.742	10.003	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.27**	**14.95**	**1.24**	--	--	--	**1.22**	**29.62**
Mean	0.16	13.2	1.10	--	--	--	1.03	19.8
St.Dev.	0.08	1.8	0.15	--	--	--	0.18	6.6
UCL	**0.19**	**14.1**	**1.18**	--	--	--	**1.13**	**23.2**
t-Stat	54.625	--	13.414	--	--	--	8.824	32.663
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	11
Max	**0.31**	**14.46**	**1.23**	--	--	--	**1.16**	**29.59**
Mean	0.15	13.0	1.06	--	--	--	0.99	18.7
St.Dev.	0.08	1.0	0.19	--	--	--	0.22	7.1
UCL	**0.19**	**13.5**	**1.16**	--	--	--	**1.11**	**22.4**
t-Stat	51.217	--	11.681	--	--	--	8.038	31.032
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q17-10 04:53 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	8	12	12	12	12	0	12	9
Max	**0.463**	**19.63**	**1.365**	**1.58**	**1.634**	--	**1.58**	**37.63**
Mean	0.21	16.5	1.17	1.33	1.38	--	1.32	19.0
St.Dev.	0.17	2.1	0.11	0.14	0.18	--	0.12	12.2
UCL	**0.28**	**17.6**	**1.23**	**1.40**	**1.47**	--	**1.38**	**25.3**
t-Stat	24.521	–	16.922	11.433	6.266	--	5.127	17.934
Prob.	0.0%	–	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.29**	**1.68**	**1.272**	--
Mean	--	--	--	--	1.12	1.41	1.12	--
St.Dev.	--	--	--	--	0.11	0.18	0.12	--
UCL	--	--	--	--	**1.18**	**1.48**	**1.18**	--
t-Stat	--	–	--	--	18.680	5433.406	11.307	--
Prob.	--	–	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	–	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	–	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.40**	**16.09**	**1.09**	--	--	--	**1.23**	**37.18**
Mean	0.11	14.3	1.01	--	--	--	1.03	16.8
St.Dev.	0.10	1.1	0.05	--	--	--	0.11	7.4
UCL	**0.15**	**14.9**	**1.04**	--	--	--	**1.08**	**20.6**
t-Stat	45.365	–	46.605	--	--	--	15.058	30.642
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.38**	**16.22**	**1.10**	--	--	--	**1.16**	**36.48**
Mean	0.12	14.0	1.01	--	--	--	1.00	16.6
St.Dev.	0.09	1.1	0.05	--	--	--	0.09	7.0
UCL	**0.16**	**14.6**	**1.04**	--	--	--	**1.05**	**20.3**
t-Stat	48.530	–	46.561	--	--	--	18.791	32.223
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q17-30 04:36 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	3	12	12	12	12	0	12	10
Max	**0.429**	**22.84**	**1.485**	**1.646**	**1.936**	--	**1.52**	**22.31**
Mean	0.10	17.3	1.26	1.35	1.32	--	1.26	11.3
St.Dev.	0.12	2.9	0.14	0.18	0.25	--	0.17	5.9
UCL	**0.14**	**18.8**	**1.34**	**1.44**	**1.45**	--	**1.35**	**14.4**
t-Stat	38.029	–	10.575	8.800	5.367	--	4.994	41.469
Prob.	0.0%	–	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.34**	**1.8**	**1.32**	--
Mean	--	--	--	--	1.24	1.48	1.18	--
St.Dev.	--	--	--	--	0.08	0.14	0.11	--
UCL	--	--	--	--	**1.28**	**1.53**	**1.24**	--
t-Stat	--	–	--	--	20.452	6994.915	9.655	--
Prob.	--	–	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	–	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	–	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	11	13	13	0	0	0	13	13
Max	**0.32**	**14.66**	**1.07**	--	--	--	**1.06**	**31.53**
Mean	0.08	13.4	0.99	--	--	--	0.98	13.2
St.Dev.	0.08	0.9	0.03	--	--	--	0.07	5.7
UCL	**0.11**	**13.8**	**1.01**	--	--	--	**1.01**	**16.0**
t-Stat	61.901	–	75.745	--	--	--	27.222	43.205
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	10	13	13	0	0	0	13	12
Max	**0.24**	**15.27**	**1.09**	--	--	--	**1.07**	**25.35**
Mean	0.07	13.7	1.02	--	--	--	0.99	13.5
St.Dev.	0.06	0.9	0.04	--	--	--	0.06	5.0
UCL	**0.09**	**14.1**	**1.04**	--	--	--	**1.02**	**16.0**
t-Stat	82.645	–	64.634	--	--	--	28.664	49.676
Prob.	0.0%	–	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q18-10 05:17 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	5	12	12	12	12	0	12	9
Max	**0.649**	**20**	**1.5**	**1.96**	**1.91**	--	**1.96**	**21.83**
Mean	0.13	16.5	1.29	1.45	1.43	--	1.44	8.8
St.Dev.	0.18	2.3	0.18	0.21	0.29	--	0.25	5.9
UCL	**0.20**	**17.7**	**1.38**	**1.55**	**1.58**	--	**1.57**	**11.9**
t-Stat	23.977	--	7.782	5.905	3.218	--	0.850	42.986
Prob.	0.0%	--	0.0%	0.0%	0.4%	--	20.7%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Fail**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	2
Hits	0	0	0	0	12	12	12	2
Max	--	--	--	--	**1.552**	**1.7**	**1.38**	**24.66**
Mean	--	--	--	--	1.23	1.39	1.11	14.9
St.Dev.	--	--	--	--	0.15	0.16	0.11	13.8
UCL	--	--	--	--	**1.31**	**1.45**	**1.16**	**76.5**
t-Stat	--	--	--	--	10.901	5999.007	12.764	6.881
Prob.	--	--	--	--	0.0%	0.0%	0.0%	4.6%
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	10	12	12	0	0	0	12	12
Max	**0.17**	**15.42**	**1.22**	--	--	--	**1.13**	**16.98**
Mean	0.07	14.0	1.09	--	--	--	1.07	12.6
St.Dev.	0.04	0.8	0.07	--	--	--	0.05	2.2
UCL	**0.09**	**14.4**	**1.13**	--	--	--	**1.10**	**13.7**
t-Stat	106.286	--	31.629	--	--	--	28.292	111.249
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.16**	**15.79**	**1.21**	--	--	--	**1.13**	**21.04**
Mean	0.08	13.6	1.09	--	--	--	1.06	12.5
St.Dev.	0.04	0.9	0.06	--	--	--	0.04	3.3
UCL	**0.09**	**14.0**	**1.12**	--	--	--	**1.08**	**14.3**
t-Stat	107.931	--	33.196	--	--	--	39.537	72.194
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q18-30 04:09 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	4	12	12	11	12	0	11	8
Max	**0.2**	**18**	**1.53**	**1.48**	**1.58**	- -	**1.48**	**13.28**
Mean	0.09	15.3	1.27	1.17	1.24	- -	1.19	6.0
St.Dev.	0.05	1.6	0.13	0.25	0.21	- -	0.26	3.2
UCL	**0.11**	**16.2**	**1.34**	**1.30**	**1.35**	- -	**1.32**	**7.7**
t-Stat	82.948	–	11.238	8.561	7.688	- -	4.115	81.001
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	0.1%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	4
Hits	0	0	0	0	12	12	12	4
Max	- -	- -	- -	- -	**1.219**	**1.4**	**1.255**	**10.75**
Mean	- -	- -	- -	- -	1.11	1.30	1.12	7.7
St.Dev.	- -	- -	- -	- -	0.12	0.11	0.08	2.4
UCL	- -	- -	- -	- -	**1.18**	**1.34**	**1.16**	**10.5**
t-Stat	- -	–	- -	- -	16.947	8804.629	16.415	62.939
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.20**	**14.34**	**1.30**	- -	- -	- -	**1.12**	**17.52**
Mean	0.11	13.0	1.19	- -	- -	- -	1.02	13.2
St.Dev.	0.05	0.7	0.08	- -	- -	- -	0.06	2.7
UCL	**0.13**	**13.3**	**1.23**	- -	- -	- -	**1.05**	**14.6**
t-Stat	81.982	–	22.393	- -	- -	- -	29.997	87.752
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.15**	**14.09**	**1.33**	- -	- -	- -	**1.08**	**18.12**
Mean	0.10	12.5	1.21	- -	- -	- -	1.01	13.0
St.Dev.	0.04	0.7	0.09	- -	- -	- -	0.04	2.7
UCL	**0.12**	**12.8**	**1.26**	- -	- -	- -	**1.03**	**14.4**
t-Stat	123.260	–	18.079	- -	- -	- -	37.918	89.014
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

Certification Unit: Q18-40 10:19 AM 07-Jul-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	0	12	12	0	12	12
Hits	3	12	0	12	12	0	12	1
Max	**0.201**	**16.4**	- -	**2.1**	**1.87**	- -	**2.1**	**22.67**
Mean	0.09	13.7	- -	1.43	1.43	- -	1.43	6.8
St.Dev.	0.05	2.0	- -	0.28	0.24	- -	0.28	5.1
UCL	**0.11**	**14.8**	- -	**1.57**	**1.56**	- -	**1.57**	**9.5**
t-Stat	84.493	–	- -	4.642	3.760	- -	0.928	50.790
Prob.	0.0%	–	- -	0.0%	0.2%	- -	18.7%	0.0%
Pass/Fail	**Pass**	–	- -	**Pass**	**Pass**	- -	**Fail**	**Pass**
2 x (P/F)	**Pass**	–	- -	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	- -	- -	- -	- -	**1.334**	**1.5405**	**1.3155**	- -
Mean	- -	- -	- -	- -	1.17	1.34	1.16	- -
St.Dev.	- -	- -	- -	- -	0.09	0.12	0.09	- -
UCL	- -	- -	- -	- -	**1.22**	**1.39**	**1.21**	- -
t-Stat	- -	–	- -	- -	19.380	8207.258	13.087	- -
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	- -
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	- -
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	- -

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	11
Max	**0.19**	**14.98**	**1.36**	- -	- -	- -	**1.17**	**15.03**
Mean	0.08	12.8	1.17	- -	- -	- -	1.03	10.8
St.Dev.	0.04	1.0	0.11	- -	- -	- -	0.08	3.3
UCL	**0.10**	**13.3**	**1.23**	- -	- -	- -	**1.07**	**12.5**
t-Stat	113.694	–	16.334	- -	- -	- -	21.183	74.136
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.15**	**15.49**	**1.31**	- -	- -	- -	**1.10**	**13.64**
Mean	0.08	12.4	1.14	- -	- -	- -	0.98	11.6
St.Dev.	0.04	1.3	0.10	- -	- -	- -	0.06	1.5
UCL	**0.09**	**13.1**	**1.19**	- -	- -	- -	**1.02**	**12.4**
t-Stat	119.626	–	19.733	- -	- -	- -	29.571	167.333
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

Certification Unit: Q19-10 01:55 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	–	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	12	12	0	12	12
Hits	6	12	12	12	12	0	12	7
Max	0.415	18.3	1.67	1.86	1.72	- -	1.86	16.79
Mean	0.16	15.7	1.37	1.36	1.33	- -	1.37	7.1
St.Dev.	0.12	2.0	0.25	0.33	0.24	- -	0.32	5.3
UCL	0.21	16.8	1.50	1.53	1.46	- -	1.54	9.9
t-Stat	35.724	–	4.517	4.710	5.301	- -	1.362	49.079
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	10.0%	0.0%
Pass/Fail	Pass	–	Pass	Pass	Pass	- -	Fail	Pass
2 x (P/F)	Pass	–	Pass	Pass	Pass	- -	Pass	Pass

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	–	1.7	1.8	1.7	280	1.5	82
Samples	0	0	0	0	12	12	12	4
Hits	0	0	0	0	12	12	12	4
Max	- -	- -	- -	- -	1.395	1.5	1.307	9.31
Mean	- -	- -	- -	- -	1.19	1.38	1.11	5.3
St.Dev.	- -	- -	- -	- -	0.12	0.07	0.11	2.7
UCL	- -	- -	- -	- -	1.25	1.41	1.17	8.5
t-Stat	- -	–	- -	- -	15.226	13819.385	12.631	56.627
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	Pass	Pass	Pass	Pass
2 x (P/F)	- -	–	- -	- -	Pass	Pass	Pass	Pass

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	–	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	0.27	15.74	1.30	- -	- -	- -	1.10	22.48
Mean	0.15	13.3	1.14	- -	- -	- -	0.99	14.6
St.Dev.	0.10	1.6	0.11	- -	- -	- -	0.15	4.5
UCL	0.19	14.1	1.20	- -	- -	- -	1.07	16.9
t-Stat	45.379	–	18.136	- -	- -	- -	11.876	52.454
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	Pass	–	Pass	- -	- -	- -	Pass	Pass
2 x (P/F)	Pass	–	Pass	- -	- -	- -	Pass	Pass

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	1.4	–	1.7	1.8	1.7	280	1.5	82
Samples	12	12	12	0	0	0	12	12
Hits	10	12	12	0	0	0	12	11
Max	0.28	15.11	1.40	- -	- -	- -	1.09	18.86
Mean	0.14	13.5	1.15	- -	- -	- -	0.98	13.0
St.Dev.	0.09	1.6	0.13	- -	- -	- -	0.12	4.5
UCL	0.18	14.3	1.22	- -	- -	- -	1.04	15.4
t-Stat	48.732	–	14.952	- -	- -	- -	15.543	53.371
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	Pass	–	Pass	- -	- -	- -	Pass	Pass
2 x (P/F)	Pass	–	Pass	- -	- -	- -	Pass	Pass

Certification Unit: Q19-20 03:05 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	12	12	0	12	12
Hits	5	12	12	12	12	0	12	10
Max	**0.425**	**19.61**	**1.227**	**1.427**	**1.266**	--	**1.266**	**14.05**
Mean	0.09	16.5	1.10	1.17	1.18	--	1.16	6.6
St.Dev.	0.12	1.7	0.10	0.12	0.07	--	0.08	4.0
UCL	**0.14**	**17.4**	**1.16**	**1.23**	**1.21**	--	**1.20**	**8.6**
t-Stat	38.570	--	20.035	18.389	24.288	--	15.572	65.966
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	12	12	12	0
Hits	0	0	0	0	12	12	12	0
Max	--	--	--	--	**1.42**	**1.67**	**1.28**	--
Mean	--	--	--	--	1.16	1.35	1.09	--
St.Dev.	--	--	--	--	0.14	0.18	0.15	--
UCL	--	--	--	--	**1.23**	**1.42**	**1.16**	--
t-Stat	--	--	--	--	13.872	5441.956	9.888	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	11
Max	**0.14**	**23.95**	**1.33**	--	--	--	**1.21**	**14.08**
Mean	0.07	14.9	1.21	--	--	--	1.10	9.5
St.Dev.	0.03	2.9	0.09	--	--	--	0.05	3.7
UCL	**0.08**	**16.4**	**1.26**	--	--	--	**1.13**	**11.5**
t-Stat	160.100	--	17.941	--	--	--	26.296	67.001
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.14**	**22.63**	**1.34**	--	--	--	**1.15**	**14.02**
Mean	0.07	15.1	1.20	--	--	--	1.06	11.0
St.Dev.	0.03	2.4	0.11	--	--	--	0.05	1.7
UCL	**0.08**	**16.4**	**1.26**	--	--	--	**1.09**	**11.9**
t-Stat	158.463	--	16.397	--	--	--	30.213	146.792
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q19-30 10:33 AM 07-Jul-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	10	13	13	13	13	0	13	12
Max	**0.556**	**19.03**	**1.262**	**1.306**	**1.377**	- -	**1.357**	**19.47**
Mean	0.14	16.7	1.14	1.18	1.20	- -	1.18	8.4
St.Dev.	0.16	1.5	0.11	0.12	0.10	- -	0.10	5.3
UCL	**0.20**	**17.4**	**1.19**	**1.24**	**1.25**	- -	**1.23**	**11.0**
t-Stat	28.656	–	19.082	19.255	17.217	- -	11.186	49.924
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	0
Hits	0	0	0	0	14	14	14	0
Max	- -	- -	- -	- -	**1.46**	**1.64**	**1.27**	- -
Mean	- -	- -	- -	- -	1.20	1.40	1.06	- -
St.Dev.	- -	- -	- -	- -	0.17	0.16	0.12	- -
UCL	- -	- -	- -	- -	**1.28**	**1.46**	**1.12**	- -
t-Stat	- -	–	- -	- -	11.193	6564.981	13.471	- -
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	- -
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	- -
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	- -

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	10	12	12	0	0	0	12	9
Max	**0.28**	**16.39**	**1.21**	- -	- -	- -	**1.12**	**20.01**
Mean	0.10	14.6	1.11	- -	- -	- -	1.02	10.6
St.Dev.	0.10	1.3	0.07	- -	- -	- -	0.08	5.9
UCL	**0.14**	**15.2**	**1.14**	- -	- -	- -	**1.06**	**13.6**
t-Stat	44.274	–	28.426	- -	- -	- -	20.515	42.227
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	9	12	12	0	0	0	12	8
Max	**0.28**	**15.57**	**1.39**	- -	- -	- -	**1.08**	**17.96**
Mean	0.10	14.0	1.05	- -	- -	- -	0.91	9.8
St.Dev.	0.10	1.4	0.23	- -	- -	- -	0.18	5.8
UCL	**0.14**	**14.7**	**1.17**	- -	- -	- -	**1.01**	**12.8**
t-Stat	46.462	–	9.893	- -	- -	- -	11.130	42.881
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

Certification Unit: Q19-40 02:42 PM 09-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	14	14	14	14	14	0	14	14
Hits	6	14	14	14	14	0	14	12
Max	**0.324**	**23.51**	**1.453**	**1.535**	**1.443**	**- -**	**1.421**	**17.17**
Mean	0.09	19.7	1.25	1.23	1.29	- -	1.27	7.3
St.Dev.	0.10	2.3	0.11	0.16	0.09	- -	0.09	4.4
UCL	**0.12**	**20.8**	**1.30**	**1.30**	**1.34**	**- -**	**1.31**	**9.4**
t-Stat	48.794	--	15.809	13.194	16.729	- -	9.442	63.508
Prob.	0.0%	--	0.0%	0.0%	0.0%	- -	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**Pass**	**Pass**	**- -**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**Pass**	**Pass**	**- -**	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	13	13	13	0
Hits	0	0	0	0	13	13	13	0
Max	**- -**	**- -**	**- -**	**- -**	**1.37**	**1.81**	**1.24**	**- -**
Mean	- -	- -	- -	- -	1.15	1.35	1.04	- -
St.Dev.	- -	- -	- -	- -	0.12	0.17	0.10	- -
UCL	**- -**	**- -**	**- -**	**- -**	**1.21**	**1.41**	**1.09**	**- -**
t-Stat	- -	--	- -	- -	16.832	5843.645	17.357	- -
Prob.	- -	--	- -	- -	0.0%	0.0%	0.0%	- -
Pass/Fail	**- -**	**--**	**- -**	**- -**	**Pass**	**Pass**	**Pass**	**- -**
2 x (P/F)	**- -**	**--**	**- -**	**- -**	**Pass**	**Pass**	**Pass**	**- -**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.31**	**21.29**	**1.37**	**- -**	**- -**	**- -**	**1.18**	**15.99**
Mean	0.11	17.5	1.19	- -	- -	- -	1.09	11.1
St.Dev.	0.10	2.1	0.10	- -	- -	- -	0.07	2.9
UCL	**0.15**	**18.6**	**1.24**	**- -**	**- -**	**- -**	**1.12**	**12.5**
t-Stat	44.856	--	16.940	- -	- -	- -	19.314	86.006
Prob.	0.0%	--	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**- -**	**- -**	**- -**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**- -**	**- -**	**- -**	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	**--**	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	10	12	12	0	0	0	12	12
Max	**0.26**	**19.85**	**1.34**	**- -**	**- -**	**- -**	**1.14**	**16.93**
Mean	0.08	16.9	1.19	- -	- -	- -	1.04	12.0
St.Dev.	0.07	1.8	0.11	- -	- -	- -	0.09	2.4
UCL	**0.11**	**17.9**	**1.25**	**- -**	**- -**	**- -**	**1.08**	**13.3**
t-Stat	67.480	--	15.637	- -	- -	- -	18.128	99.518
Prob.	0.0%	--	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	**--**	**Pass**	**- -**	**- -**	**- -**	**Pass**	**Pass**
2 x (P/F)	**Pass**	**--**	**Pass**	**- -**	**- -**	**- -**	**Pass**	**Pass**

Certification Unit: Q20-20 02:42 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	9	13	13	13	13	0	13	13
Max	**0.7**	**26**	**1.461**	**1.7**	**1.68**	--	**1.68**	**23.09**
Mean	0.30	19.4	1.09	1.19	1.25	--	1.23	9.5
St.Dev.	0.28	2.5	0.18	0.17	0.19	--	0.19	6.9
UCL	**0.40**	**20.6**	**1.18**	**1.28**	**1.35**	--	**1.32**	**12.9**
t-Stat	14.263	--	12.364	12.574	8.330	--	5.123	38.146
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	13	13	13	0
Hits	0	0	0	0	13	13	13	0
Max	--	--	--	--	**1.6**	**1.72**	**1.4**	--
Mean	--	--	--	--	1.29	1.49	1.17	--
St.Dev.	--	--	--	--	0.18	0.14	0.14	--
UCL	--	--	--	--	**1.38**	**1.54**	**1.24**	--
t-Stat	--	--	--	--	8.273	7292.032	8.633	--
Prob.	--	--	--	--	0.0%	0.0%	0.0%	--
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	--
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	--

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.55**	**17.73**	**1.19**	--	--	--	**1.14**	**23.49**
Mean	0.33	15.7	0.98	--	--	--	0.98	15.8
St.Dev.	0.18	1.4	0.13	--	--	--	0.10	4.3
UCL	**0.40**	**16.5**	**1.05**	--	--	--	**1.03**	**18.0**
t-Stat	20.985	--	18.502	--	--	--	17.664	52.803
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	0	0	0	13	13
Hits	11	13	13	0	0	0	13	12
Max	**0.49**	**16.73**	**1.16**	--	--	--	**1.08**	**19.23**
Mean	0.30	15.1	0.95	--	--	--	0.93	13.8
St.Dev.	0.17	1.1	0.12	--	--	--	0.09	5.3
UCL	**0.36**	**15.6**	**1.01**	--	--	--	**0.98**	**16.5**
t-Stat	23.852	--	22.871	--	--	--	22.156	46.478
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

Certification Unit: Q20-30 02:48 PM 10-Jun-97

GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	17	17	17	17	17	0	17	17
Hits	17	17	17	17	17	0	17	17
Max	**0.695**	**27.34**	**1.4**	**1.5**	**1.6**	--	**1.6**	**15.84**
Mean	0.58	23.1	1.13	1.27	1.25	--	1.24	10.4
St.Dev.	0.08	2.7	0.16	0.15	0.17	--	0.17	3.2
UCL	**0.60**	**24.3**	**1.20**	**1.33**	**1.33**	--	**1.32**	**11.8**
t-Stat	44.789	--	14.428	14.874	11.037	--	6.173	91.358
Prob.	0.0%	--	0.0%	0.0%	0.0%	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	**Pass**	**Pass**	--	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	17	17	17	11
Hits	0	0	0	0	17	17	17	11
Max	--	--	--	--	**1.7**	**1.834**	**1.4**	**18.26**
Mean	--	--	--	--	1.39	1.50	1.21	14.4
St.Dev.	--	--	--	--	0.23	0.23	0.17	2.7
UCL	--	--	--	--	**1.49**	**1.57**	**1.28**	**15.8**
t-Stat	--	--	--	--	5.492	5089.371	6.831	83.708
Prob.	--	--	--	--	0.0%	0.0%	0.0%	0.0%
Pass/Fail	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	--	--	--	--	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	11	12	12	0	0	0	12	12
Hits	11	12	12	0	0	0	12	12
Max	**0.51**	**20.69**	**0.95**	--	--	--	**0.97**	**19.12**
Mean	0.45	17.9	0.79	--	--	--	0.87	15.6
St.Dev.	0.04	1.5	0.07	--	--	--	0.07	2.2
UCL	**0.46**	**18.6**	**0.83**	--	--	--	**0.91**	**16.7**
t-Stat	77.390	--	43.606	--	--	--	30.065	103.124
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	--	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.53**	**19.89**	**0.95**	--	--	--	**0.98**	**19.26**
Mean	0.44	17.7	0.81	--	--	--	0.88	16.3
St.Dev.	0.04	1.1	0.06	--	--	--	0.07	2.2
UCL	**0.46**	**18.3**	**0.84**	--	--	--	**0.91**	**17.4**
t-Stat	75.967	--	50.979	--	--	--	30.685	103.771
Prob.	0.0%	--	0.0%	--	--	--	0.0%	0.0%
Pass/Fail	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**
2 x (P/F)	**Pass**	--	**Pass**	--	--	--	**Pass**	**Pass**

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GAMMA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	13	13	13	13	13	0	13	13
Hits	13	13	13	13	13	0	13	12
Max	**0.63**	**22.14**	**1.551**	**1.459**	**1.616**	- -	**1.616**	**13.10**
Mean	0.51	20.1	1.32	1.23	1.27	- -	1.27	7.8
St.Dev.	0.08	1.7	0.21	0.18	0.21	- -	0.21	3.6
UCL	**0.54**	**20.9**	**1.43**	**1.32**	**1.37**	- -	**1.37**	**9.6**
t-Stat	41.301	–	6.428	11.500	7.597	- -	4.104	74.722
Prob.	0.0%	–	0.0%	0.0%	0.0%	- -	0.1%	0.0%
Pass/Fail	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	**Pass**	**Pass**	- -	**Pass**	**Pass**

ALPHA

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	0	0	0	0	14	14	14	14
Hits	0	0	0	0	14	14	14	14
Max	- -	- -	- -	- -	**1.732**	**1.9**	**1.409**	**18.99**
Mean	- -	- -	- -	- -	1.49	1.63	1.26	12.5
St.Dev.	- -	- -	- -	- -	0.16	0.14	0.12	3.0
UCL	- -	- -	- -	- -	**1.56**	**1.68**	**1.32**	**13.9**
t-Stat	- -	–	- -	- -	4.948	7494.379	7.487	85.951
Prob.	- -	–	- -	- -	0.0%	0.0%	0.0%	0.0%
Pass/Fail	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**
2 x (P/F)	- -	–	- -	- -	**Pass**	**Pass**	**Pass**	**Pass**

HPGe-1ft

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.52**	**17.31**	**1.04**	- -	- -	- -	**1.01**	**18.88**
Mean	0.40	15.2	0.91	- -	- -	- -	0.83	14.4
St.Dev.	0.07	1.7	0.09	- -	- -	- -	0.09	2.8
UCL	**0.43**	**16.0**	**0.96**	- -	- -	- -	**0.88**	**15.9**
t-Stat	49.772	–	31.516	- -	- -	- -	26.376	82.190
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

HPGe-1m

	Cesium-137	Potassium-40	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium, Total
FRL	**1.4**	–	**1.7**	**1.8**	**1.7**	**280**	**1.5**	**82**
Samples	12	12	12	0	0	0	12	12
Hits	12	12	12	0	0	0	12	12
Max	**0.51**	**16.83**	**1.04**	- -	- -	- -	**0.99**	**18.25**
Mean	0.40	15.0	0.91	- -	- -	- -	0.81	13.5
St.Dev.	0.06	1.5	0.09	- -	- -	- -	0.08	2.7
UCL	**0.43**	**15.8**	**0.96**	- -	- -	- -	**0.85**	**14.9**
t-Stat	57.284	–	30.375	- -	- -	- -	29.260	88.454
Prob.	0.0%	–	0.0%	- -	- -	- -	0.0%	0.0%
Pass/Fail	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**
2 x (P/F)	**Pass**	–	**Pass**	- -	- -	- -	**Pass**	**Pass**

APPENDIX D

STATISTICAL CORRELATION ANALYSIS

APPENDIX D
STATISTICAL CORRELATION ANALYSIS

This appendix contains the statistical analyses using a commercial statistics program on data for the Part B characterization comparability study to demonstrate the degree of correlation between laboratory and HPGe data.

Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height (w/o PBC-03-01)
3/8/1997 3:27 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	2.20245	4.11399	0.535355	0.6070
Slope	0.969319	0.0365488	26.5212	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	67344.1	1	67344.1	703.38	0.0000
Residual	765.954	8	95.7442		
Total (Corr.)	68110.1	9			

Correlation Coefficient = 0.994361
R-squared = 98.8754 percent
Standard Error of Est. = 9.7849

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 2.20245 + 0.969319*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 98.8754% of the variability in HMean. The correlation coefficient equals 0.994361, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 9.7849. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height (w/o PBC-03-01)
3/8/1997 3:27 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	95.00% Prediction Limits Upper	95.00% Confidence Limits Lower	95.00% Confidence Limits Upper
0.0	2.20245	-22.2749	26.6798	-7.28446	11.6894
20.0	21.5888	-2.51309	45.6908	13.1174	30.0603
50.0	50.6684	26.9154	74.4214	43.2477	58.0891
82.0	81.6866	58.0121	105.361	74.5209	88.8524
1030.0	1000.6	916.639	1084.56	919.728	1081.48

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height (w/o PBC-03-01)
3/8/1997 3:27 PM

Influential Points

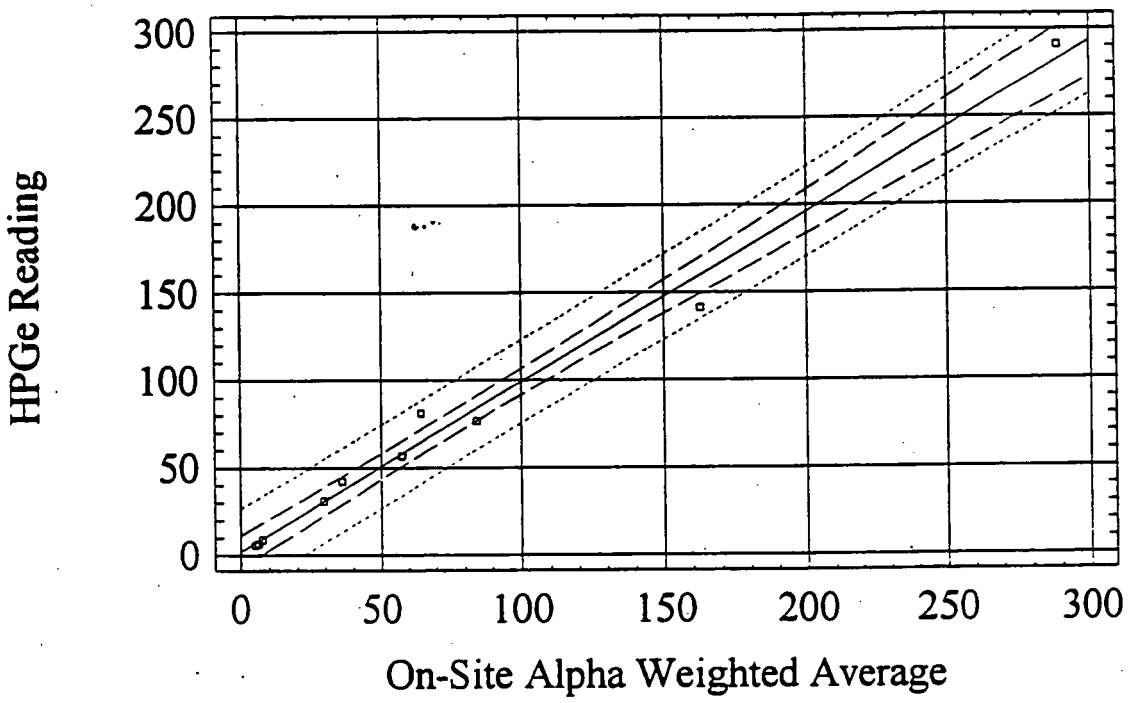
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	288.805	290.741	282.147	2.05	0.742683

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Total Uranium at 1 foot (w/o PBC-03-01)



Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height (w/o PEC-03-01)
3/8/1997 3:30 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	1.51658	5.61154	0.270261	0.7938
Slope	0.949428	0.0494692	19.1923	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	65522.3	1	65522.3	368.34	0.0000
Residual	1423.07	8	177.883		
Total (Corr.)	66945.4	9			

Correlation Coefficient = 0.989314
R-squared = 97.8743 percent
Standard Error of Est. = 13.3373

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 1.51658 + 0.949428*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 97.8743% of the variability in HMean. The correlation coefficient equals 0.989314, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 13.3373. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height (w/o PBC-03-01)
3/8/1997 3:30 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	95.00% Prediction Limits Upper	95.00% Confidence Limits Lower	95.00% Confidence Limits Upper
0.0	1.51658	-31.8507	34.8839	-11.4237	14.4568
20.0	20.5052	-12.3526	53.3629	8.94198	32.0683
50.0	48.988	16.6069	81.3691	38.8582	59.1178
82.0	79.3697	47.1022	111.637	69.6094	89.13
1030.0	979.428	865.79	1093.07	870.032	1088.82

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height (w/o PBC-03-01)
3/8/1997 3:30 PM

Influential Points

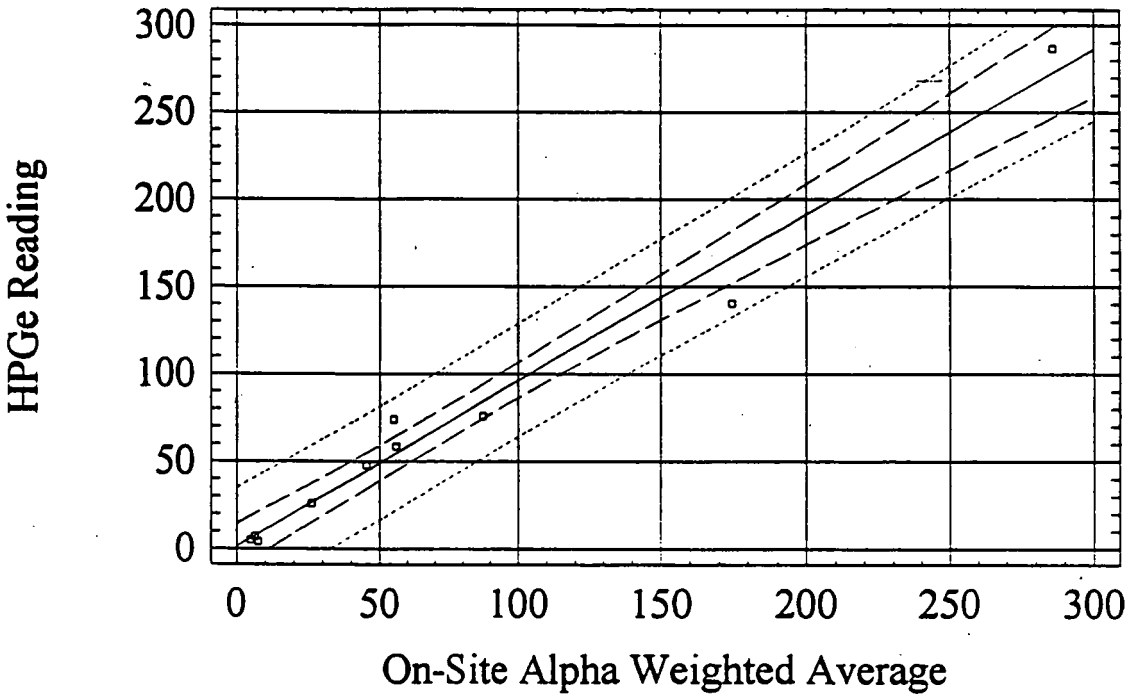
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	285.877	286.643	272.936	2.44	0.712796

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Total Uranium at 1 meter (w/o PBC-03-01)



Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:17 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	36.4674	11.6025	3.14306	0.0137
Slope	0.242537	0.0328055	7.39318	0.0001

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	59414.1	1	59414.1	54.66	0.0001
Residual	8695.95	8	1086.99		
Total (Corr.)	68110.1	9			

Correlation Coefficient = 0.933983
R-squared = 87.2325 percent
Standard Error of Est. = 32.9696

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 36.4674 + 0.242537*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 87.2325% of the variability in HMean. The correlation coefficient equals 0.933983, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 32.9696. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:17 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	36.4674	-44.1313	117.066	9.71186	63.2228
20.0	41.3181	-39.0741	121.71	15.1911	67.4451
50.0	48.5942	-31.5409	128.729	23.2693	73.9191
82.0	56.3554	-23.5756	136.286	31.6839	81.0269
1030.0	286.281	182.656	389.905	215.869	356.692

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Total Uranium - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:17 PM

Influential Points

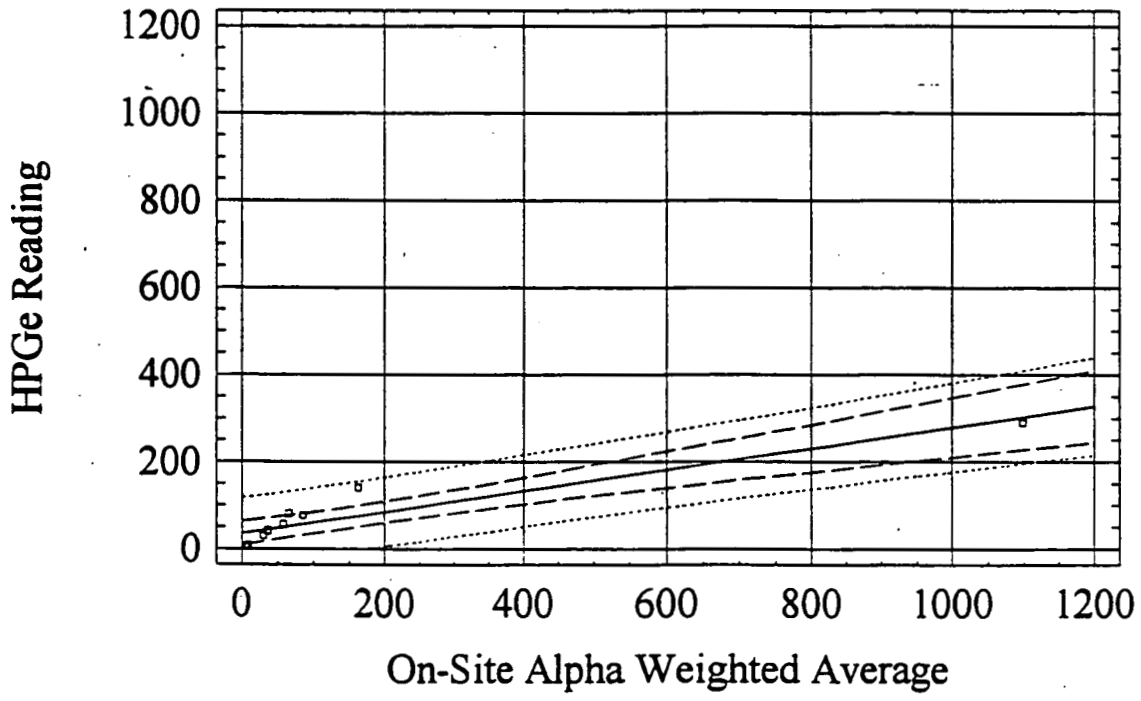
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	1098.9	290.741	302.99	-10.96	0.98174

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Total Uranium at 1 foot (unedited)



Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:21 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	15.5078	5.65777	2.74098	0.0254
Slope	0.624036	0.0357046	17.4778	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	65236.9	1	65236.9	305.47	0.0000
Residual	1708.49	8	213.561		
Total (Corr.)	66945.4	9			

Correlation Coefficient = 0.987157
R-squared = 97.4479 percent
Standard Error of Est. = 14.6137

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 15.5078 + 0.624036*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 97.4479% of the variability in HMean. The correlation coefficient equals 0.987157, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 14.6137. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:21 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	15.5078	-20.629	51.6446	2.46094	28.5547
20.0	27.9885	-7.84151	63.8186	15.8171	40.1599
50.0	46.7096	11.2013	82.218	35.5206	57.8987
82.0	66.6788	31.3261	102.032	55.9939	77.3636
1030.0	658.265	573.288	743.242	580.256	736.275

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Total Uranium - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:21 PM

Influential Points

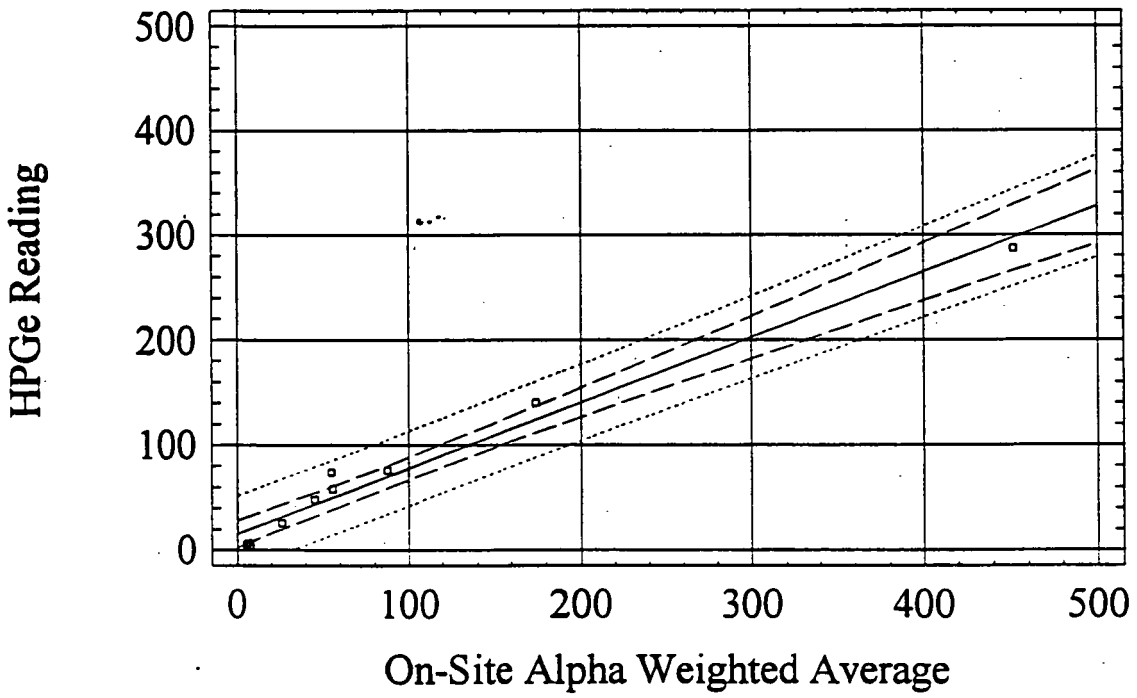
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	451.827	286.643	297.464	-2.92	0.875382

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Total Uranium at 1 meter (unedited)



Thorium-232 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:09 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.0901081	0.0249718	3.60839	0.0069
Slope	0.950955	0.0118073	80.5393	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	23.9814	1	23.9814	6486.58	0.0000
Residual	0.0295766	8	0.00369707		
Total (Corr.)	24.0109	9			

Correlation Coefficient = 0.999384
R-squared = 99.8768 percent
Standard Error of Est. = 0.0608036

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 0.0901081 + 0.950955*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 99.8768% of the variability in HMean. The correlation coefficient equals 0.999384, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.0608036. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Thorium-232 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:09 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.0901081	-0.06147	0.241686	0.0325229	0.147693
0.5	0.565585	0.41672	0.714451	0.515576	0.615595
1.0	1.04106	0.893698	1.18843	0.995714	1.08641
1.5	1.51654	1.36943	1.66365	1.47201	1.56107
2.0	1.99202	1.8439	2.14014	1.94427	2.03976

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Thorium-232 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:09 PM

Influential Points

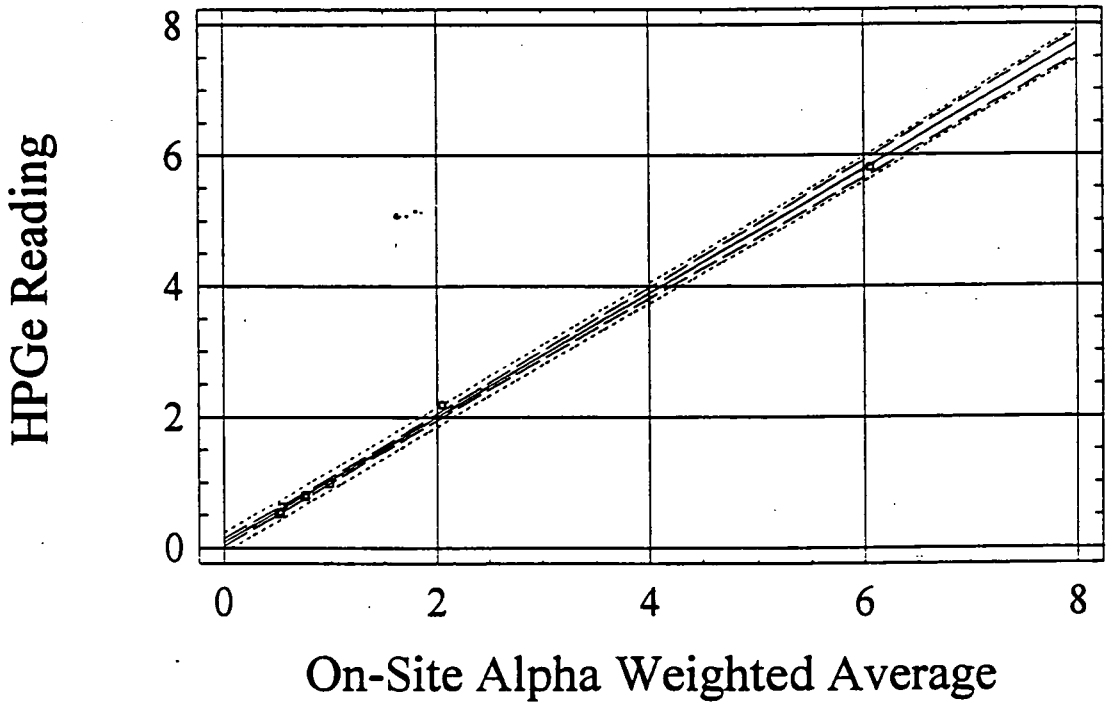
Row	X	Y	Predicted Y	Studentized Residual	Leverage
10	6.05639	5.815	5.84946	-3.39	0.935444

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Thorium-232 at 1 foot



Thorium-232 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:13 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.106383	0.0628462	1.69276	0.1290
Slope	0.940542	0.0253464	37.1075	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	35.0243	1	35.0243	1376.96	0.0000
Residual	0.203487	8	0.0254359		
Total (Corr.)	35.2278	9			

Correlation Coefficient = 0.997108
R-squared = 99.4224 percent
Standard Error of Est. = 0.159486

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 0.106383 + 0.940542*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 99.4224% of the variability in HMean. The correlation coefficient equals 0.997108, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.159486. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Thorium-232 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:13 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.106383	-0.288918	0.501684	-0.0385407	0.251307
0.5	0.576654	0.186702	0.966606	0.447028	0.70628
1.0	1.04692	0.660181	1.43367	0.927296	1.16655
1.5	1.5172	1.13147	1.90293	1.40089	1.6335
2.0	1.98747	1.60054	2.37439	1.86725	2.10768

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Thorium-232 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:13 PM

Influential Points

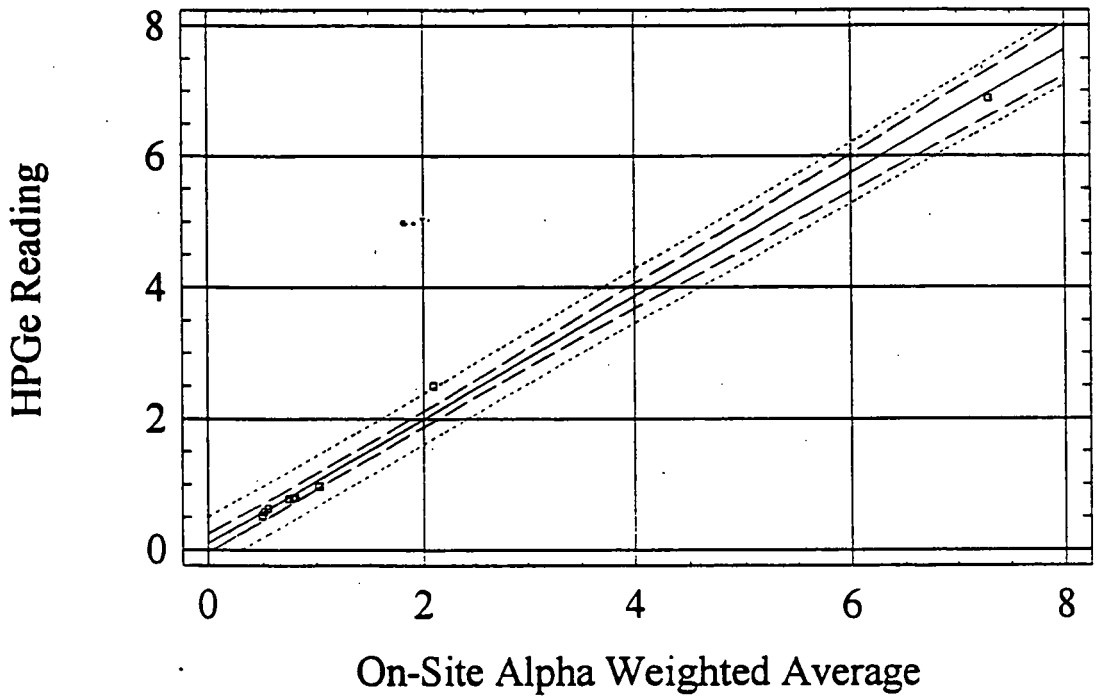
Row	X	Y	Predicted Y	Studentized Residual	Leverage
10	7.2923	6.88	6.96509	-4.76	0.953441

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Thorium-232 at 1 meter



Radium-226 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:01 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.613568	0.0529223	11.5937	0.0000
Slope	0.26813	0.0118305	22.6643	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	11.0794	1	11.0794	513.67	0.0000
Residual	0.172552	8	0.021569		
Total (Corr.)	11.2519	9			

Correlation Coefficient = 0.992303
R-squared = 98.4665 percent
Standard Error of Est. = 0.146864

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 0.613568 + 0.26813*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 98.4665% of the variability in HMean. The correlation coefficient equals 0.992303, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.146864. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Radium-226 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:01 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.613568	0.253581	0.973555	0.491528	0.735607
0.5	0.747633	0.38961	1.10566	0.631515	0.863751
1.0	0.881698	0.525128	1.23827	0.77014	0.993256
1.7	1.06939	0.713982	1.4248	0.961607	1.17717
2.5	1.28389	0.928562	1.63923	1.17636	1.39143

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Radium-226 - HPGe vs. Alpha(Lab): 1 foot detector height
3/8/1997 3:01 PM

Influential Points

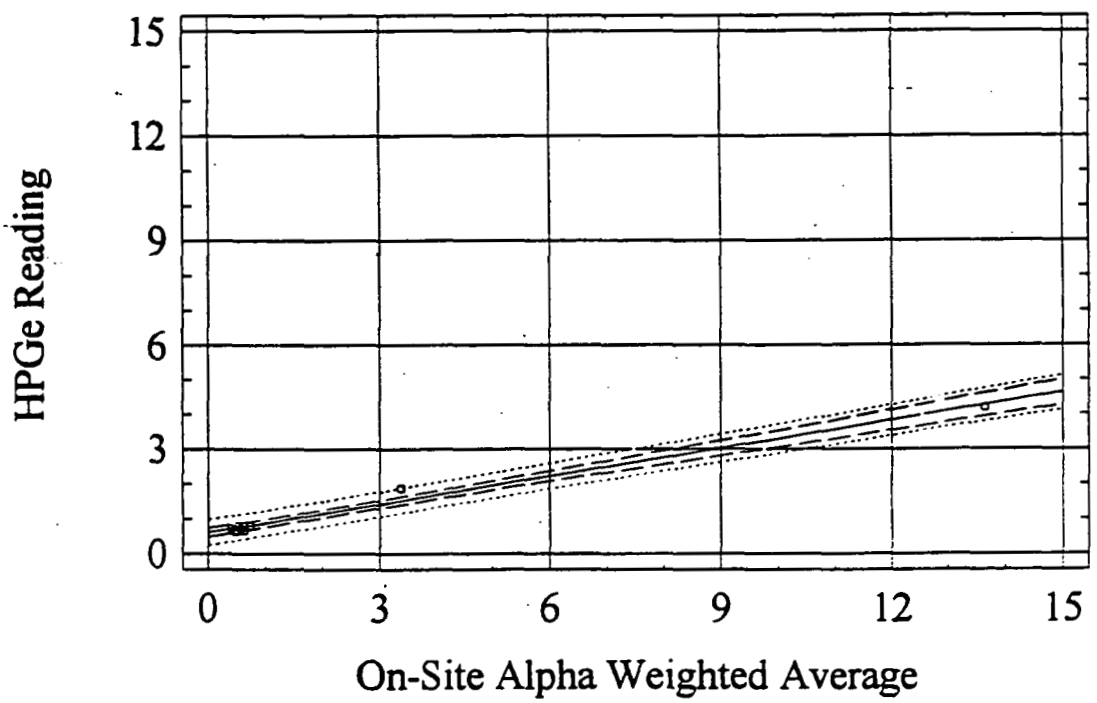
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	13.6441	4.195	4.27197	-5.62	0.958061

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Radium-226 at 1 foot



Radium-226 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:05 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HMean
Independent variable: LMean

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.604907	0.0449678	13.452	0.0000
Slope	0.273944	0.0101164	27.0793	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	11.4195	1	11.4195	733.29	0.0000
Residual	0.124584	8	0.015573		
Total (Corr.)	11.5441	9			

Correlation Coefficient = 0.994589
R-squared = 98.9208 percent
Standard Error of Est. = 0.124792

Statistical Interpretation:

The output shows the results of fitting a linear model to describe the relationship between HMean and LMean. The equation of the fitted model is

HMean = 0.604907 + 0.273944*LMean

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HMean and LMean at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 98.9208% of the variability in HMean. The correlation coefficient equals 0.994589, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.124792. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Radium-226 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:05 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.604907	0.299023	0.910792	0.501211	0.708604
0.5	0.741879	0.437673	1.04609	0.643243	0.840516
1.0	0.878851	0.575883	1.18182	0.784102	0.973601
1.7	1.07061	0.768627	1.3726	0.979057	1.16217
2.5	1.28977	0.987827	1.59171	1.19836	1.38117

Statistical Interpretation:

This table shows the predicted values for HMean using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Radium-226 - HPGe vs. Alpha(Lab): 1 meter detector height
3/8/1997 3:05 PM

Influential Points

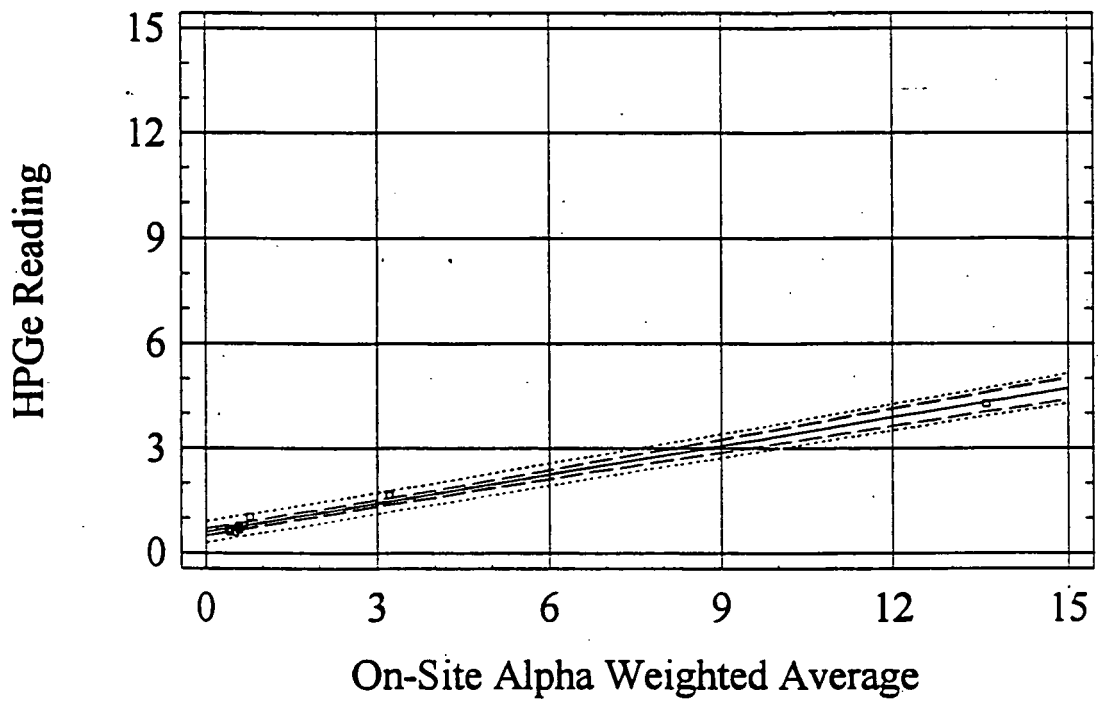
Row	X	Y	Predicted Y	Studentized Residual	Leverage
3	13.5874	4.285	4.32709	-2.07	0.962501

Average leverage of single data point = 0.2

Statistical Interpretation:

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Radium-226 at 1 meter



Cesium-137 - HPGe vs. Gamma(Lab): 1 foot detector height (w/o PBC-03-01)
5/1/1997 3:52 PM

Predicted Values

X	Predicted Y	95.0% Prediction Limits Lower	Upper	95.0% Confidence Limits Lower	Upper
0.0	0.0611281	-0.0603644	0.182621	-0.014852	0.137108
0.5	0.419179	0.318278	0.52008	0.384631	0.453728
1.0	0.77723	0.633234	0.921227	0.668844	0.885617
1.5	1.13528	0.919823	1.35074	0.9418	1.32876
2.0	1.49333	1.19796	1.7887	1.21359	1.77308

Statistical Interpretation

This table shows the predicted values for HPGE_1FT using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Cesium-137 - HPGe vs. Gamma(Lab): 1 foot detector height (w/o PBC-03-01)
5/1/1997 3:52 PM

Influential Points

Row	X	Y	Predicted Y	Studentized Residual	Leverage

Average leverage of single data point = 0.2

Statistical Interpretation

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There are no data points with more than 3 times the average leverage.

Cesium-137 - HPGe vs. Gamma(Lab): 1 foot detector height
5/1/1997 3:52 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HPGE_1FT
Independent variable: LAB_1FT

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.0611281	0.0329487	1.85525	0.1007
Slope	0.716102	0.0754436	9.49188	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	0.152272	1	0.152272	90.10	0.0000
Residual	0.0135209	8	0.00169011		
Total (Corr.)	0.165792	9			

Correlation Coefficient = 0.958356
R-squared = 91.8447 percent
Standard Error of Est. = 0.0411109

The StatAdvisor

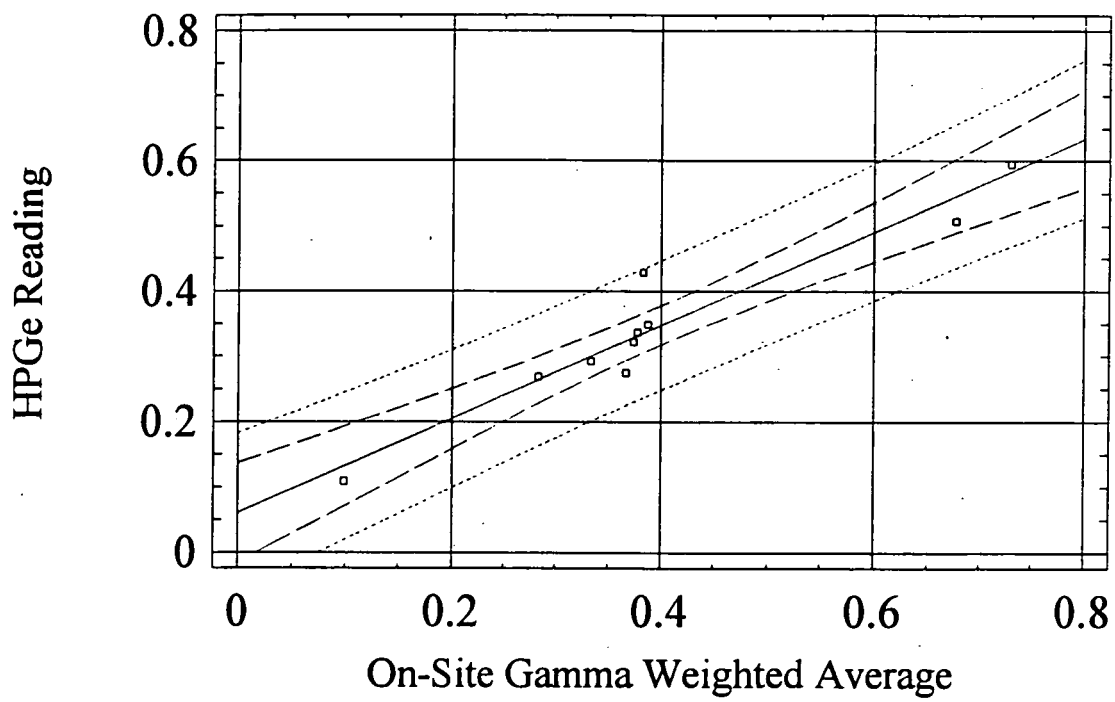
The output shows the results of fitting a linear model to describe the relationship between HPGE_1FT and LAB_1FT. The equation of the fitted model is

HPGE_1FT = 0.0611281 + 0.716102*LAB_1FT

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HPGE_1FT and LAB_1FT at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 91.8447% of the variability in HPGE_1FT. The correlation coefficient equals 0.958356, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.0411109. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Plot of Fitted Model: Cesium-137 - 1 foot



Cesium-137 - HPGe vs. Gamma(Lab): 1 meter detector height
5/1/1997 3:53 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HPGE_1M
Independent variable: LAB_1M

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.0269388	0.0214384	1.25657	0.2444
Slope	0.774012	0.0521057	14.8547	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	0.0987349	1	0.0987349	220.66	0.0000
Residual	0.00357961	8	0.000447451		
Total (Corr.)	0.102315	9			

Correlation Coefficient = 0.982351
R-squared = 96.5014 percent
Standard Error of Est. = 0.021153

Statistical Interpretation

The output shows the results of fitting a linear model to describe the relationship between HPGE_1M and LAB_1M. The equation of the fitted model is

HPGE_1M = 0.0269388 + 0.774012*LAB_1M

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HPGE_1M and LAB_1M at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 96.5014% of the variability in HPGE_1M. The correlation coefficient equals 0.982351, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.021153. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Cesium-137 - HPGe vs. Gamma(Lab): 1 meter detector height (w/o PBC-03-01)
5/1/1997 3:53 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.0269388	-0.0425122	0.0963897	-0.0224984	0.0763759
0.5	0.413945	0.361132	0.466757	0.393701	0.434188
1.0	0.800951	0.711655	0.890246	0.726156	0.875746
1.5	1.18796	1.04521	1.3307	1.0538	1.32211
2.0	1.57496	1.37497	1.77496	1.381	1.76892

Statistical Interpretation

This table shows the predicted values for HPGE_1M using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Cesium-137 - HPGe vs. Gamma(Lab): 1 meter detector height (w/o PBC-03-01)
5/1/1997 3:53 PM

Influential Points

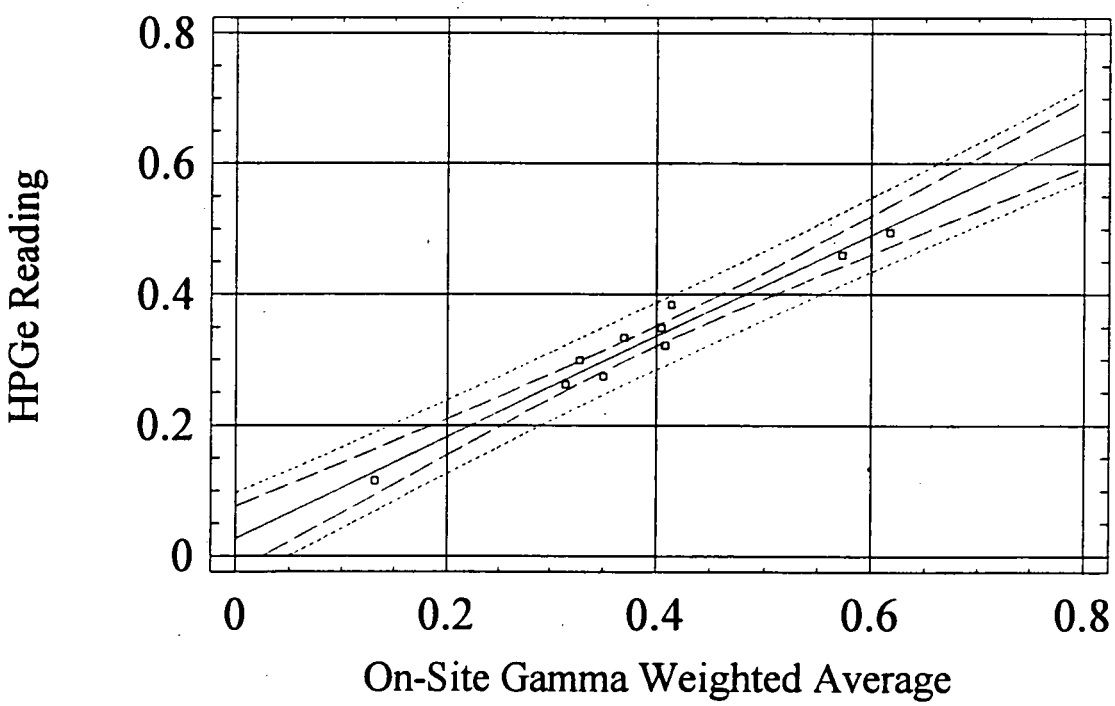
Row	X	Y	Predicted Y	Studentized Residual	Leverage

Average leverage of single data point = 0.2

Statistical Interpretation

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There are no data points with more than 3 times the average leverage.

Plot of Fitted Model: Cesium-137 - 1 meter



Potassium-40 - HPGe vs. Gamma(Lab): 1 foot detector height
5/5/1997 3:28 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HPGE_1FT
Independent variable: LAB_1FT

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	-0.471046	1.65611	-0.28443	0.7833
Slope	0.914467	0.147739	6.18976	0.0003

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	10.6045	1	10.6045	38.31	0.0003
Residual	2.21428	8	0.276785		
Total (Corr.)	12.8188	9			

Correlation Coefficient = 0.90954
R-squared = 82.7263 percent
Standard Error of Est. = 0.526103

The StatAdvisor

The output shows the results of fitting a linear model to describe the relationship between HPGE_1FT and LAB_1FT. The equation of the fitted model is

HPGE_1FT = -0.471046 + 0.914467*LAB_1FT

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HPGE_1FT and LAB_1FT at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 82.7263% of the variability in HPGE_1FT. The correlation coefficient equals 0.90954, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.526103. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Potassium-40 - HPGe vs. Gamma(Lab): 1 foot detector height
5/5/1997 3:28 PM

Predicted Values

X	Predicted Y	95.0% Prediction Limits Lower	Upper	95.0% Confidence Limits Lower	Upper
0.0	-0.471046	-4.47811	3.53602	-4.29004	3.34795
5.0	4.10129	1.64909	6.55349	1.97022	6.23235
10.0	8.67362	7.34195	10.0053	8.12454	9.2227
15.0	13.246	11.4193	15.0726	11.8803	14.6116
20.0	17.8183	14.5467	21.0899	14.7799	20.8567

Statistical Interpretation

This table shows the predicted values for HPGE_1FT using the fitted model. In addition to the best predictions, the table shows:

(1) 95.0% prediction intervals for new observations

(2) 95.0% confidence intervals for the mean of many observations

The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Potassium-40 - HPGe vs. Gamma(Lab): 1 foot detector height
5/5/1997 3:28 PM

Influential Points

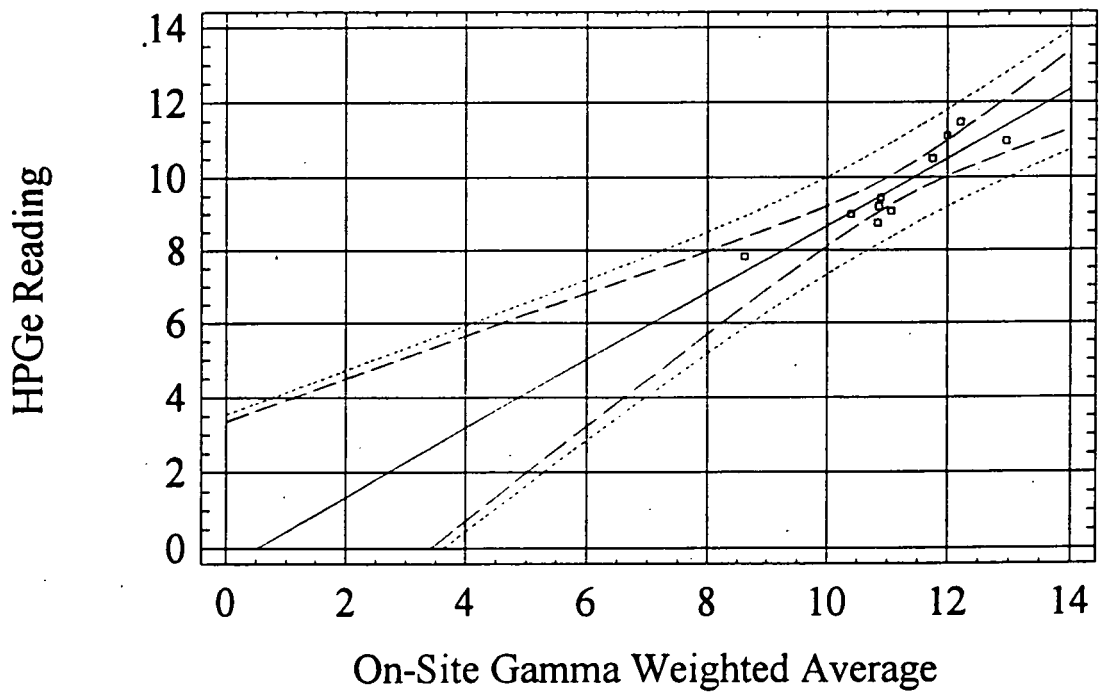
Row	X	Y	Predicted Y	Studentized Residual	Leverage
2	8.62	7.84	7.41166	1.37	0.60596

Average leverage of single data point = 0.2

Statistical Interpretation

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Potassium-40 at 1 foot



Potassium-40 - HPGe vs. Gamma(Lab): 1 meter detector height
5/5/1997 3:29 PM

Regression Analysis - Linear model: Y = a + b*X

Dependent variable: HPGE_1M
Independent variable: LAB_1M

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.22166	1.1602	0.191053	0.8532
Slope	0.821535	0.102662	8.00231	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	8.69664	1	8.69664	64.04	0.0000
Residual	1.08645	8	0.135806		
Total (Corr.)	9.78309	9			

Correlation Coefficient = 0.942839
R-squared = 88.8946 percent
Standard Error of Est. = 0.368519

The StatAdvisor

The output shows the results of fitting a linear model to describe the relationship between HPGE_1M and LAB_1M. The equation of the fitted model is

HPGE_1M = 0.22166 + 0.821535*LAB_1M

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between HPGE_1M and LAB_1M at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 88.8946% of the variability in HPGE_1M. The correlation coefficient equals 0.942839, indicating a relatively strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.368519. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu.

Potassium-40 - HPGe vs. Gamma(Lab): 1 meter detector height
5/5/1997 3:29 PM

Predicted Values

X	Predicted Y	95.00% Prediction Limits Lower	Upper	95.00% Confidence Limits Lower	Upper
0.0	0.22166	-2.5855	3.02882	-2.45378	2.8971
5.0	4.32934	2.60322	6.05545	2.8269	5.83177
10.0	8.43701	7.49833	9.37569	8.03832	8.8357
15.0	12.5447	11.2857	13.8037	11.6158	13.4736
20.0	16.6524	14.396	18.9087	14.5621	18.7426

Statistical Interpretation

This table shows the predicted values for HPGE_1M using the fitted model. In addition to the best predictions, the table shows:
(1) 95.0% prediction intervals for new observations
(2) 95.0% confidence intervals for the mean of many observations
The prediction and confidence intervals correspond to the inner and outer bounds on the graph of the fitted model.

Potassium-40 - HPGe vs. Gamma(Lab): 1 meter detector height
5/5/1997 3:29 PM

Influential Points

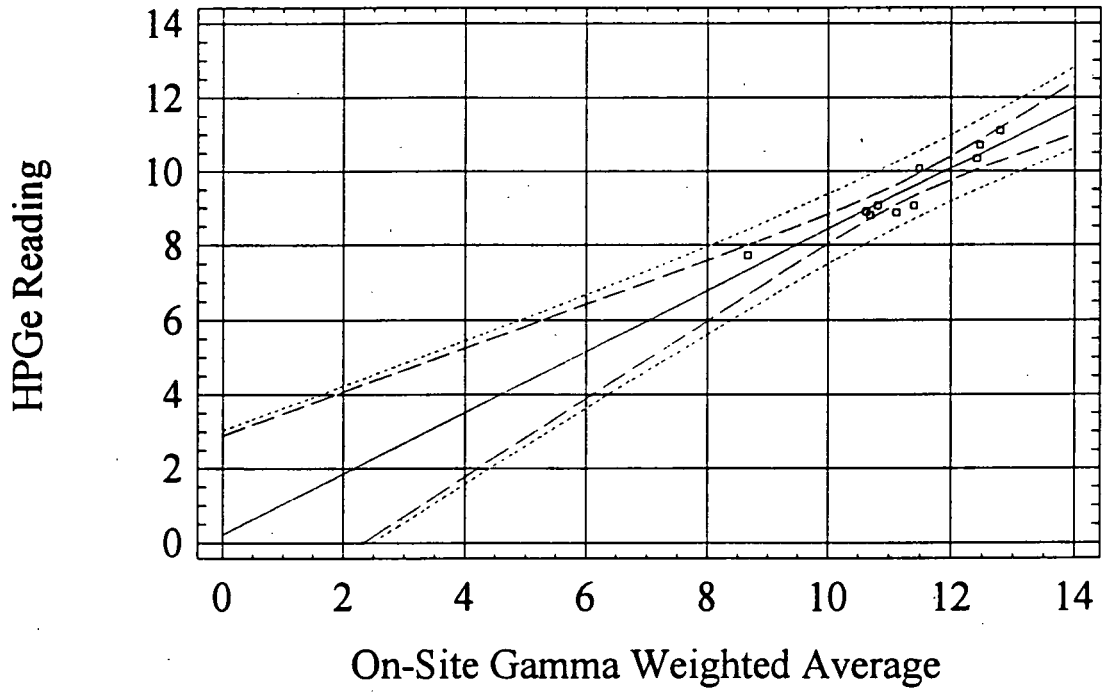
Row	X	Y	Predicted Y	Studentized Residual	Leverage
2	8.66	7.73	7.33615	2.04	0.618186

Average leverage of single data point = 0.2

Statistical Interpretation

The table of influential data points lists all observations which have leverage values greater than 3 times that of an average data point. Leverage is a statistic which measures how influential each observation is in determining the coefficients of the estimated model. In this case, an average data point would have a leverage value equal to 0.2. There is one data point with more than 3 times the average leverage, but none with more than 5 times.

Plot of Fitted Model: Potassium-40 at 1 meter



APPENDIX E

FIELD DETECTION INSTRUMENTATION AND LABORATORY ANALYTICAL METHODS

APPENDIX E
FIELD DETECTION INSTRUMENTATION AND LABORATORY ANALYTICAL METHODS

E.1 FIELD DETECTION INSTRUMENTATION

This section provides an overview of the basic principles of HPGe detectors and in situ gamma ray spectrometry. For a more detailed discussion, refer to IRCU Report #53, "Gamma Ray Spectrometry in the Environment."

E.1.1 Types of Detectors

There are three general types of radiation detectors: gas-filled, scintillation, and semiconductor. Semiconductor detectors, including HPGe or other high energy resolution detectors, are needed for complex gamma and x-ray spectra. Typically "N" type, or reverse electrode HPGe, detectors are used when a high degree of resolution is required in energy regions less than 100 keV. "P" type HPGe detectors are used in situations when resolution below 100 keV is not critical. Advantages of semiconductor detectors over scintillation and gas-filled detectors include very low resolving time and very high degree of energy resolution. A disadvantage of HPGe detectors is sensitivity to thermal excitation (heat). Because of this, HPGe detectors are maintained at liquid nitrogen temperatures during operation. HPGe detectors typically exhibit high energy resolution on the order of 1 to 3 keV full width half maximum (FWHM) of detected photopeaks. This high resolution enhances the ability to identify photopeaks and quantify their emitting radionuclides, making this sensor the detector of choice for in-situ characterization of radionuclides.

Radiation detection devices such as HPGe detectors use products of the ionization or excitation process to produce a measurable output that is proportional to the incident radiation intensity and/or the incident radiation energy. Radiation detectors are coupled to various types of supporting processors, depending on the desired application, to provide a source of power to the detector and to enable the quantity and quality of the radiation interactions to be processed and measured. The Multichannel Analyzer (MCA) is a common device used in high resolution gamma spectrometry.

MCAs are sophisticated instruments designed to measure and record the number of pulses generated by nuclear events in a detector that occur at multiple energy levels. Typical MCAs can separate nuclear events occurring in a detector into a number of energy bands, or channels. MCAs available today are capable of dividing the total observed energy spectrum into as few as 512 channels to as many as

16,384 channels, depending on the desired application. The result is that a full energy spectrum can be resolved to discern individual energy photopeaks associated with each radioactive decay event in the sample with minimal overlap of peaks having different energies. Gamma ray spectrum resolution using high speed computers provides a rapid, semi-automatic, reasonably accurate method to quantify gamma photons impinging on a HPGe detector.

E.1.2 High Purity Germanium Detector System

A high-purity germanium (HPGe) detector system was used to measure gamma radionuclides in both Part A and Part B of the comparability study. The error associated with a HPGe measurement can be predicted by the following equation:

$$\sigma = \sqrt{\frac{N + (2 * B)}{T}}$$

where:

N = net photopeak counts or detector signal

B = background counts or noise

t = count time = 900 seconds for the Part A and B Comparability Studies

Gamma ray in-situ measurements of soil use detectors of known angular response and energy calibration to detect and measure the gamma or x-ray emission from an unknown distribution of radionuclides in the soil. The unscattered photon flux above the soil-air interface from radioactive emitters distributed in the soil can be modeled mathematically and combined with a detector response function to estimate the average source activity in the area and volume of soil within the detector's field of view. The most important consideration when performing in-situ spectrometry is that the accuracy of the analysis depends on the radioactivity distribution with soil depth and, to a lesser extent, on the soil density, soil moisture content, and soil chemical composition. Parameters that must be known or approximated for use in the in-situ model include source activity depth distribution, soil bulk density, soil moisture content, air and soil total photon attenuation coefficients, and detector response functions.

Measurements are performed with the detector positioned over the area of interest, and a gamma-ray energy spectrum is collected for a specific acquisition time to achieve a desired minimum detectable concentration (MDC; see Section 5.4 for definition and discussion of MDC). The MDC is a function of gamma-ray energy, distribution in the media, other gamma emitting radionuclides present, the detector and its geometry, count time, and analysis methodology. There are many factors that can affect MDC. If obstructing materials, such as water or snow, gravel, pavement, concrete, or even clean soil, are between the area to be characterized and the detector, the measurement becomes more complex and the interferences must be compensated for during post processing analysis. Any material between the detector and the area of interest will reduce the intensity of photons impinging upon the HPGe detector, therefore effectively shielding a potential source term and requiring the application of a correction factor based on the gamma or x-ray attenuation of the interfering material.

Sample geometry of the detector field of view may have to be taken into consideration during the measurement setup. Models used in the derivation of conversion factors relating photopeak count rate data to isotope concentration in the ground assume an infinite flat plane. In practice, a flat horizontal plane sample geometry rarely exists. Hills, valleys, ditches and contours are frequently a part of the landscape that requires characterization. The effect of the concave (concave upward) geometry of a valley or ditch area on the computed HPGe activity is normally to yield a higher value than the actual soil activity depending upon the degree of concavity. This relationship holds true for both point and distributed sources. This is because a concave area to be characterized is effectively brought closer to the detector, thereby reducing distance and attenuation effects and increasing the gamma photon flux at the detector. Because calculated results are higher than actual concentrations for concave areas, the data are conservative from an environmental cleanup approach, resulting in excessive cleanup efforts and wasted resources. When the sample geometry features a convex (concave downward) surface (such as a hill), the computed activity is lower than actual for both point and distributed sources depending upon the degree of convexity. This is because the convex area to be characterized has effectively been moved away from the detector. The field of view has effectively increased so that the total volume is greater. In this case, the detector response to sample concentration conversion model and assumptions used to compute conversion factors are no longer valid. Actual detector field of view geometries experienced in the field may be any combination of either concave or convex configurations in varying degrees. The correction plan for both scenarios is to develop appropriate area

characterization sampling strategies to minimize topographical effects. To date, soil surface geometries do not appear to have had any significant effects upon HPGe measurements at the FEMP.

To relate photopeak count rate to activity in the soil, a conversion factor must be determined for the detector, the energy lines of the nuclides of interest, and the source distribution. This conversion factor is determined in the characterization of the detector. Table E-1 lists the photopeaks used to measure the analyte radionuclides in soil. Section E.1.3 discusses detector characterization and the determination of conversion factors.

E.1.3 Detector Characterization

The detector's response characteristics must be determined to compute conversion factors and to assess the appropriateness of a detector to an application. The detector characterization is accomplished by measuring the detector sensitivity to a number of gamma-ray energies at angles ranging from 0 to 90 degrees. Radioactive standards, certified by the United States Department of Commerce, National Institute of Standards and Technology (NIST) as to their isotopic activity are used for the detector characterization. Standards commonly used are Am-241, Cs-137, Co-60, and Eu-152. These standards emit gamma and/or x-rays that can be used for calibration at energies ranging from 32.1 keV to 1408.0 keV.

The standards are placed one at a time in a reproducible geometric configuration at one meter from the detector face while a measurement is made. At the completion of each measurement, the source is moved ten degrees within the configuration and another measurement is made. This is repeated until measurements are made from 0 to 90 degrees for each standard. At the completion of the 90 degree measurement, the source is placed at 0 degrees and a duplicate measurement is made. This duplicate measurement is made to account for determinate errors. The 0 degree measurements are used to determine the detector's effective area at 0 degrees by solving Equation (1).

$$A_0=\{(4\pi r^2CR)/(S_0)\}e^{(r/l)} \qquad (1)$$

where:

A_0 = detector effective area at 0 degrees in units of cm^2*cps/γ/s

r = source distance from the detector in units of cm

CR = measured photopeak count rate in units of cps

S_0 = source strength in units of γ/s

l = mean free path in air for the gamma energy in units of cm

The effective area varies as a function of gamma-ray energy and gamma-ray angle of incidence. This relationship for a given energy can expressed as:

$$A = A_0 R(\theta) \qquad (2)$$

where:

$R(\theta)$ = the ratio of the detector response at an angle q to that at q = 0 degrees.

The angular response of the detector package is folded into a sensitivity calculation to determine conversion factors for the in-situ measurement. The theory of in-situ measurements is provided in Section E.1.3.1, and the sensitivity calculation formulas are derived in that section. It is convenient to compute conversion factors for two detector heights with a branching of unity and to plot the results (pCi/g/cps) as a function of energy. The curves are fitted and the coefficients are loaded into analysis software. The software package can then compute the appropriate conversion factor for any isotope within its library for given detector height.

The conversion factors computed and loaded into the analysis software for the in-situ detectors reflect the following assumptions:

soil density = 1.5 g/cm^3

soil moisture = 10%

vertical distribution = homogeneous

averaging depth = 3.0 cm

air density = 0.001293 g/cm^3

The detector 'field of view' can be determined from the sensitivity calculations. In this regard, the detector theoretically measures an infinite plane when an in-situ measurement is made. The detector 'field of view' is defined as that circle on the plane where 90% of the gamma rays originate that contribute to the photopeak counts. The 'field of view' is a function of gamma-ray energy, vertical distribution, and detector height.

E.1.3.1 Measurement Theory

The unscattered flux of gamma-rays of energy E at a height above a smooth air-ground interface due to an emitter distributed in the soil is given by:

$$\Phi = \int_0^\infty \int_0^\infty \left(\frac{S_v}{4\pi r^2}\right) e^{-\left(\frac{\mu}{\rho}\right)_a \rho_a r_a} e^{-\left(\frac{\mu}{\rho}\right)_s \rho_s r_s} 2\pi x\,dx\,dz \qquad (3)$$

where:

S_v = the activity per unit volume in units of $(\gamma/s)/cm^3$

$r = r_a + r_s$ in units of cm = distance from the activity source to the detector where r_a is the distance in air and r_s is the distance in soil

$(\mu/\rho)_a$ = air mass attenuation coefficient in units of cm^2/g

$(\mu/\rho)_s$ = soil mass attenuation coefficient in units of cm^2/g

ρ_a = air density in units of g/cm^3

ρ_s = soil density in units of g/cm^3

This expression assumes a source distribution which varies only with depth. The relationship between source and detector is shown in the diagram below.

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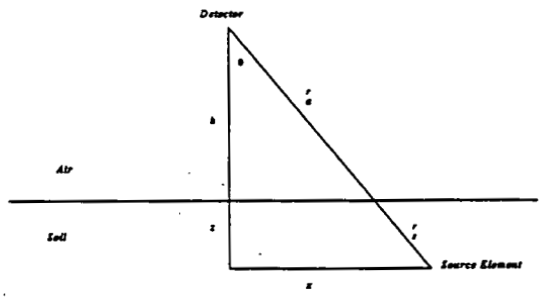

Geometry used in the derivation of conversion factors relating in situ photopeak count rate data to isotope concentration in the ground.

For fallout activity, the distribution after a period of time can be reasonably approximated by an exponential distribution given by:

$$S_v = S^0_v \, e^{\alpha z} \qquad (4)$$

where:

S = the activity per unit volume at the surface and

α = the reciprocal of the relaxation length in units of cm^{-1}.

Combining Equation (3) with Equation (4) and integrating over z leads to the following expression:

$$\Phi = \frac{S_v^0}{2} \int_0^{\pi/2} \frac{TAN\Theta e^{-(\frac{\mu}{\rho})_a \rho_a h \sec\theta}}{\alpha + (\frac{\mu}{\rho})_s \rho_s \sec\theta} d\theta \qquad (5)$$

E.1.3.2 Conversion Factors from Point Sources

The detector response to a given flux of gamma-rays (F) of energy E incident at an angle q can be given in terms of an effective detector area, A, defined by:

$$A = N_p/\Phi \qquad (6)$$

where:

N_p = the net photopeak count rate in units of cps.

The effective area, as stated above, for a given energy, varies as a function of the gamma-ray angle of incidence and is normally written as:

$$A = A_0 R(\theta) \tag{2}$$

Both A_0 and $R(\theta)$ can be determined experimentally with point gamma-ray sources.

Combining Equations (6) and (2) with Equation (5) leads to an expression which relates the measured photopeak count rate to source activity in the soil. This is given by:

$$\frac{N_p}{S_v^0} = \frac{A_0}{2}\int_0^{\pi/2} \frac{R(\theta)\tan\theta e^{-(\frac{\mu}{\rho})_a \rho_a h \sec\theta}}{\alpha + (\frac{\mu}{\rho})_s \rho_s \sec\theta} d\theta \tag{7}$$

The conversion factor given by Equation (7) is in units of cps/(γ/cm^{3}s)

$$\frac{N_p}{S_v^0}$$

For a specific isotope, the conversion factor is normally changed to units of cps/(pCi/cm^3). Multiplying the expression in the brackets in Equation (7) by the soil density (γ/cm^3) leads to the conversion factor normally given in units of cps (pCi/g).

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$$\frac{N_p}{S_\nu^0/\rho}$$

In general, the average concentration in the top z cm, for a source distributed exponentially with depth is given by:

$$S_\nu^z = \frac{1}{z}\int_0^z S_\nu^0 e^{-\alpha z} dz = \frac{S_\nu^0}{\alpha z}(1-e^{-\alpha z}) \tag{8}$$

Combining Equations (7) and (8) leads to:

$$\frac{\frac{S_\nu^z}{\rho}}{N_p} = \frac{1-e^{-\alpha z}}{\alpha z}\beta\left[\frac{A_0\rho_s}{2}\int_0^{\pi/2}\frac{R(\theta)\tan\theta e^{-(\frac{\mu}{\rho})_a\rho_a h\sec\theta}}{\alpha+(\frac{\mu}{\rho})_s\rho_s\sec\theta}d\theta\right]^{-1} \tag{9}$$

in units of (pCi/g)/cps, where β converts γ/s to pCi for a specific isotope.

This conversion factor has utility when comparing in-situ results with soil sample results where the soil sample is taken from 0 to z units deep and is finite.

E.1.4 Data Computation and Output

A combination of commercial turn-key (comes with HPGe detector), and customized software uses the conversion factor given in Equation 9 to compute activity concentrations in pCi/g for isotopes of interest. Table E-2 provides an example of software output.

The photon energy detected is given in the first column. Net counts and background counts for the energy peak are given in the second and third columns. The counting error (expressed as % of the calculated activity in the seventh column) is shown in the fourth column. The fifth and sixth columns

show the radionuclides which emit gamma photons and the theoretical, or generally accepted, value for the energies of the gamma photons.

Column 7 displays calculated activity concentrations using the conversion factor in Equation 9. Columns 8 and 9 contain information not used in this study and not previously discussed in Appendix E.

The gamma photons listed in Table E-1 are used to calculate a weighted average activity concentration for the analyte isotopes in Table E-1. The counting errors are used as the weighting factors. The weighted average activity concentrations for the various isotopes are listed under the "Nuclide Summary" heading. Sample-specific MDAs (MCCs) are also provided for each isotope. These MDCs are "a posteriori," as opposed to MDCs given in Section 5, which are "a priori." These sample-specific MDCs can be used to assess data useability.

Finally, at the top of Table E-2, a data quality control parameter is given. The energy for the gamma photon, 1460.8 keV, is given along with the width of the photon peak at half the maximum peak height (full width, half maximum, or FWHM). When this value is greater than 3.0, the data may not be useable due to poor spectral energy resolution.

E.1.5 Temperature Issues

The total temperature instability for the field-deployed HPGe system is typically <50 ppm/°C over an operating range of 0° C to 50° C, according to manufacturer's specifications. It should be noted that 50 ppm does not refer to concentration of analytes; it refers to drift in the assignment of channels in a multichannel analyzer to a gamma photon of a given energy. This means that a photopeak at the upper end of 8192 channels (HPGe) could drift as much as 20 channels ($50 \times 10^{-6} \times 8192$ channels x 50) if the temperature went from 50° C (122° F) to 0° C (32° F). Table 5-6 indicates that the channel acceptance position criteria in the daily performance check is $\pm$ 3 channels at 1332.5 keV. The 1332.5 gamma photon is assigned to channel 3553 in a multichannel analyzer. The temperature instability at this channel per °C is $(50 \times 10^{-6})(3553) = 0.178$ channels. Thus, to exceed the ± 3 channel QC acceptance criterion, a temperature shift of $3/0.178 = 16.8$ °C (30.4 °F) is required. On days when a temperature change in excess of 30 °F occurs, field crews need to be especially aware of potential drift in the HPGe energy calibration. However, the normal operation of the field system employs a digital spectrum

stabilizer to reduce spectrum drift. In addition, personnel have been trained to maintain spectrum energy calibration. Finally, the analysis software monitors the system response with respect to peak shift and photopeak resolution and performs analysis based on the actual spectrum. Thus, temperature instability in the multichannel analyzer does not appear to present operational limitations.

E.2 LABORATORY ANALYSIS

E.2.1 Sample Preparation

E.2.2.1 Laboratory Sample Preparation

Upon receipt of the physical sample, the on-site/off-site laboratory:

1. Removed, weighed, and recorded all sample material (including any organic matter) in the sample core tube and place it in a disposable aluminum pan. The analyst performing this step described the appearance of each sample.
2. Dried the entire sample at 105° to 112° C for at least 8 hours to constant weight.
3. Calculated and recorded the percent moisture content of the sample.
4. Ground the entire sample until all material passed through a 1-mm sieve.
5. Blended the sample either by hand or machine.
6. Removed the necessary aliquot for analysis and archived the remaining sample material.

For Part B of this study, 113 samples were submitted to the lab in 3x6 inch plastic tubes for total uranium analysis. Each sample was frisked by a rad tech to determine the radiation reading. In addition to radiation safety concerns, frisking samples had a practical aspect. For example, Sample 200264208 Area PBC-03-01 frisked 60K on one side of the sample core, but low on the opposite side of the core. When ground, it was discovered the sample core contained a piece of cement which frisked high. This particular sample was passed through the grinder several times to ensure that the cement piece was dispersed evenly throughout the sample. Aliquots were taken from dried and ground samples for alpha and gamma spectrometry analyses. The sample drying procedure for the comparability study soil samples was performed using a Fisher Scientific Drying Oven model 630F at 110°C for 12 hours, and the grinding procedure utilized a Retsch BB-0 Jawed-Tooth Crusher.

E.2.3 Standard Radiological Methods

E.2.3.1 Isotopic Measurements by Gamma Spectrometry

Many radioactive nuclei decay by the emission of gamma rays with distinct energies that are characteristic of the specific isotope which emitted them. Just as fingerprints can be used to identify a specific individual, detection of gamma rays which have a unique energy can be used to identify the presence of specific radionuclides. For example, the technique of gamma spectrometry can be used to identify the presence and quantity of U-235 and U-238, the important uranium isotopes. Since gamma rays are highly penetrating radiation, samples can be analyzed by this technique without any chemical preparation other than homogenizing the samples. HPGe detectors are used in a high resolution gamma spectrometry system to detect the gamma rays emitted from the samples. Samples are placed in a standardized geometry on the HPGe gamma detector and an energy spectrum of the gamma emissions from the sample is collected in a multichannel pulse height analyzer. From the peaks in the accumulated spectrum, the energy of the various gamma emissions detected indicates which isotopes are present. The number of gamma rays counted at a specific energy (i.e. the area under the spectral peak) is used to calculate the amount of that particular radionuclide which is present in the sample. Any radionuclide that emits characteristic gamma rays can be quantified in this manner.

The accuracy of the method is reduced if a sample contains two or more radionuclides which emit characteristic gamma rays of nearly the same energy. Modern gamma spectrometry systems generally will not resolve two gamma rays if their characteristic energies are less than 2 to 3 keV apart. This is especially true if the activity of an interfering radionuclide is more that 5 times greater than that of the other nuclide. A high environmental background or the presence of other gamma emitting radionuclides in a sample can elevate the MDA for a given sample even though the other nuclides are not analytes of concern. To reduce the effects of extraneous background radiation, modern HPGe detectors are generally surrounded by a shield which is typically composed of four inches of lead. Gamma spectrometry is suitable for the analysis of isotopes of uranium, thorium, radium, potassium-40 (K-40), cesium-137 and other gamma emitting or gamma-discernable (based on daughters) radionuclides.

For this comparability study, each soil sample which underwent gamma spectral analysis in the laboratory consisted of approximately 125 grams of dried, ground and homogenized soil. All samples were counted in a standardized container of approximately 125 milliliter volume. They were counted

for 3600 seconds on a Canberra Industries Genie gamma spectrometry system coupled to HPGe detectors which were calibrated with an NIST traceable mixed gamma standard containing accurately known quantities of ten radionuclides which emitted thirteen different gamma lines between 59 keV and 1836 keV. The standard was counted in the same type of container as the samples. In some cases, gamma rays from radioactive daughters were used to quantify the activity concentration of the radioactive parent. This practice was employed in the field gamma measurements as well as in those performed in the lab. The gamma rays important for this study are listed in Table E-3.

Each characteristic peak that appears in a spectrum can be used separately to compute the analyte activity concentration in the sample. When more than one analyte characteristic peak was present in a sample spectrum, the average concentration was reported.

E.2.3.2 Isotopic Measurements by Alpha Spectrometry

Like gamma rays, alpha emissions from radioactive nuclei are expelled with discreet energies that are characteristic of the isotope emitting them. The technique of alpha spectrometry utilizes this property to identify and quantify the isotopes which are present in a sample. Since alpha particles are very weakly penetrating and can be absorbed by the sample material itself, a chemical extraction must be performed to separate (isolate) the analyte of interest from the sample matrix. This process involves a mineral acid digestion of the sample and separation of the element of interest from other elements utilizing ion exchange resins. Extreme care must be exercised to ensure preparation of a uniform and very thin sample for counting in an alpha spectrometer. A known quantity of a radioactive isotope of the element being analyzed is added to the sample at the start of the chemical preparation process to provide a quantitative measure of the losses that occur during sample preparation. This radio-tracer must be an isotope of the analyzed element which is not present in the samples. The alpha spectrometry technique offers double assurance that only the isotopes of interest are being counted. First, the chemical separation process is designed to separate the element of interest from all others. Secondly, the spectrometric technique ensures that only the alpha emissions from the desired isotopes are used to calculate the activity in the samples. If the chemical separation is not complete for some reason or the chemical losses are greater than normal, the sample spectrum will reveal evidence of these conditions. The chemical processing required for this technique is labor-intensive and time-consuming. While alpha spectrometry is highly selective and extremely sensitive, sample analyses take longer and may be more expensive than other laboratory analysis techniques. It generally takes five to

six days to complete the analysis of a batch of 20 soil samples. Laboratory methods involving alpha spectrometry have been developed for all of the important alpha-emitting isotopes of concern in the cleanup of the FEMP. Specifically, this technique is capable of accurately quantifying Ra-226 and the major isotopes of uranium and thorium. The alpha spectrometry system used in the FDF Analytical Laboratory is a computer controlled system which uses silicon surface barrier detectors and Alpha Management Software available from Canberra Industries Nuclear Products Group.

Uranium Analysis Procedure (Alpha Spectrometry) - FDF Method 256-S-3022

The samples are dried and ground to homogenize them and the percent moisture is measured. Typically a 0.5 gram aliquot of each sample is heated in a muffle furnace at 550° C for two hours. Approximately 5 pCi of U-232 is added to each sample as a tracer to determine the uranium chemical yield from the preparation process. The samples are dissolved using a mixture of concentrated nitric acid and concentrated hydrofluoric acid to ensure complete digestion of the sample matrix. Uranium is then co-precipitated with iron by making the solution basic with ammonium hydroxide (carbonate free). The hydroxide precipitate is dissolved in 8 molar hydrochloric acid (8 M HCl) with a small amount of hydriodic acid (HI) present. The 8 M HCl/HI solution is passed through an anion exchange resin column. Uranium is absorbed on the resin while iron is eluted with 8 M HCl containing HI. The uranium is eluted from the column with 1 molar HCl. Neodymium fluoride mounting of the uranium extract onto a polypropylene filter paper is performed in accordance with FEMP Analytical Method 256-S-3002. The filters are counted in vacuum chambers to reduce absorption and scattering of the alpha radiation emitted from the mounted sample extract. Silicon surface barrier detectors are used to count the samples. With a typical count time of twenty hours, minimum detectable concentrations of 0.1 pCi/g (dry weight) or lower are obtained.

Thorium Analysis Procedure (Alpha Spectrometry) - FDF Method 256-S-3026

The samples are dried and ground to homogenize them and the percent moisture is measured. Typically a 3 to 5 gram aliquot is taken for analysis. A thorium-229 (Th-229) tracer is added to each sample and they are digested using a conventional mineral acid dissolution with a mixture of concentrated nitric, hydrofluoric and perchloric acid. The sample digestates are loaded onto an anion exchange resin column in an 8 molar nitric acid medium. The thorium is eluted from the column with a solution of 8 M HCl. The purified thorium fraction is prepared for counting by using the FEMP Analytical Method 256-S-3002, the neodymium fluoride mounting procedure. The samples are counted

in vacuum chambers to reduce absorption and scattering of the alpha radiation emitted from the mounted sample extract. Silicon surface barrier detectors are used to count the samples, usually for a period of twenty hours. Minimum detectable concentrations of 0.1 pCi/g (dry weight) or lower can be obtained with this procedure.

Radium Analysis Procedure - FDF Method 256-S-3016

The samples are dried and ground to homogenize them and the percent moisture is measured. Typically a 2 to 5 gram aliquot is taken for analysis. Since the element barium behaves chemically like radium, Barium-133 is added as a yield tracer for the Ra-226 and Ra-228 analysis. The samples are dissolved in a mixture of concentrated nitric acid and hydrochloric acid. Radium and barium are separated from interfering elements using a co-precipitation with barium and lead carriers as sulfates. Further purification and separation from lead carrier and radium daughter isotopes are achieved by dissolution of the precipitated sulfates with alkaline EDTA solution and selective recrystalization with barium sulfate using glacial acetic acid. In preparation for counting, the radium/barium sulfate extract is mounted on a polypropylene filter and dried in accordance with the neodymium fluoride mounting procedure, FDF Analytical Method 256-S-3002. Samples are counted for Ra-226 by alpha spectrometry and for Ra-228 and Ba-133 tracer by gamma spectrometry. The gamma emissions from Ac-228, the direct daughter of Ra-228 are used to determine the Ra-228 sample activity. By accurately recording the time interval between the final radium precipitation and the mid point of the gamma count, the degree of equilibrium between Ac-228 and its parent, Ra-228, can be computed, and this factor can be used to derive the parent activity from a count of the daughter gamma emissions. The samples are typically counted for 20 hours in an alpha spectrometer which uses silicon surface barrier detectors. Ra-226 Minimum Detectable Concentrations (MDCs) for samples counted under typical conditions for this project are 0.01 pCi/g (dry). With gamma spectrometry counts from 1 to 6 hours, Ra-228 MDCs are typically in the range of 0.1 to 0.3 pCi/g (dry weight).

TABLE E-1
GAMMA PHOTONS USED TO QUANTIFY U-238, Th-232, Ra-226, Cs-137, AND K-40 FOR HPGe MEASUREMENTS

Analyte Radionuclide	Radionuclide of Emission	Gamma Photon Energy (keV)	Gamma Photon Abundance (%)
U-238	Th-234 Th-234 Pa-234m	63.2 92.6 1001.0	3.9 5.41 0.845
U-235	U-235	185.7	54.0
Th-232	Pb-212 Tl-208 Ac-228	238.6 583.1 911.1	45.0 30.6* 29.0
Cs-137	Ba-137m	661.6	84.62**
K-40	K-40	1460.8	10.7
Ra-226	Pb-214 Bi-214 Bi-214	351.9 609.3 1120.4	35.0 43.0 17.0

* Includes 0.359 branching ratio from decay of Bi-212.
** Includes 0.946 branching ratio from decay of Cs-137.

TABLE E-2

f:381.CHN , 30904 1m 900s Comp study #3 10-25-96 35uR #381

** Software Version: 043097/ 30904/Q by R. T. Reiman *

Energy (keV)	Resolution FWHM (keV)	Live Time Seconds	Real Time Seconds	Quad Value	Gain (kev/ch)	OFFSET (keV)	HEIGHT (cm)
1460.8	2.40	900	1072	.158E-07	.375	.929	100

Nuclide Summary

Isotope	Activity pCi/g	Activity uCi/m2	Error %	MDA pCi/g
K- 40	11.2	.168E+06	1.8	.655
U- 238	93.7	.141E+07	1.4	4.45
Ra 226	4.32	.648E+05	1.1	.157
U- 235	5.22	.784E+05	1.7	.296
Th 232	2.51	.377E+05	1.7	.143
Cs 137	.459	.688E+04	5.0	.752E-01

ENERGY (keV)	NET COUNT	BACKGROUND COUNT	ERROR (%)	ISOTOPE	PHOTO-PEAK	ACTIVITY (pCi/g)	ACTIVITY (uCi/m2)	EXPOSURE (uR/Hr)
14.2	4555.8	5454.2	3	Th 231	13.3	17.	.26E+06	.00
				Th 234	13.3	.16E+03	.24E+07	
				Pa 234	13.6	.40E+04	.59E+08	
				Pu 238	13.6	.40E+03	.60E+07	
				AM 241	13.9	57.	.85E+06	
				Am 243	13.9	95.	.14E+07	
				Y- 88	14.1	30.	.45E+06	
				Cm 244	14.3	.15E+03	.23E+07	
				Co 57	14.4	.17E+03	.25E+07	
24.2	4522.6	15455.4	4	Sn 113	24.0	52.	.79E+06	.00
				In 115	24.2	11.	.16E+06	
				Sn 113	24.2	28.	.42E+06	
				Cd 109	24.9	76.	.11E+07	
27.5	829.4	16849.6	22	Th 231	26.6	9.0	.14E+06	.00
				Sn 113	27.3	15.	.23E+06	
				Pa 231	27.4	18.	.27E+06	
				Sn 113	27.9	80.	.12E+07	
32.0	591.9	21208.1	35	Am 243	31.1	.13E+04	.19E+08	.00
				CS 137	32.1	16.	.24E+06	
				Ce 139	33.0	3.9	.58E+05	
36.9	462.2	31710.8	55	CS 137	36.4	45.	.68E+06	.14E-02
				AM 241	37.1	4.3	.65E+05	
				CS 137	37.3	.21E+03	.32E+07	
				Ce 139	37.8	3.6	.54E+05	
53.4	1246.5	80525.5	32	Ba 133	53.2	26.	.39E+06	.13E-01
63.2	12010.3	91747.7	4	TH 234	63.2	100.	.15E+07	.13
				U- 238	63.2	100.	.15E+07	
74.9	1580.6	89621.4	27	Am 243	74.7	.71	.11E+05	.22E-01
				Pb 212	74.8	4.9	.74E+05	
				U- 235	74.9	.47E+05	.71E+09	
				Px 82	75.0	.47	.71E+04	
77.4	1976.5	86417.5	21	Lu 174	76.5	7.1	.11E+06	.29E-01
				Pu 241	77.0	.24E+07	.36E+11	
				Pb 212	77.1	3.3	.49E+05	
				Bi 209	77.1	.58	.87E+04	

				PU 239	77.6	.13E+06	.20E+10	
84.2	1699.6	79397.4	24	Th 231	84.2	59.	.88E+06	.27E-01
				U- 235	84.2	9.2	.14E+06	
				Px 82	84.7	1.4	.21E+05	
				Hg 203	84.9	74.	.11E+07	
87.5	748.1	76699.9	52	Am 243	86.8	60.	.90E+06	.13E-01
				Th 234	87.0	.28E+04	.42E+08	
				Ac 225	87.0	70.	.10E+07	
				Pb 212	87.2	3.2	.48E+05	
				Cd 109	88.0	5.3	.80E+05	
				Th 227	88.5	7.2	.11E+06	
92.5	19468.2	72639.8	2	TH 234	92.6	93.	.14E+07	.34
				U- 238	92.6	93.	.14E+07	
				U- 235	93.3	.20E+03	.30E+07	
98.5	2827.1	61852.9	13	Pa 234	98.4	.69E+03	.10E+08	.52E-01
				Pu 238	98.4	.47E+06	.70E+10	
				PU 239	98.4	.12E+05	.18E+09	
				Pu 241	98.4	.15E+05	.22E+09	
				Am 243	98.5	.75E+04	.11E+09	
				Cm 244	98.9	.45E+05	.68E+09	
				AM 241	99.0	.34E+04	.51E+08	
113.4	971.9	51539.1	33					.19E-01
143.8	2834.9	33744.1	9	Th 230	143.6	.12E+04	.18E+08	.71E-01
				U- 235	143.8	5.7	.86E+05	
				PU 239	144.2	.19E+06	.29E+10	
163.3	1217.9	26012.1	19	Ba 140	162.7	2.8	.43E+05	.36E-01
				U- 235	163.4	5.3	.79E+05	
185.8	14650.8	24533.2	2	Un 235	185.7	2.4	.36E+05	.52
				U- 235	185.7	5.5	.82E+05	
				Un 238	186.1	49.	.74E+06	
				U 238	186.1	87.	.13E+07	
205.3	966.1	19385.9	21	U- 235	205.3	4.0	.60E+05	.40E-01
209.7	440.3	18421.7	44	Ac 228	209.4	2.0	.30E+05	.19E-01
				Th 227	210.6	8.1	.12E+06	
238.6	4544.5	14672.5	4	Pb 212	238.6	2.2	.33E+05	.23
				Th 232	238.6	2.1	.32E+05	
242.0	948.0	13840.0	18	U- 235	240.9	.29E+03	.43E+07	.49E-01
				Pb 214	241.9	2.7	.40E+05	
270.1	636.1	9767.9	22	Ac 228	270.3	3.7	.55E+05	.38E-01
				U- 232	270.5	.38E+04	.57E+08	
				Th 227	270.6	.17E+04	.26E+08	
				Th 227	270.7	.43E+03	.65E+07	
				Np 240	270.8	1.5	.23E+05	
295.2	3351.0	7695.0	4	Pb 214	295.2	3.9	.58E+05	.23
				EU 152	296.0	.19E+03	.28E+07	
300.1	448.1	7498.9	28	TH 227	299.9	4.5	.68E+05	.31E-01
				U- 235	299.9	5.0	.75E+05	
				Pb 212	300.1	2.9	.44E+05	
				Pa 231	300.1	4.3	.65E+05	
				AM 241	300.1	.17E+07	.26E+11	
338.3	1362.1	5551.9	8	Ac 228	338.4	2.6	.39E+05	.11
				U- 235	338.6	11.	.17E+06	
351.8	6660.0	6046.0	2	Ra 226	351.9	4.4	.66E+05	.57
				Pb 214	352.0	4.3	.64E+05	
				Co 57	352.2	.48E+05	.72E+09	
409.5	235.2	4100.8	39	Ac 228	409.4	2.5	.38E+05	.25E-01
				Pa 234	409.8	14.	.21E+06	
				Ra 224	410.0	.14E+04	.21E+08	
				U- 235	410.3	.19E+04	.28E+08	
				Pa 231	410.5	.37E+04	.55E+08	
463.2	534.0	3119.0	15	Pa 228	463.0	1.0	.15E+05	.67E-01
				Ac 228	463.0	2.9	.44E+05	

				Sb 125	463.4	1.2	.19E+05	
510.8	1935.9	2776.1	4	I- 133	510.4	33.	.50E+06	.28
				TL 208	510.8	2.2	.32E+05	
				Na 22	511.0	.28	.41E+04	
				ZN 65	511.0	18.	.26E+06	
				Y 88	511.0	.12E+03	.19E+07	
				Ru 106	511.8	2.4	.36E+05	
583.1	3154.7	2221.3	3	Tl 208	583.1	.98	.15E+05	.54
				Th 232	583.1	2.8	.42E+05	
609.4	7212.8	2022.2	1	Xe 135	608.6	75.	.11E+07	1.3
				Bi 214	609.3	4.1	.62E+05	
				Ra 226	609.3	4.5	.68E+05	
				Ru 103	610.3	36.	.54E+06	
661.5	1403.1	1744.9	5	Cs 137	661.6	.46	.69E+04	.28
				AM 241	662.4	.11E+06	.17E+10	
727.1	748.1	1526.9	8	AC 228	727.0	.26E+03	.39E+07	.17
				Bi 212	727.2	1.8	.27E+05	
				U- 239	727.5	.85E+04	.13E+09	
				BI 214	727.8	.13E+04	.20E+08	
				PU 239	727.9	.17E+09	.26E+13	
742.9	450.1	1449.9	13	Pa 234	742.8	4.2	.63E+05	.10
				Pu 238	742.8	.23E+07	.34E+11	
				U- 235	743.1	2.5	.38E+05	
766.8	1727.0	1542.0	4	Nb 95	765.8	.49	.73E+04	.41
				Pu 238	766.4	.20E+07	.30E+11	
				Pa 234	766.6	.23E+03	.35E+07	
				PA 234	766.6	.23E+03	.35E+07	
				Rh 102	766.8	1.4	.21E+05	
				AM 241	766.9	.95E+07	.14E+12	
786.0	411.1	1280.9	13	Bi 212	785.4	5.8	.87E+05	.10
				Pa 234	786.3	.34E+03	.50E+07	
				Pu 238	786.3	.33E+07	.49E+11	
795.0	552.1	1127.9	10	Pa 228	794.7	7.8	.12E+06	.14
				Ac 228	794.8	3.2	.49E+05	
				TL 210	795.0	.16	.23E+04	
				CS 134	795.8	.18	.27E+04	
				Pa 234	796.2	4.6	.69E+05	
806.2	302.3	1049.7	16	Pu 238	805.4	.61E+08	.92E+12	.77E-01
				Bi 214	806.2	69.	.10E+07	
835.8	189.8	1121.2	26	Kr 88	834.7	.41	.62E+04	.50E-01
				Mn 54	834.8	.54E-01	.81E+03	
				Ac 228	835.6	3.0	.44E+05	
839.9	215.0	1049.0	22	AC 228	840.2	6.2	.93E+05	.57E-01
860.6	520.7	1059.3	10	Tl 208	860.4	1.2	.18E+05	.14
911.2	2549.7	981.3	3	Ac 228	911.1	2.5	.38E+05	.75
				Th 232	911.1	2.5	.38E+05	
934.0	549.0	835.0	9	Bi 214	934.1	5.0	.75E+05	.17
946.1	183.4	870.6	24	Pa 234	946.0	.44	.66E+04	.56E-01
				Pu 238	946.1	.53E+08	.79E+12	
				Pa 234	946.3	.76E+03	.11E+08	
964.4	215.8	1465.2	26	EU 152	964.0	.43	.64E+04	.68E-01
				Ac 228	964.6	1.1	.17E+05	
				Pa 228	964.6	.62	.94E+04	
968.9	1390.1	1252.9	4	Ac 228	968.9	2.3	.35E+05	.44
1001.2	2692.2	715.8	2	PA 234	1001.0	93.	.14E+07	.88
				Pa 234	1001.0	93.	.14E+07	
				U- 238	1001.0	93.	.14E+07	
				Pu 238	1001.1	.60E+08	.90E+12	
1094.5	132.9	578.1	27	U- 239	1093.8	.41E+04	.62E+08	.48E-01
				TL 208	1093.9	11.	.16E+06	
				Np 240	1094.2	11.	.17E+06	
				Am 240	1094.6	.24E+03	.37E+07	

				AC 228	1095.7	29.	.44E+06	
1120.4	2153.8	721.2	3	Bi 214	1120.4	3.7	.56E+05	.81
				Ra 226	1120.4	3.7	.56E+05	
1155.3	297.6	594.4	13	BI 214	1155.2	5.2	.78E+05	.12
1208.1	134.1	628.9	28					.55E-01
1238.1	843.1	649.9	5	I- 133	1237.5	16.	.24E+06	.36
				Bi 214	1238.1	4.3	.64E+05	
1281.2	213.1	595.9	18	BI 214	1281.0	4.4	.65E+05	.94E-01
1377.6	512.8	501.2	8	Bi 214	1377.7	3.9	.59E+05	.25
1385.1	116.1	462.9	28	Ag 110	1384.3	.15	.22E+04	.56E-01
				Bi 214	1385.3	4.6	.69E+05	
1401.2	140.0	484.0	24	Pa 234	1399.7	19.	.28E+06	.68E-01
				BI 214	1401.5	3.1	.47E+05	
1408.0	303.9	452.1	11	Bi 214	1408.0	3.8	.57E+05	.15
				EU 152	1408.0	.45	.67E+04	
				Al 28	1408.8	7.8	.12E+06	
1460.9	3870.4	438.6	2	K- 40	1460.8	11.	.17E+06	2.0
1495.7	106.9	369.1	27	AC 228	1495.8	3.2	.47E+05	.57E-01
				Np 240	1496.9	2.5	.38E+05	
1509.2	346.2	380.8	10	Bi 214	1509.2	4.9	.74E+05	.19
				Pa 234	1510.5	.12E+04	.18E+08	
1588.4	324.9	521.1	11	Al 28	1590.0	10.	.15E+06	.19
				TL 210	1590.0	5.2	.77E+05	
1621.0	159.6	323.4	18	Bi 212	1620.6	1.8	.28E+05	.93E-01
				Al 28	1622.6	1.5	.23E+05	
1630.7	144.6	322.4	19	AC 228	1630.4	2.3	.35E+05	.85E-01
1638.2	63.0	266.0	39	BI 214	1636.6	.11E+03	.16E+07	.37E-01
				Pa 234	1638.0	5.0	.75E+05	
				AC 228	1638.0	3.7	.55E+05	
1661.5	179.0	236.0	14	BI 214	1661.3	4.9	.74E+05	.11
1729.7	359.5	243.5	8	Bi 214	1729.6	3.8	.57E+05	.23
1764.6	1994.2	223.8	2	Bi 214	1764.0	3.8	.57E+05	1.3
				Pa 234	1765.4	.11E+05	.16E+09	
1847.5	285.3	215.7	9	BI 214	1847.4	4.4	.66E+05	.20
1896.6	90.8	188.2	24	BI 214	1896.3	17.	.25E+06	.64E-01
				Pa 234	1897.1	20.	.30E+06	
1910.1	84.8	157.2	24	Pa 234	1911.8	.75E+03	.11E+08	.61E-01
2103.2	397.9	191.1	7	TL 208	2103.5	1.3	.20E+05	.32
2119.0	187.3	164.7	12	BI 214	2118.5	5.2	.78E+05	.15
2204.1	606.5	194.5	5	Bi 214	2204.1	4.1	.62E+05	.52
2447.9	197.7	135.3	11	Bi 214	2447.7	4.5	.67E+05	.19
2614.8	3452.7	63.3	2	TL 208	2614.6	1.2	.18E+05	3.7

SUM OF ESTIMATED EXTERNAL EXPOSURE RATE: 20.2 uR/Hr

TABLE E-3
GAMMA RAYS UTILIZED FOR COMPARABILITY STUDY
FOR LABORATORY MEASUREMENTS

Analyte Isotope	Half Life (Years)	Energy (KeV)	Abundance (%)	Isotope of Emission
U-238	4.47E+9	63.29	3.8	Th-234
		92.59	5.41	Th-234
		766.41	0.207	Pa-234m
		1001.03	0.845	Pa-234m
U-235	7.04E+8	143.76	10.5	U-235
		185.72	54.0	U-235
Th-232	1.41E+10	238.63	44.6	Pb-212
		583.14	30.6*	Tl-208
		727.17	11.8	Bi-212
		911.07	27.7	Ac-228
Ra-226	1.60E+3	295.21	19.2	Pb-214
		351.92	37.2	Pb-214
		609.31	46.3	Bi-214
		1120.29	15.1	Bi-214
		1764.49	15.8	Bi-214
Cs-137	3.03E+1	661.65	84.62**	Ba-137m
K-40	1.28E+9	1460.81	10.7	K-40

* Includes 0.359 branching ratio from decay of Bi-212
** Includes 0.946 branching ratio from decay of Cs-137

APPENDIX F

TWO MEMORANDA DESCRIBING EML COMPARABILITY STUDY RESULTS

Department of Energy
Environmental Measurements Laboratory
201 Varick Street
New York, NY 10014-4811

April 9, 1997

Robert J. Janke, Fernald Area Office, FN

RESULTS OF COMPARABILITY STUDY

Enclosed are the results of our analyses of the field and laboratory measurements of total U, ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra, and ^{40}K in surface soils as part of a quality assurance effort associated with the Comparability Study. We have included a comparison of the *in situ* results to an averaged wet concentration derived from the analysis of the soil samples. Also included are the results for the quality control samples which were analyzed concurrently with the laboratory samples associated with this project. All radionuclide concentrations in soil were reported in units of pCi/g. We were successful in obtaining *in situ* concentrations for nine of the ten locations used in this study. We were also able to collect soil samples for seven of the ten locations.

Table 1 reports values of radionuclide concentrations reported in units of pCi/g of dry soil along with soil core parameters. The soil core data consists of a location ID which consistent with the identification scheme established by Fluor Daniel Fernald (FDF) for the purposes of this study (figure C-1 of the Characterization Comparability Study, February 1997, Rev. A). The sample ID pertains to EML's soil samples. The depth column indicates the depth, or depth range, from which the soil samples were obtained. For locations 5 and 6 several sections were taken from a single core to establish a concentration profile . The mass column refers to the mass of the sample and reflects the soil density. The percent water is the percent moisture per unit wet soil (w/w) . In the reporting of radionuclide concentrations, we have included a combined uncertainty in parenthesis and a minimum detectable concentration (MDC). For convenience, we have reported a total uranium concentration in ppm of dry soil. Also included in Table 1 is the activity ratio of $^{235}U/^{238}U$. Table 2 uses the soil moisture data to establish concentrations per unit wet soil. In reporting the uncertainties, we have adopted the recommendations of the BIPM Working Group on the Statement of Uncertainty. The uncertainties reported in tables 1 and 2 are the combined uncertainly of the calibration standard and a one-sigma counting error.
Table 3 shows the results for the *in situ* measurements for the heights of 1 m and 0.305 m (1ft) . Included in the these tables are the results of replicate measurements. Just as in tables 1 and 2, we have included an uncertainty in parenthesis and a MDC. We must point out that the uncertainty in Table 3 reflects only a one-sigma counting error. Figure 1 illustrates the agreement between the two measurements. Most results agree to within the statistical uncertainty of the measurement. At location 10, however, we see a significant difference between the 1ft and the 1m measurements for ^{226}Ra. This difference reflects the heterogeneity of the ^{226}Ra distribution in the soil.

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The top section of Table 4 reports wet concentrations obtained from the laboratory analysis of the soil samples. These values can be compared to the bottom section which reports the *in situ* values. The weighting factors used in the averaging of the wet concentrations reported in Table 2, are consistent with the values in Table C-7 of the Characterization Comparability Study, February 1997, Rev. A. Figure 2 is a plot of the *in situ* concentration as a function of the averaged wet concentrations derived from laboratory sample analysis (AWCLSA) . The dark line represents perfect agreement with the AWCLSA. The two lighter lines represents bands of 20% which has been mentioned as the limit for demonstrating comparability . In a similar fashion, Figures 3, 4, 5, 6, and 7 demonstrate the agreement of the *in situ* concentrations with the AWCLSA for ^{238}U, total U, ^{40}K, ^{226}Ra, and ^{232}Th respectively. In Figures 3, 4 and 6, we have indicted the location ID for each data point. Comparisons of *in situ* concentrations with the AWCLSA for ^{235}U were excluded because many of the measured *in situ* concentrations were at or below the MDC. It was felt that for locations 1, 4, 5, 8, and 9 the 1 foot *in situ* measurement would best reflect the AWCLSA. It should be pointed out it most cases that the concentrations reported for a 1 ft measurement were identical to the 1 m results.

While we believe that the relatively small differences between in the *in situ* and the AWCLSA are a result of real variations within the detector's field of view, we note that for ^{40}K, a naturally occurring radionuclide whose levels should not have been altered by activities at Fernald, the *in situ* concentrations are about 10% lower than the AWCLSA. This effect is most likely a result of the soil moisture profile. We can see from Table 1 that the soil moisture for the 0-5 cm sections are greater that the 10-15 cm sections by almost a factor of two. The corresponding wet concentration for ^{40}K in the 0-5 cm section is lower than for either the 5-10 cm or the 10-15 cm sections. If we realize that well over 50% the fluence rate for a uniformly distributed source comes from the first 5 centimeters of soil, it seems reasonable that the *in situ* values will be lower than the AWCLSA.

As a quality assurance measure for the *in situ* results, we have provided values for the parameters used to establish conversion factors for our instrument. These parameters include gamma ray intensities, mass attenuation coefficients for air and soil, and corresponding fluence rates . For medium to high energy gamma rays, variations in the soil composition have a small effect on the fluence rate. The values of the fluence rate that FDF uses to establish their conversion factors should not differ from the values listed in Table 5 by more than a few percent.

We can also see from Table 5 that the concentration of ^{226}Ra is inferred from its progeny ^{214}Pb and ^{214}Bi . This situation can be problematic when comparing AWCLSA to *in situ* data because the progeny ^{214}Pb and ^{214}Bi occur after ^{222}Rn in the decay chain of ^{226}Ra. ^{222}Rn is a noble gases which can escape from the soil disrupting the radioactive equilibrium existing between parent and progeny. The situation can be acute because the half-life of ^{222}Rn is almost 4 days. Disequilibrium factors for ^{226}Ra vary by soil type but typically fall within the range of 10 to 30%. We can see for locations 1,5, and 6 the disagreement between the AWCLSA and the *in situ* concentrations varies between 17- 28%. Agreement between the AWCLSA and the *in situ* concentrations can be further complicated by precipitation scavenging of ^{222}Rn progeny in the atmosphere. The effects of disequilibrium between ^{226}Ra and its progeny ^{214}Pb and ^{214}Bi can be masked by precipitation. If an *in situ* measurement of ^{226}Ra is made within 3 to 4 hours after a

shower, the levels of ^{214}Pb and ^{214}Bi present in the rain water can sufficiently increase the fluence rate from those nuclides to enhance the reported ^{226}Ra concentration. We suspect that we are seeing this effect in locations 8 and 9. Our measurements were performed in the morning not long after a soaking rain. The agreement between the AWCLSA and the *in situ* concentrations for those locations are much better than for any other location, suggesting that the effects of disequilibrium have been obscured by excess ^{214}Pb and ^{214}Bi present in the rain water. In general, caution must be exercised when interpreting *in situ* data for ^{226}Ra. We do point out, however, that by applying a correction factor for disequilibrium and performing measurements well after a precipitation event, comparability between AWCLSA and the *in situ* concentrations should be established. Moreover, the implications of this for the certification of confirmations units is clear: once a conservative correction is made for disequilibrium, the effects of precipitation will, in the worst case, cause a CU at, or near the FRL to fail.

In general, the observed agreement between concentrations inferred from soil sampling and *in situ* measurements is consistent with similar studies performed by EML over the past 30 years. We believe that the technique is well-suited for this application and will provide accurate and expedient results. Furthermore, we want to emphasize that *in situ* spectrometry should not be thought of as a replacement to standard soil sampling techniques; it should not even be recognized as a alternative. It is a tool to be used to enhance, expand, and expedite standard characterization and certification methodologies used in the decontamination and decommissioning process.

Peter Shebell, Physicist
Environmental Science Division

Enclosure: As stated

cc: Kevin Miller, EME
Mathew Monetti, EME

EML: Analytical Results for Comparability Study

Soil Core Data					Dry Concentration (pCi/g)													
Location ID	Sample ID	depth (cm)	mass‡ (g)	% Water	^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC	Total U (ppm)	MDC	$^{235}U/^{238}U$
1	1L1†	0-15	132.6	20.4%	2.64 (.07)	0.7	17.4 (.1)	0.1	0.88 (.01)	0.06	0.09 (.01)	0.05	0.83 (.03)	0.04	7.9 (.2)	2.2	0.034 (.004)
4	4M2	0-15	131.7	25.5%	25.7 (.2)	1.0	14.3 (.2)	0.2	1.29 (.02)	0.10	0.82 (.03)	0.10	1.29 (.04)	0.08	77.1 (.6)	3.3	0.032 (.001)
	4M3	0-15	133.3	24.6%	22.2 (.2)	1.0	14.3 (.2)	0.2	1.32 (.02)	0.10	0.72 (.03)	0.09	1.25 (.04)	0.07	66.6 (.6)	3.3	0.032 (.001)
	4M4	0-15	128.2	26.9%	24.3 (.2)	1.0	14.2 (.2)	0.2	1.24 (.01)	0.10	0.82 (.03)	0.09	1.23 (.04)	0.07	73.0 (.6)	3.3	0.034 (.001)
5	5M2a	0-5	119.3	30.3%	21.8 (.2)	1.0	16.3 (.2)	0.2	1.14 (.02)	0.10	0.67 (.04)	0.10	1.29 (.05)	0.09	65.5 (.6)	3.3	0.031 (.002)
	5M2b	5-10	141.9	18.1%	13.2 (.2)	1.0	17.0 (.2)	0.2	1.23 (.01)	0.10	0.45 (.03)	0.09	1.17 (.04)	0.08	39.7 (.6)	3.3	0.034 (.002)
	5M2c	10-15	146.2	16.6%	6.0 (.1)	1.0	16.7 (.2)	0.2	1.21 (.01)	0.10	0.21 (.03)	0.08	1.11 (.02)	0.06	18.1 (.3)	3.2	0.035 (.005)
	5M3a	0-5	118.6	30.2%	20.3 (.2)	2.0	16.8 (.3)	0.2	1.21 (.02)	0.10	0.70 (.03)	0.10	1.23 (.05)	0.10	61.0 (.6)	6.3	0.034 (.002)
	5M3b	5-10	137.3	21.7%	16.4 (.2)	1.0	16.9 (.2)	0.2	1.25 (.02)	0.10	0.57 (.04)	0.10	1.38 (.05)	0.10	49.3 (.6)	3.3	0.035 (.002)
	5M3c	10-15	138.3	18.9%	9.0 (.3)	2.0	16.8 (.2)	0.3	1.28 (.03)	0.20	0.35 (.05)	0.20	1.23 (.05)	0.20	27.0 (.9)	6.6	0.039 (.006)
	5M4a	0-5	123.4	30.2%	19.5 (.3)	2.0	16.3 (.3)	0.4	1.09 (.02)	0.20	0.62 (.05)	0.20	1.31 (.05)	0.10	58.6 (.9)	6.6	0.032 (.003)
	5M4b	5-10	136.8	22.7%	17.1 (.1)	0.9	16.6 (.2)	0.1	1.20 (.01)	0.08	0.61 (.02)	0.07	1.27 (.04)	0.06	51.4 (.3)	2.9	0.036 (.001)
	5M4c	10-15	146.1	17.8%	7.40 (.09)	0.6	17.6 (.1)	0.1	1.24 (.01)	0.06	0.24 (.02)	0.05	1.14 (.04)	0.04	22.2 (.3)	1.9	0.032 (.003)
6	6M1a	0-5	116.2	29.2%	31.6 (.2)	1.0	14.4 (.2)	0.2	1.29 (.01)	0.10	1.13 (.03)	0.09	1.29 (.04)	0.08	94.9 (.6)	3.3	0.036 (.001)
	6M1b	5-10	126.5	23.2%	38.5 (.1)	0.8	14.3 (.1)	0.1	1.38 (.01)	0.07	1.29 (.02)	0.07	1.29 (.04)	0.05	115.6 (.3)	2.6	0.034 (.001)
	6M1c	10-15	133.8	19.4%	23.0 (.1)	0.8	14.5 (.1)	0.1	1.36 (.01)	0.07	0.80 (.02)	0.07	1.21 (.04)	0.06	69.1 (.3)	2.6	0.035 (.001)
	6M2a	0-5	115.2	31.5%	41.1 (.2)	1.0	13.9 (.2)	0.2	1.28 (.02)	0.10	1.40 (.04)	0.10	1.25 (.04)	0.09	123.4 (.6)	3.3	0.034 (.001)
	6M2b	5-10	138.8	22.8%	31.3 (.1)	0.7	14.3 (.1)	0.1	1.43 (.01)	0.06	1.04 (.02)	0.06	1.29 (.04)	0.05	93.8 (.3)	2.3	0.033 (.001)
	6M2c	10-15	142.3	19.0%	9.1 (.2)	1.0	14.4 (.2)	0.2	1.28 (.01)	0.10	0.34 (.02)	0.09	1.15 (.04)	0.07	27.3 (.6)	3.3	0.037 (.002)
	6M3	0-15	120.3	27.1%	44.3 (.3)	1.0	14.0 (.2)	0.2	1.38 (.02)	0.10	1.54 (.03)	0.10	1.36 (.05)	0.09	133.0 (.9)	3.3	0.035 (.001)
	6M4	0-15	130.1	24.7%	32.7 (.2)	1.0	14.2 (.2)	0.2	1.37 (.02)	0.10	1.14 (.03)	0.10	1.28 (.04)	0.09	98.2 (.6)	3.3	0.035 (.001)
	6M5a	0-5	116.6	30.9%	37.7 (.3)	1.0	14.0 (.2)	0.2	1.32 (.02)	0.10	1.23 (.03)	0.10	1.28 (.05)	0.09	113.2 (.9)	3.3	0.033 (.001)
	6M5b	5-10	134.1	22.2%	29.8 (.2)	1.0	14.7 (.2)	0.2	1.43 (.02)	0.10	0.99 (.03)	0.10	1.30 (.04)	0.08	89.5 (.6)	3.3	0.033 (.001)
	6M5c	10-15	137.8	19.9%	10.8 (.1)	0.8	14.6 (.1)	0.2	1.29 (.01)	0.07	0.37 (.02)	0.06	1.12 (.04)	0.05	32.4 (.3)	2.6	0.034 (.002)
	6M6	0-15	120.6	29.8%	40.5 (.2)	0.9	14.0 (.1)	0.2	1.36 (.01)	0.07	1.30 (.02)	0.07	1.35 (.04)	0.05	121.6 (.6)	2.9	0.032 (.001)
	6M7	0-15	123.8	27.4%	32.0 (.2)	1.0	13.9 (.2)	0.2	1.26 (.20)	0.10	1.03 (.03)	0.10	1.24 (.04)	0.09	96.1 (.6)	3.3	0.032 (.001)
	6M8	0-15	124.6	26.3%	38.3 (.2)	1.0	14.0 (.2)	0.2	1.29 (.01)	0.10	1.32 (.03)	0.10	1.26 (.04)	0.08	115.0 (.6)	3.3	0.034 (.001)
	6M9	0-15	127.1	24.8%	32.0 (.2)	1.0	14.3 (.2)	0.2	1.36 (.02)	0.10	1.09 (.03)	0.10	1.32 (.05)	0.08	96.1 (.6)	3.3	0.034 (.001)
	6M10	0-15	124.9	28.2%	41.6 (.1)	0.7	14.0 (.1)	0.1	1.38 (.01)	0.06	1.39 (.02)	0.06	1.33 (.04)	0.04	124.9 (.3)	2.3	0.033 (.000)
8	8L1†	0-15	126.4	30.0%	1.70 (.07)	0.8	15.1 (.1)	0.1	1.08 (.01)	0.07	0.06 (.01)	0.05	0.89 (.03)	0.05	5.1 (.2)	2.5	0.035 (.01)
9	9L1†	0-15	124.5	27.0%	2.72 (.06)	0.5	14.2 (.1)	0.09	1.11 (.01)	0.05	0.08 (.01)	0.04	0.98 (.03)	0.04	8.2 (.2)	1.6	0.029 (.004)

† composite core
‡ 90 ml sample volume

Table 1

000358

924

EML: Analytical Results for Comparability Study

Soil Core Data					Wet Concentrations (pCi/g)											
Location ID	Sample ID	depth (cm)	mass‡ (g)	% Water	^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC	Total U (ppm)	MDC
1	1L1†	0-15	132.6	20.4%	2.1 (.1)	0.6	13.9 (.1)	0.1	0.70 (.01)	0.05	0.07 (.01)	0.04	0.66 (.02)	0.03	6.3 (.2)	1.8
4	4M2	0-15	131.7	25.5%	19.2 (.2)	0.7	10.7 (.1)	0.1	0.96 (.01)	0.07	0.61 (.02)	0.07	0.96 (.03)	0.06	57.5 (.4)	2.4
	4M3	0-15	133.3	24.6%	16.7 (.2)	0.8	10.8 (.2)	0.2	1.00 (.02)	0.08	0.54 (.02)	0.07	0.94 (.03)	0.05	50.3 (.5)	2.5
	4M4	0-15	128.2	26.9%	17.8 (.2)	0.7	10.4 (.1)	0.1	0.91 (.01)	0.07	0.60 (.02)	0.07	0.90 (.03)	0.05	53.4 (.4)	2.4
5	5M2a	0-5	119.3	30.3%	15.2 (.2)	0.7	11.4 (.1)	0.1	0.79 (.01)	0.07	0.47 (.03)	0.07	0.90 (.03)	0.06	45.7 (.4)	2.3
	5M2b	5-10	141.9	18.1%	10.8 (.2)	0.8	13.9 (.2)	0.2	1.01 (.01)	0.08	0.37 (.02)	0.07	0.96 (.03)	0.07	32.5 (.5)	2.7
	5M2c	10-15	146.2	16.6%	5.0 (.1)	0.8	13.9 (.2)	0.2	1.01 (.01)	0.08	0.18 (.03)	0.07	0.93 (.02)	0.05	15.1 (.2)	2.7
	5M3a	0-5	118.6	30.2%	14.2 (.1)	1.4	11.7 (.2)	0.1	0.85 (.01)	0.07	0.49 (.02)	0.07	0.86 (.03)	0.07	42.6 (.4)	4.4
	5M3b	5-10	137.3	21.7%	12.8 (.2)	0.8	13.2 (.2)	0.2	0.98 (.02)	0.08	0.45 (.03)	0.08	1.08 (.04)	0.08	38.6 (.5)	2.6
	5M3c	10-15	138.3	18.9%	7.3 (.2)	1.6	13.6 (.2)	0.2	1.04 (.02)	0.16	0.28 (.04)	0.16	1.00 (.04)	0.16	21.9 (.7)	5.3
	5M4a	0-5	123.4	30.2%	13.6 (.2)	1.4	11.4 (.2)	0.3	0.76 (.01)	0.14	0.43 (.03)	0.14	0.91 (.03)	0.07	40.9 (.6)	4.6
	5M4b	5-10	136.8	22.7%	13.2 (.1)	0.7	12.8 (.2)	0.1	0.93 (.01)	0.06	0.47 (.02)	0.05	0.98 (.03)	0.05	39.7 (.2)	2.2
	5M4c	10-15	146.1	17.8%	6.1 (.1)	0.5	14.5 (.1)	0.1	1.02 (.01)	0.05	0.20 (.02)	0.04	0.94 (.03)	0.03	18.3 (.2)	1.6
6	6M1a	0-5	116.2	29.2%	22.4 (.1)	0.7	10.2 (.1)	0.1	0.91 (.01)	0.07	0.80 (.02)	0.06	0.91 (.03)	0.06	67.2 (.4)	2.3
	6M1b	5-10	126.5	23.2%	29.5 (.1)	0.6	11.0 (.1)	0.1	1.06 (.01)	0.05	0.99 (.02)	0.05	0.99 (.03)	0.04	88.7 (.2)	2.0
	6M1c	10-15	133.8	19.4%	18.5 (.1)	0.6	11.7 (.1)	0.1	1.10 (.01)	0.06	0.64 (.02)	0.06	0.98 (.03)	0.05	55.7 (.2)	2.1
	6M2a	0-5	115.2	31.5%	28.2 (.1)	0.7	9.5 (.1)	0.1	0.88 (.01)	0.07	0.96 (.03)	0.07	0.86 (.03)	0.06	84.6 (.4)	2.3
	6M2b	5-10	138.8	22.8%	24.1 (.1)	0.5	11.0 (.1)	0.1	1.10 (.01)	0.05	0.80 (.02)	0.05	1.00 (.03)	0.04	72.4 (.2)	1.8
	6M2c	10-15	142.3	19.0%	7.4 (.2)	0.8	11.7 (.2)	0.2	1.04 (.01)	0.08	0.28 (.02)	0.07	0.93 (.03)	0.06	22.1 (.5)	2.6
	6M3	0-15	120.3	27.1%	32.3 (.2)	0.7	10.2 (.1)	0.1	1.01 (.01)	0.07	1.12 (.02)	0.07	0.99 (.04)	0.07	97.0 (.7)	2.4
	6M4	0-15	130.1	24.7%	24.6 (.2)	0.8	10.7 (.2)	0.2	1.03 (.02)	0.08	0.86 (.02)	0.08	0.96 (.03)	0.07	74.0 (.5)	2.5
	6M5a	0-5	116.6	30.9%	26.0 (.2)	0.7	9.7 (.1)	0.1	0.91 (.01)	0.07	0.85 (.02)	0.07	0.88 (.03)	0.06	78.2 (.6)	2.3
	6M5b	5-10	134.1	22.2%	23.2 (.2)	0.8	11.4 (.2)	0.2	1.11 (.02)	0.08	0.77 (.02)	0.08	1.01 (.03)	0.06	69.6 (.5)	2.6
	6M5c	10-15	137.8	19.9%	8.7 (.1)	0.6	11.7 (.1)	0.2	1.03 (.01)	0.06	0.30 (.02)	0.05	0.90 (.03)	0.04	26.0 (.2)	2.1
	6M6	0-15	120.6	29.8%	28.4 (.1)	0.6	9.8 (.1)	0.1	0.96 (.01)	0.05	0.91 (.01)	0.05	0.95 (.03)	0.04	85.4 (.4)	2.0
	6M7	0-15	123.8	27.4%	23.2 (.1)	0.7	10.1 (.1)	0.1	0.91 (.15)	0.07	0.75 (.02)	0.07	0.90 (.03)	0.07	69.7 (.4)	2.4
	6M8	0-15	124.6	26.3%	28.2 (.1)	0.7	10.3 (.1)	0.1	0.95 (.01)	0.07	0.97 (.02)	0.07	0.93 (.03)	0.06	84.8 (.4)	2.4
	6M9	0-15	127.1	24.8%	24.1 (.2)	0.8	10.8 (.2)	0.2	1.02 (.02)	0.08	0.82 (.02)	0.08	0.99 (.04)	0.06	72.2 (.4)	2.5
	6M10	0-15	124.9	28.2%	29.9 (.1)	0.5	10.1 (.1)	0.1	0.99 (.01)	0.04	1.00 (.01)	0.04	0.95 (.03)	0.03	89.7 (.2)	1.6
8	8L1†	0-15	126.4	30.0%	1.19 (.05)	0.6	10.6 (.1)	0.1	0.76 (.01)	0.05	0.04 (.01)	0.03	0.62 (.02)	0.03	3.6 (.1)	1.8
9	9L1†	0-15	124.5	27.0%	1.99 (.04)	0.4	10.4 (.1)	0.1	0.81 (.01)	0.04	0.06 (.01)	0.03	0.72 (.02)	0.03	6.0 (.1)	1.2

† composite core
‡ 90 ml sample volume

Table 2

0003359

EML: Analytical Results for Comparability Study

In Situ Concentrations (pCi/g): (100 cm)

Location ID	^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC	Total U (ppm)	MDC
1	4.6 (.6)	2.7	12.0 (.2)	0.2	0.56 (.02)	0.06	0.0 (.2)	0.6	0.60 (.02)	0.06	14 (2)	8
2	8.1 (.5)	3.0	8.1 (.2)	0.2	0.75 (.02)	0.07	0.4 (.1)	0.6	0.75 (.02)	0.07	24 (2)	10
4	18.5 (.9)	3.0	9.9 (.2)	0.2	0.81 (.02)	0.06	1.0 (.2)	0.6	0.85 (.02)	0.06	56 (3)	12
5	14.9 (.6)	2.9	11.0 (.2)	0.2	0.69 (.02)	0.07	0.6 (.2)	0.7	0.90 (.02)	0.07	45 (2)	10
Replicate	18.2 (.5)	2.8	11.1 (.2)	0.3	0.67 (.02)	0.07	1.0 (.2)	0.6	0.95 (.03)	0.07	55 (2)	11
6	25.8 (.7)	3.1	9.6 (.2)	0.2	0.87 (.02)	0.06	1.1 (.2)	0.6	0.86 (.02)	0.06	78 (2)	13
Replicate	25.4 (.5)	2.9	9.6 (.2)	0.2	0.77 (.02)	0.06	1.2 (.2)	0.5	0.89 (.02)	0.06	76 (2)	12
7	50.6 (.6)	2.9	9.9 (.2)	0.2	0.80 (.02)	0.07	2.6 (.2)	0.6	1.05 (.03)	0.07	152 (2)	16
8	1.3 (.4)	1.4	9.8 (.2)	0.1	0.67 (.01)	0.04	0.1 (.1)	0.3	0.61 (.01)	0.04	4 (1)	4
9	1.3 (.6)	1.8	9.9 (.2)	0.1	0.87 (.01)	0.04	0.2 (.1)	0.3	0.65 (.01)	0.04	4 (2)	6
Replicate	1.7 (.4)	1.2	9.6 (.2)	0.1	0.72 (.01)	0.04	0.2 (.1)	0.3	0.67 (.02)	0.04	5 (1)	4
10	24.3 (.2)	4.1	10.7 (.2)	0.4	1.73 (.04)	0.14	1.4 (.2)	0.9	7.64 (.06)	0.14	73.1 (.7)	16

(30.5 cm)

Location ID	^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC	Total U (ppm)	MDC
1	3.3 (.7)	2.4	12.1 (.2)	0.2	0.58 (.02)	0.06	0.3 (.1)	0.4	0.62 (.02)	0.06	10 (2)	8
2	10.8 (.7)	2.4	8.1 (.2)	0.2	0.60 (.02)	0.07	0.3 (.2)	0.7	0.75 (.02)	0.07	32 (2)	8
4	18.1 (.8)	2.8	10.0 (.2)	0.2	0.87 (.02)	0.06	1.4 (.1)	0.5	0.86 (.02)	0.06	55 (2)	12
5	12.7 (.7)	2.9	11.4 (.2)	0.2	0.65 (.02)	0.07	0.7 (.2)	0.6	0.86 (.02)	0.07	38 (2)	11
Replicate	12.3 (.6)	2.5	12.0 (.2)	0.2	0.71 (.02)	0.07	1.1 (.2)	0.6	0.86 (.02)	0.07	37 (2)	11
6	24.8 (.8)	2.7	9.8 (.2)	0.2	0.88 (.02)	0.06	1.1 (.1)	0.4	0.91 (.02)	0.06	75 (2)	11
7	51.0 (.7)	3.0	9.6 (.2)	0.2	0.78 (.02)	0.07	2.0 (.2)	0.6	1.11 (.03)	0.07	153 (2)	15
8	1.0 (.3)	1.3	9.7 (.1)	0.1	0.71 (.01)	0.04	0.2 (.1)	0.3	0.62 (.01)	0.04	3 (1)	4
9	2.3 (.5)	1.7	9.9 (.1)	0.1	0.82 (.01)	0.04	0.2 (.1)	0.3	0.67 (.01)	0.04	7 (1)	6
10	26.6 (.7)	4.5	10.7 (.2)	0.3	1.77 (.03)	0.11	1.2 (.2)	0.8	6.26 (.05)	0.11	80 (2)	17

Table 3

EML: Analytical Results for Comparability Study

Averaged Wet Concentrations from Laboratory Sample Analysis (AWCLSA) (pCi/g)

Location	^{238}U	MDC	^{40}K	^{226}Ra	^{235}U	MDC	^{232}Th	Total U (ppm)	MDC
1	2.1 (.1)	0.6	13.9 (.1)	0.70 (.01)	0.07 (.01)	0.04	0.66 (.02)	6.3 (.2)	1.7
4	18 (1)	1.0	10.6 (.2)	0.95 (.04)	0.58 (.04)	0.07	0.93 (.03)	54 (4)	3
5	10.7 (.1)	1.0	13.0 (.2)	0.94 (.01)	0.36 (.03)	0.08	0.96 (.04)	32.0 (.4)	2.9
6	25.3 (.1)	0.7	10.5 (.1)	0.99 (.02)	0.85 (.02)	0.06	0.95 (.02)	76.0 (.4)	2.1
8	1.19 (.05)	0.6	10.6 (.1)	0.76 (.01)	0.04 (.01)	0.03	0.62 (.02)	3.6 (.1)	1.7
9	1.99 (.04)	0.4	10.4 (.1)	0.81 (.01)	0.06 (.04)	0.03	0.72 (.03)	6.0 (.1)	1.1

In Situ Concentrations (pCi/g)

Location	^{238}U	MDC	^{40}K	^{226}Ra	^{235}U	MDC	^{232}Th	Total U (ppm)	MDC
1†	3.3 (.7)	2.4	12.1 (.2)	0.58 (.02)	0.3 (.1)	0.4	0.62 (.02)	10 (2)	8
4†	18.1 (.8)	2.8	10.0 (.2)	0.87 (.02)	1.4 (.1)	0.5	0.86 (.02)	55 (2)	12
5†	12 (.3)	3	11.1 (.2)	0.68 (.02)	0.8 (.3)	0.6	0.93 (.03)	38 (2)	11
6*	25.6 (.3)	2.9	9.6 (.2)	0.82 (.07)	1.2 (.1)	0.6	0.87 (.02)	77 (2)	13
8†	1.0 (.3)	1.3	9.7 (.1)	0.71 (.01)	0.2 (.1)	0.3	0.62 (.01)	3 (1)	4
9†	2.3 (.5)	1.7	9.9 (.1)	0.82 (.01)	0.2 (.2)	0.3	0.67 (.01)	7 (1)	6

† 30 cm in situ measurement

* 100 cm in situ measurement

Table 4

000361

Radionuclide Data and Fluence Rate:

Parent Nuclide	Progeny	Energy (keV)	γ/dis.[§] s^{-1} Bq^{-1}	Fluence Rate (cm^{-2} s^{-1} Bq^{-1} g)
U-238				
	Th-234 (24.10 d)	63.3	0.0381	0.0709
	Pa-234m (1.17m)	1001.1	0.00845[†]	0.0622
U-234		143.8	0.105	0.33
Ra-226				
	Pb-214 (26.8 m)	351.9	0.371	0.8134
	Bi-214 (19.9 m)	609.3	0.461	2.67
		1120	0.15	1.172
		1765	0.159	1.578
Th-232				
	Ac-228 (6.13 h)	338.4	0.124	0.5379
		911	0.29	0.2037
	Th-208 (3.07 m)	583	0.306*	1.737
		2614.7	0.359*	4.389
K-40		1460	0.107	0.9607

[§] Gamma emission per disintegration (ICRU-38)

[†] Siemon at al.,1992

* includes 0.359 branching ratio from the decay of ^{212}Bi (ICRU-38)

Soil Composition Data:

Element	Relative Weight Fraction
H	0.028
C	0.0102
O	0.613
Al	0.0595
Si	0.263
Fe	0.0262

Energy (keV)	Mass Attenuation Coefficient (cm^{-2} g) air	soil
63.3	0.246	0.175
143.8	0.147	0.136
338.4	0.105	0.101
351.9	0.103	0.0999
583	0.0837	0.0815
609.3	0.0821	0.08
911	0.0682	0.0665
1001.1	0.0652	0.0636
1120	0.0615	0.06
1460	0.0583	0.0525
1764.9	0.0488	0.0475
2614.7	0.0389	0.0385

Table 5

000362

924

QA for LSA

Soil Core Data			Dry Concentration (pCi/g)													
Sample ID	depth (cm)	mass (g)	^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC	Total U (ppm)	MDC	$^{235}U/^{238}U$
5M3a	0-5	118.6	20.3 (.2)	2.0	16.8 (.3)	0.2	1.21 (.02)	0.10	0.70 (.03)	0.10	1.23 (.05)	0.10	65.5 (.2)	2.2	0.034 (.002)
5M3a*		118.6	19.9 (.2)	1.0	16.5 (.2)	0.2	1.18 (.02)	0.10	0.70 (.04)	0.10	1.27 (.05)	0.09	59.8 (.6)	3.3	0.035 (.002)
5M3a**		120.1	20.3 (.1)	0.8	16.4 (.1)	0.1	1.15 (.01)	0.07	0.70 (.02)	0.06	1.23 (.04)	0.05	61.0 (.3)	2.6	0.034 (.001)
6M2a	0-5	115.2	41.1 (.2)	1.0	13.9 (.2)	0.2	1.28 (.02)	0.10	1.40 (.04)	0.10	1.25 (.04)	0.09	123.4 (.6)	3.3	0.034 (.001)
6M2a*		115.2	41.5 (.2)	1.0	14.2 (.2)	0.2	1.30 (.01)	0.10	1.33 (.03)	0.10	1.27 (.04)	0.09	124.6 (.6)	3.3	0.032 (.001)
6M2a**		113.6	41.4 (.2)	1.0	14.1 (.2)	0.2	1.27 (.02)	0.10	1.43 (.03)	0.10	1.27 (.05)	0.09	124.3 (.6)	3.3	0.035 (.001)
9L1†	0-15	124.5	2.72 (.06)	0.5	14.2 (.1)	0.09	1.11 (.01)	0.05	0.08 (.01)	0.04	0.98 (.03)	0.04	8.2 (.6)	3.3	0.029 (.004)
9L1*		124.5	2.71 (.05)	0.6	14.1 (.1)	0.1	1.11 (.01)	0.05	0.13 (.01)	0.04	0.95 (.03)	0.04	8.2 (.1)	1.9	0.048 (.004)
9L1**		125.1	2.66 (.05)	0.6	14.0 (.1)	0.1	1.05 (.01)	0.05	0.11 (.01)	0.04	0.94 (.03)	0.04	8.0 (.1)	1.9	0.041 (.004)
6M3	0-15	120.3	44.3 (.3)	1.0	14.0 (.2)	0.2	1.38 (.02)	0.10	1.54 (.03)	0.10	1.36 (.05)	0.09	133.0 (.9)	3.3	0.035 (.001)
6M3*		120.3	44.1 (.3)	1.0	13.7 (.2)	0.2	1.36 (.02)	0.10	1.54 (.03)	0.10	1.29 (.05)	0.09	132.5 (.9)	3.3	0.035 (.001)
6M3**		123.3	44.5 (.3)	1.0	14.0 (.2)	0.2	1.30 (.02)	0.10	1.48 (.03)	0.10	1.25 (.04)	0.09	133.6 (.9)	3.3	0.033 (.001)
6M3**		120.3	44.1 (.2)	1.0	14.2 (.2)	0.2	1.32 (.01)	0.10	1.45 (.03)	0.10	1.36 (.05)	0.08	132.4 (.6)	3.3	0.033 (.001)

* QC Sample-recounted
** QC realiquoted

Blank (Deionized water)

^{238}U	MDC	^{40}K	MDC	^{226}Ra	MDC	^{235}U	MDC	^{232}Th	MDC
0.0 (.04)	1.0	0.0 (.1)	0.2	0.00 (.01)	0.09	0.00 (.02)	0.07	0.02 (.02)	0.08

QAP† Reference Soil

	^{238}U	MDC	^{40}K	MDC
QAP	3.8 (.1)	-	16.4 (.1)	-
LSA for comp. study	3.2 (.3)	0.6	16.2 (.1)	0.1

† EML's Quality Assurance Program

NBS‡ Reference Soil

	^{238}U	MDC	^{232}Th	MDC	^{40}K	MDC
NBS	1.1 (.1)	-	1.9 (.1)	-	20 (2)	-
LSA for comp. study	1.2 (.3)	0.6	1.81 (.06)	0.1	18.2 (.3)	0.1

‡ National Bureau of Standards

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1 ft - 1m chart

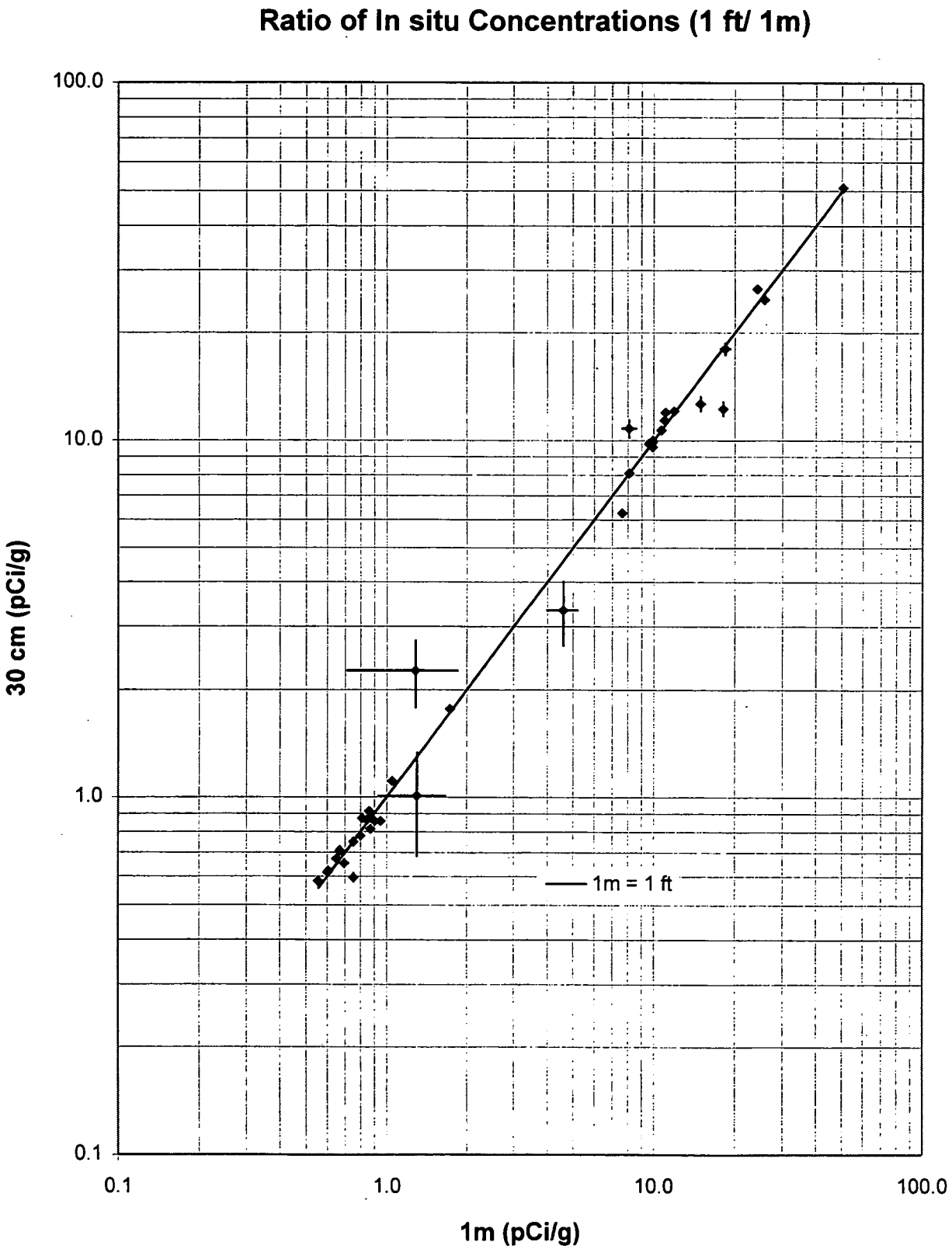

Figure 1

Comparison of Reported Concentrations for All Nuclides (except ^{235}U) : In Situ vs. AWCLSA

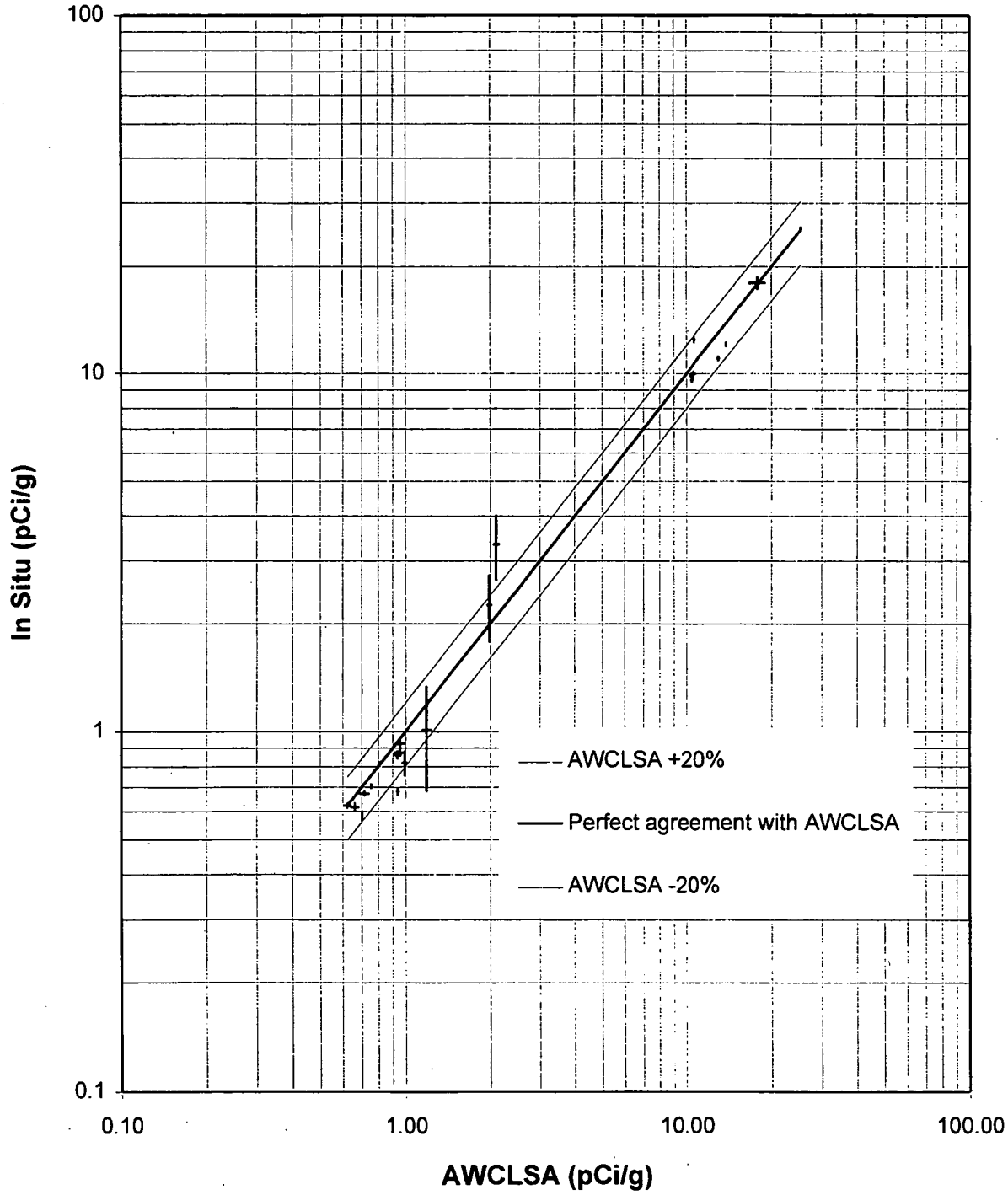

Figure 2

U-238 chart

Comparison of Reported Concentrations for ^{238}U: In Situ vs. AWCLSA

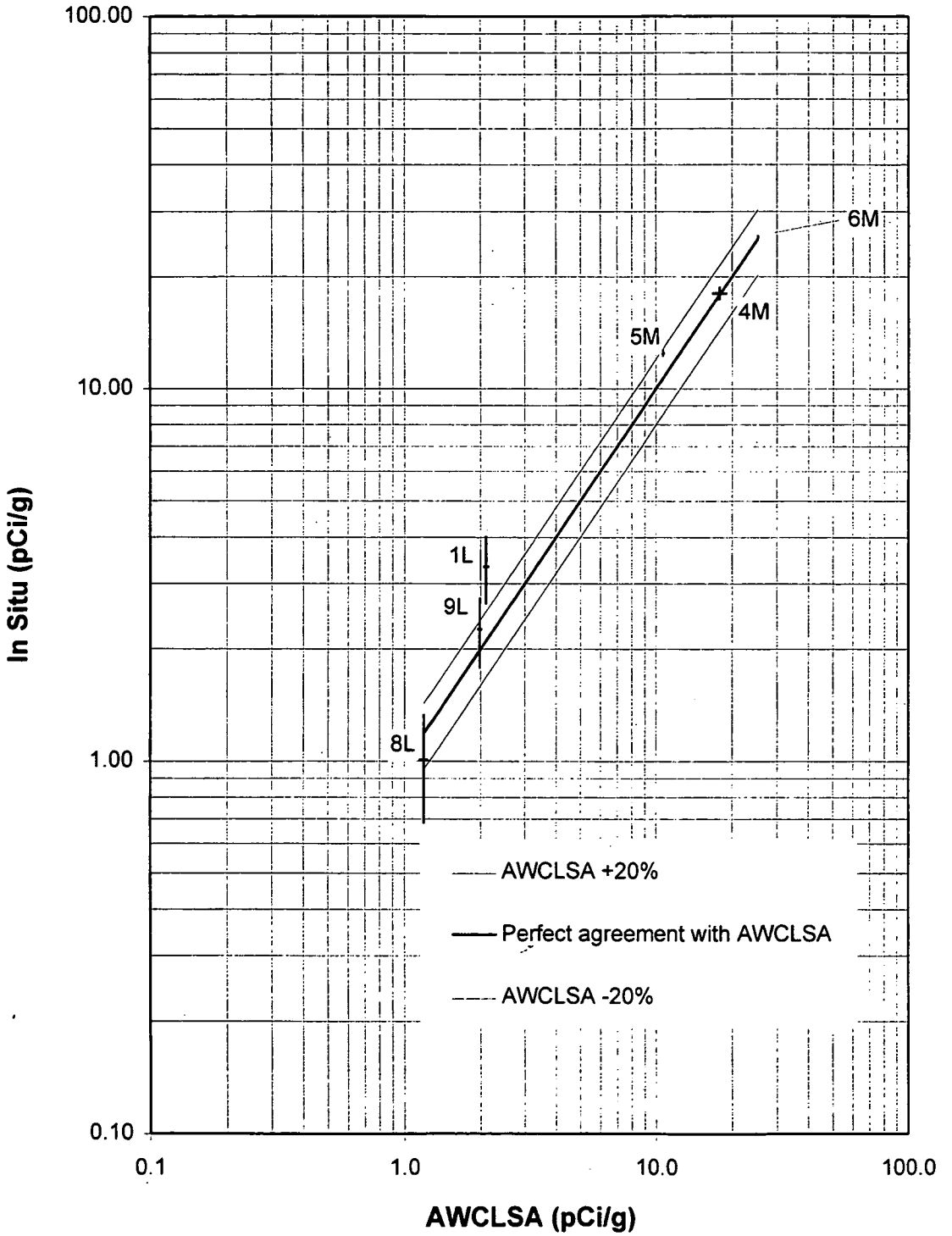

Figure 3

Comparison of Reported Concentrations for Total U: In Situ vs. AWCLSA

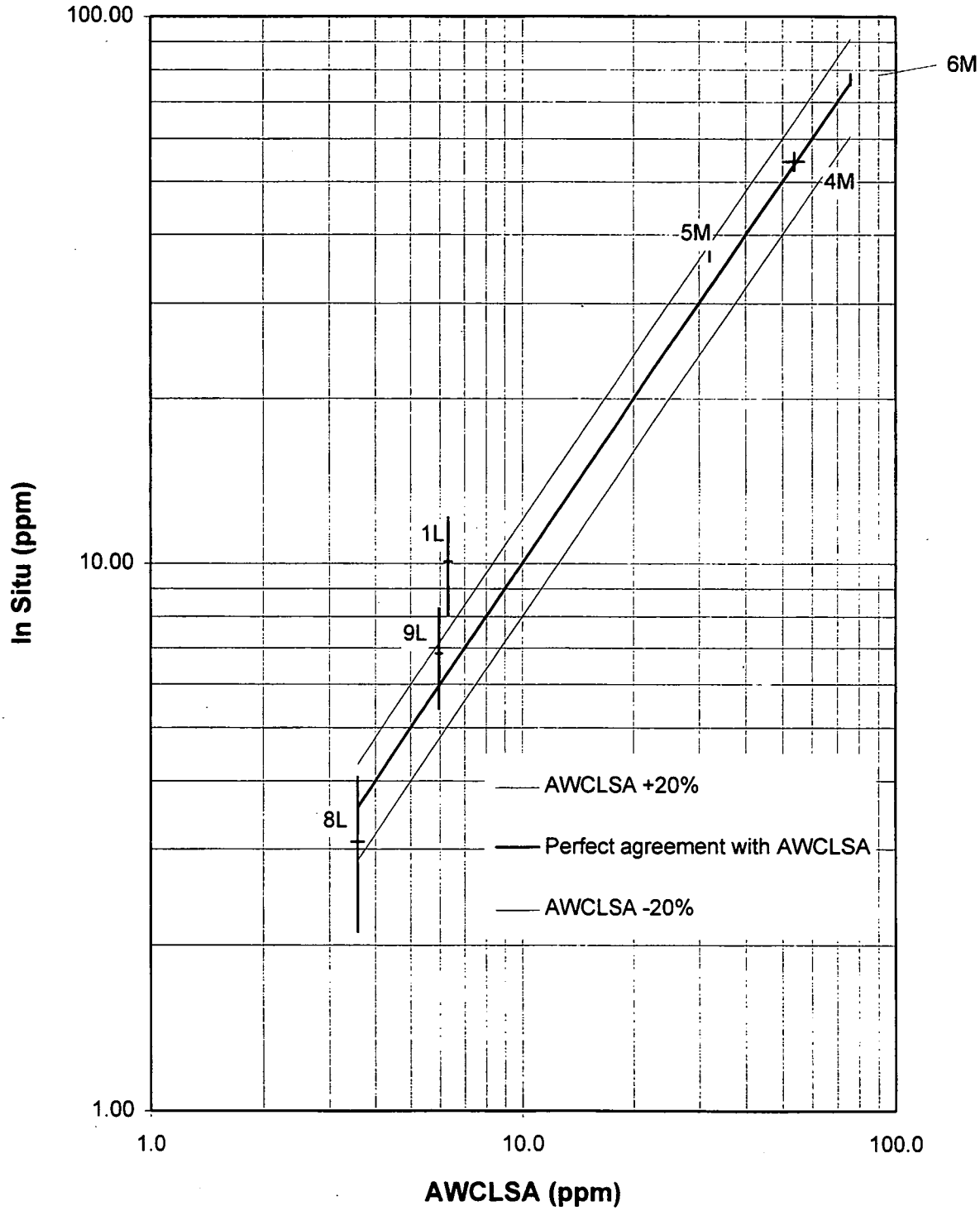

Figure 4

K-40 chart

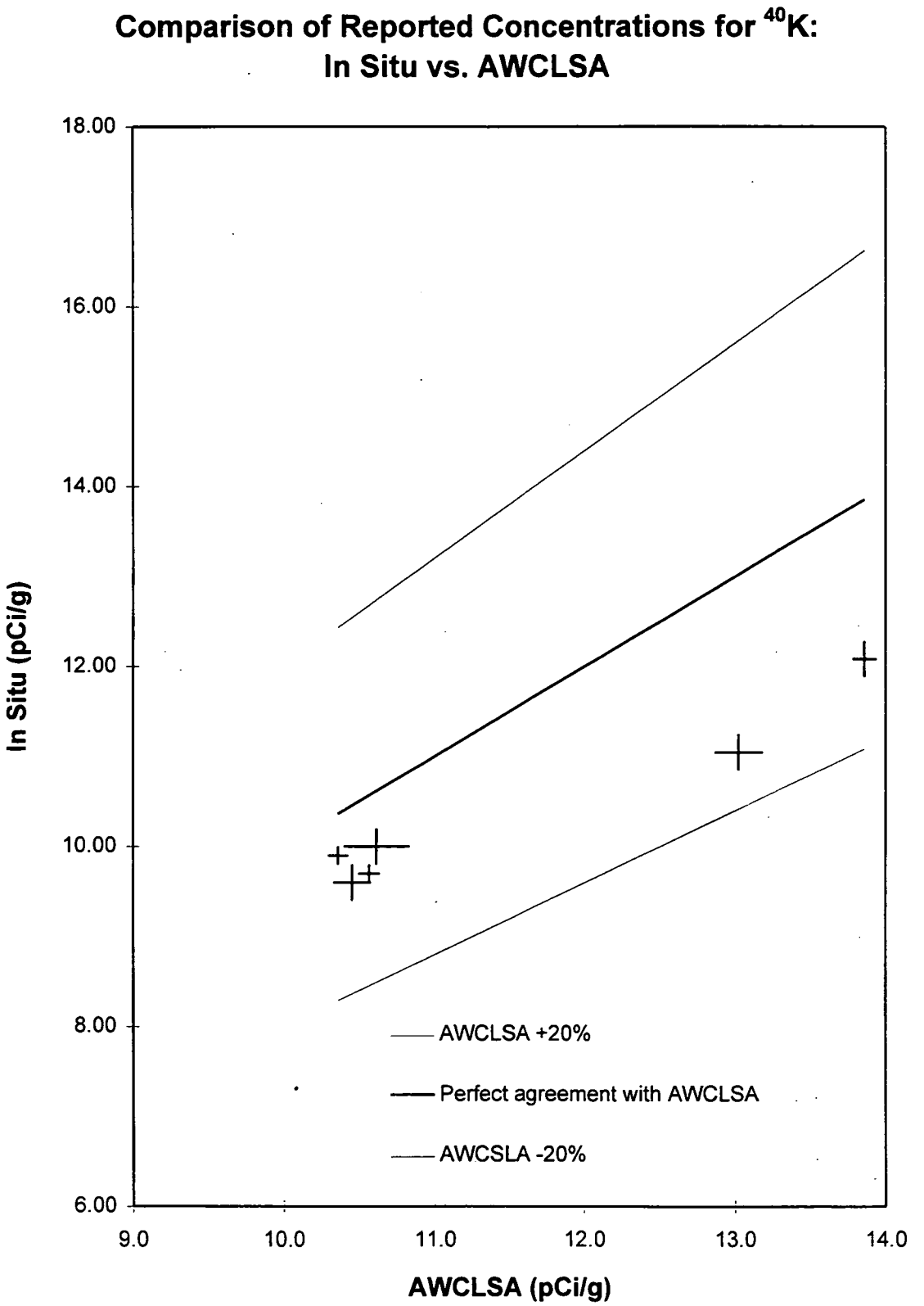

Figure 5

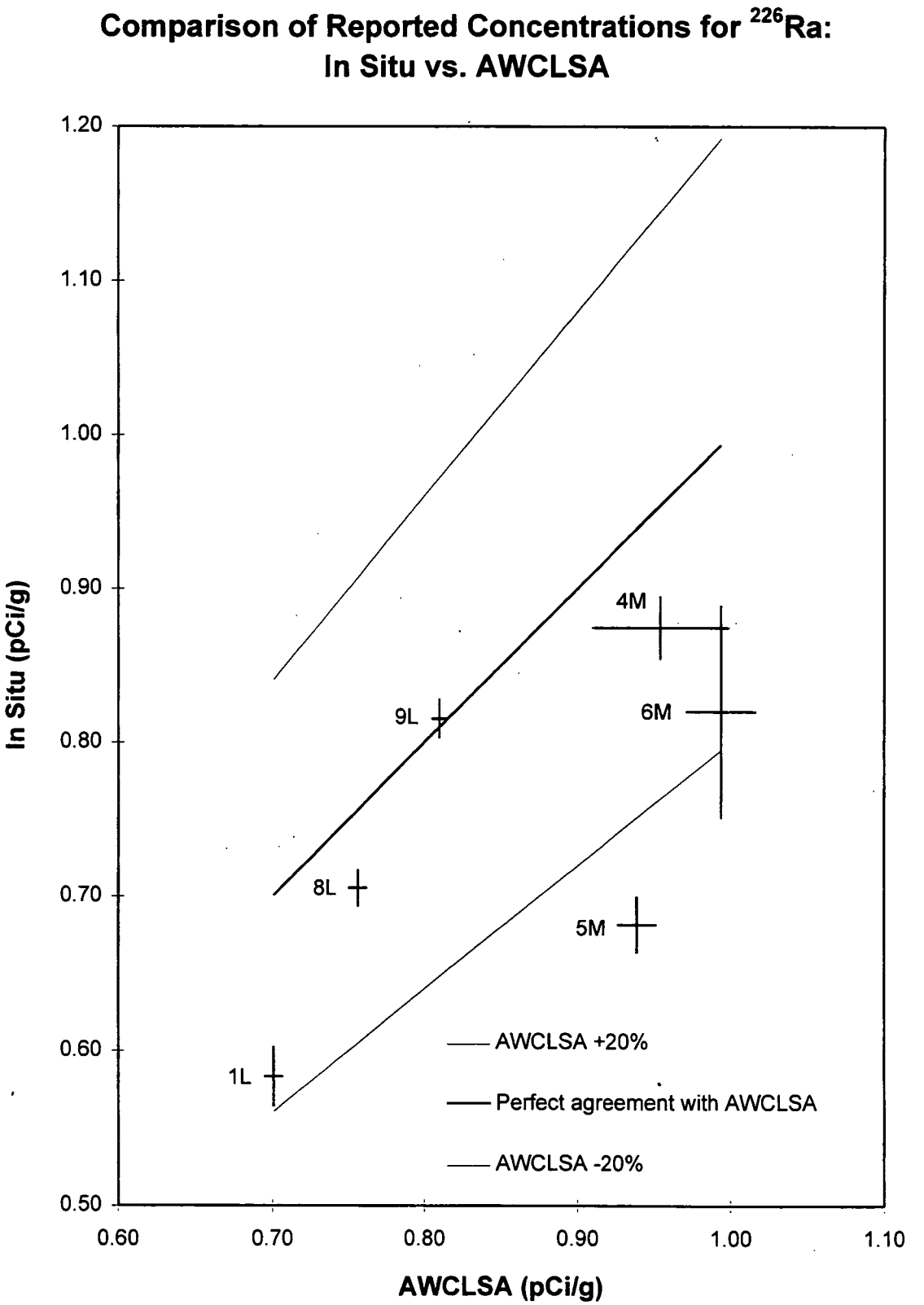

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Figure 6

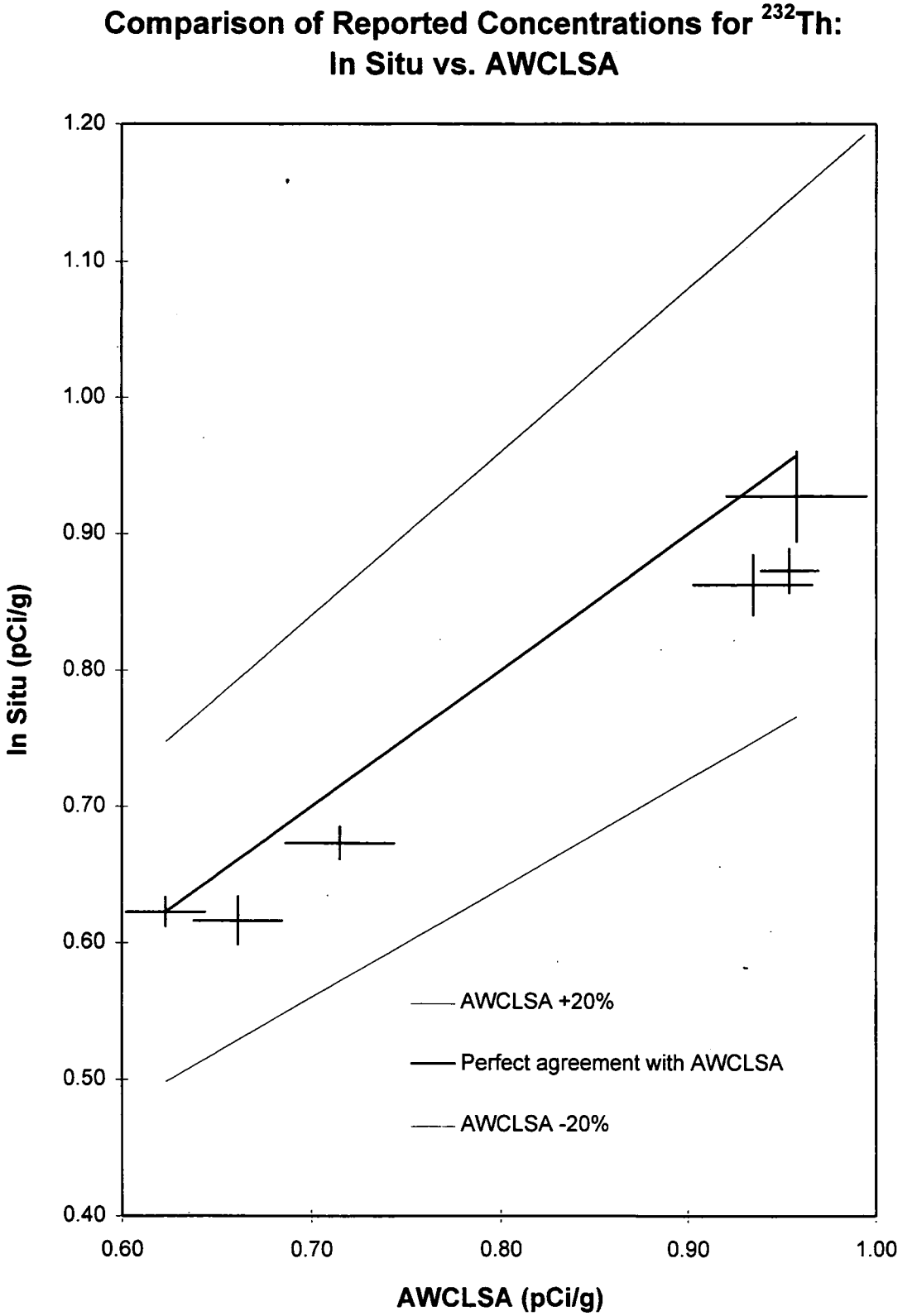
Comparison of Reported Concentrations for 232Th:
In Situ vs. AWCLSA
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
In Situ (pCi/g)
0.60
0.70
0.80
0.90
1.00
AWCLSA (pCi/g)
AWCLSA +20%
Perfect agreement with AWCLSA
AWCLSA -20%

Figure 7

Department of Energy
Environmental Measurements Laboratory
201 Varick Street
New York, NY 10014-4811

April 25, 1997

Robert J. Janke, FN

A SUGGESTED SAMPLING PROTOCOL WITH A REVISION OF THE COMPARABILITY STUDY

To avoid any confusion regarding the use of *in situ* spectrometry for characterization and confirmation, we would like to clarify our position and suggest a sampling protocol for *in situ* measurements and discrete soil sampling. One conclusion drawn from our data on the comparability study is that *in situ* measurements can provide accurate, reliable, and reproducible results. The discrete soil sampling approach is a well-documented, time-honored approach; its strength is in the confirmation process because of the many superior analytical techniques which can be performed on the samples. Unfortunately, it suffers in the characterization process because the samples may or may not be representative of the larger soil body, depending on how well the sample is selected and collected. The *in situ* spectrometric approach is also well-documented, but it is relatively new to the characterization and confirmation process; its strength is in characterization because of the detector's large field of view. The approach, however, assumes a uniform horizontal and vertical source distribution which may or may not be consistent with the actual pattern of contamination. This comparability study and other similar studies have demonstrated that deviations from the assumed source distribution do not introduce large systematic errors that would preclude its use in characterization and confirmation activities. Moreover, the assumption of a uniform distribution yields an average that is weighted towards the detector's position.

As suggested in my memo dated 4/9/97, *in situ* measurements are not identical to discrete soil samples for exactly the reasons mentioned above. The goal is to blend the techniques for optimum benefit. We recommend using the *in situ* technique as the primary tool in the characterization and confirmation process for uranium, ^{232}Th, and ^{226}Ra, ^{137}Cs with discrete soil sampling playing a QA/QC role. We therefore suggest that 10 % percent of the measurements be soil samples, with a sampling depth no less than 5 cm or more than 15. We also recommend that some of the soil cores be sectioned to document the depth distribution of the various soil parameters (soil density, soil moisture, etc.) in addition to the COCs. To be sure, a more complete discussion concerning this issue is needed; the approach mentioned above is a reasonable start.

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Enclosed are corrections to the results of our comparability study. Please be aware that a transcription error has caused the ^{226}Ra value for location 10 to change.

Peter Shebell, Physicist
Environmental Science Division

Enclosure: As Stated

cc: Kevin Miller, EME

APPENDIX G

WILCOXON SIGNED RANKS TESTS

APPENDIX G
WILCOXON SIGNED RANKS TESTS

Wilcoxon signed ranks tests were performed to determine if two sets of measurements differed from one another (i.e., exhibited bias). The process used to perform these tests is in the National Bureau of Standards Handbook 91, entitled "Experimental Statistics" (Natrella 1963), Chapter 16, and is outlined below.

1. Choose a value of $\alpha = 0.05$ for this two-sided test. Discard any observations in which a pair of measurments is equal, and let n = the number of pairs of measurements actually used.

2. The critical value of $T_{0.05}^{(n)} = 6$ for n = 9 and 8 for n = 10 (n = 9 or n = 10 are the numbers of pairs of measurements tested in Tables G-1 and G-2).

3. For each pair of measurements, compute the difference:

$$x_1 - x_2$$

   where x_1 and x_2 are the values of the two measurements.

4. Disregarding signs, rank the differences $x_1 - x_2$ according to the magnitude of their numerical values. Thus, the numerically smallest diffence is ranked one, the next numerically smallest difference is ranked two, etc. Prefix a + or - sign to the assigned ranks to show whether the corresponding difference is positive or negative.

5. Sum the ranks prefixed by a + sign and then sum the ranks prefixed by a - sign. Let T = the smaller of the two sums, ignoring signs.

6. If $T \leq T_{0.05}^{(n)}$, conclude that there is a difference between the two sets of measurements at the 95% confidence level. If $T \geq T_{0.05}^{(n)}$, there is no reason to believe that the two sets of measurements are different (i.e., they exhibit no bias).

Table G-1 presents the results of the Wilcoxon Signed Ranks Tests for pairs of measurements taken by the FEMP HPGe and the EML HPGe. The measurement data are contained in Tables 4-1 and 4-2. Table G-2 presents the results of the Wilcoxon Signed Ranks Tests for pairs of measurements made by the laboratory and FEMP HPGe analyses. These measurement data are contained in Tables 3-1 through 3-5.

TABLE G-1
RESULTS OF WILCOXON SIGNED RANKS TEST ON FEMP AND EML HPGe MEASUREMENTS

Item	Total U, 31 cm		Total U, 1.0 m		Th-232, 31 cm		Th-232 1.0 m	
	Δ* (ppm)	Signed Rank	Δ* (ppm)	Signed Rank	Δ* (ppm)	Signed Rank	Δ* (ppm)	Signed Rank
PBC-01	-1.0	-4	-6.0	-8	-0.10	-5.5	-0.09	-6
PBC-02	-0.7	-2	+2.0	+4	-0.11	-7	-0.12	-7
PBC-04	+1.5	+5	+2.6	+7	-0.06	-2	-0.07	-1
PBC-05	+4.2	+8	-2.1	-5	-0.07	-3.5	-0.14	-8
PBC-06	+1.7	+6	-1.1	-2	-0.10	-5.5	-0.08	-3.5
PBC-07	-12	-9	-12	-9	-0.12	-8	-0.08	-3.5
PBC-08	+2.8	+7	+1.3	+3	-0.07	-3.5	-0.08	-3.5
PBC-09	-0.5	-1	+2.4	+6	-0.04	-1	-0.08	-3.5
PBC-10	+0.9	+3	+0.9	+1	-0.46	-9	-1.74	-9
Sum Positive Rankings		+29		+21		0		0
Sum Negative Rankings		-16		-24		-45		-45
T		16		21		0		0
$T_{0.05}$		6		6		6		6
Bias?		No		No		Yes		Yes

* Difference (FEMP - EML) = Δ between FEMP and EML HPGe Measurements
** If $T < T_{0.05}$, conclude that the sets of measurements differ from one another

TABLE G-1
(continued)

Item	Total U, 31 cm		Total U, 1.0 m		Th-232, 31 cm		Th-232 1.0 m	
	Δ* (pCi/g)	Signed Rank	Δ* (pCi/g)	Signed Rank	Δ* (pCi/g)	Signed Rank	Δ* (pCi/g)	Signed Rank
PBC-01	+0.07	+6	+0.04	+4	-0.7	-7	-1.3	-9
PBC-02	+0.06	+4.5	-0.07	-7	-0.3	-2.5	-0.4	-1
PBC-04	-0.05	-3	-0.01	-1	-0.6	-4.5	-0.8	-5
PBC-05	+0.04	+1.5	+0.05	+5	-0.7	-7	-0.6	-2
PBC-06	-0.08	+7	-0.02	-2	-0.3	-2.5	-0.8	-5
PBC-07	+0.04	+1.5	+0.23	+9	-0.6	-4.5	-0.8	-5
PBC-08	-0.06	-4.5	-0.06	-6	-1.0	-9	-0.9	-7
PBC-09	-0.09	-8	-0.11	-8	-0.7	-7	-1.0	-8
PBC-10	+0.13	+9	-0.03	-3	-0.2	-1	-0.7	-3
Sum Positive Rankings		-29.5		+18		0		0
Sum Negative Rankings		-15.5		-27		-45		-45
T		15.5		18		0		0
$T_{0.05}$		6		6		6		6
Bias?		No		No		Yes		Yes

* Difference (FEMP - EML)= Δ between FEMP and EML HPGe Measurements
** If $T < T_{0.05}$, conclude that the sets of measurements differ from one another

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TABLE G-2
RESULTS OF WILCOXON SIGNED RANKS TEST ON LABORATORY AND HPGe MEASUREMENTS

Item	Total U, 31 cm		Total U, 1.0 m		Th-232, 31 cm		Th-232 1.0 m	
	Δ* (ppm)	Signed Rank	Δ* (ppm)	Signed Rank	Δ* (pCi/g)	Signed Rank	Δ* (pCi/g)	Signed Rank
PBC-01	-1.5	-4	-0.6	-3	-0.02	-2.5	-0.01	-1.5
PBC-02	-1.7	-5	+0.2	+1	-0.09	-8	-0.08	-8
PBC-03	-3.0	-6	-2.0	-5	-0.02	-2.5	-0.04	-4.5
PBC-04	+0.9	+3	-2.7	-7	-0.03	-5.5	-0.04	-4.5
PBC-05	-6.1	-7	-2.6	-6	-0.03	-5.5	0	0
PBC-06	+7.6	+8	+11.3	+8	-0.05	-7	-0.01	-1.5
PBC-07	+2.1	+10	+34	+10	0	0	+0.05	+6
PBC-08	-0.8	-2	-0.4	-2	-0.02	-2.5	-0.03	-3
PBC-09	-0.6	-1	-0.7	-4	-0.10	-9	-0.06	-7
PBC-10	-16.5	-9	-19	-9	+0.2	+2.5	+0.4	+9
Sum Positive Rankings		+21		+19		+2.5		+15
Sum Negative Rankings		-34		-36		-42.5		-30
T		21		19		2.5		15
$T_{0.05}$		8		8		6		6
Bias?***		No		No		Yes		No

* Difference (laboratory - HPGe) = Δ between FEMP and EML HPGe Measurements
** If $T < T_{0.05}$, conclude that the sets of measurements differ from one another
*** Excludes sample PBC-03-01

TABLE G-2
(continued)

Item	Ra-226, 31 cm		Ra-226, 1.0 m		Cs-137, 31 cm		Cs-137 1.0 m	
	Δ*	Signed Rank	Δ*	Signed Rank	Δ*	Signed Rank	Δ*	Signed Rank
PBC-01	-0.14	-3	-0.08	-1.5	-0.05	-6.5	+0.03	+2.5
PBC-02	-0.03	-1	-0.08	-1.5	+0.13	+9	+0.12	+10
PBC-03	+9.4	+10	+9.3	+1.0	+0.17	+10	+0.11	+9
PBC-04	-0.28	-7	-0.12	-3	+0.04	+4	+0.04	+4
PBC-05	-0.26	-6	-0.18	-6	+0.04	+4	+0.05	+5.5
PBC-06	-0.18	-4	-0.14	-4	+0.05	+6.5	+0.09	+8
PBC-07	-0.06	-2	-0.26	-8	+0.04	+4	+0.07	+7
PBC-08	-0.22	-5	-0.19	-5	-0.01	-1.5	+0.01	+1
PBC-09	-0.33	-8	-0.25	-7	+0.01	+1.5	+0.05	+5.5
PBC-10	+1.5	+9	+1.5	+9	+0.09	+8	+0.03	+2.5
Sum Positive Rankings		+19		+19		+47		+55
Sum Negative Rankings		-36		-36		-8		0
T		19		19		8		0
$T_{0.05}$		8		8		8		8
Bias?**		No		No		Yes		No

* Difference (laboratory - HPGe) = Δ between laboratory and HPGe Measurements
** If $T < T_{0.05}$, conclude that the sets of measurements differ from one another

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TABLE G-2
(continued)

Item	K-40, 31 cm		K-40, 1.0 m	
	Δ*	Signed Rank	Δ*	Signed Rank
PBC-01	+0.8	+1.5	+1.8	+6
PBC-02	+0.8	+1.5	+1.0	+1
PBC-03	+0.9	+3	+1.7	+4
PBC-04	+1.5	+6	+2.3	+9.5
PBC-05	+2.0	8.5	+2.0	+8
PBC-06	+2.0	+8.5	+2.3	+9.5
PBC-07	+1.4	+5	+1.7	+4
PBC-08	+2.1	+10	+1.7	+4
PBC-09	+1.6	+7	+1.9	+7
PBC-10	+1.3	+4	+1.5	+2
Sum Positive Rankings		+55		+55
Sum Negative Rankings		0		0
T		0		0
$T_{0.05}$		8		8
Bias?**		Yes		Yes

* Difference (laboratory - HPGe) = Δ between laboratory and HPGe Measurements
** If $T < T_{0.05}$, conclude that the sets of measurements differ from one another