TECHNICAL MEMORANDUM

Review and Evaluation of Radiological Survey and Laboratory Results for the Sterling Project West Hills, CA

Prepared For:

Allwest Remediation, Inc.
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Prepared by:

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

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1.0 INTRODUCTION

Cabrera Services, Inc. (CABRERA) has been requested to review and evaluate existing radiological survey and laboratory results from the Sterling Project for Allwest Remediation, Inc. The Sterling Project is located within the community of West Hills, in the incorporated area of the City of Los Angeles, and is approximately one mile east of the Santa Susanna Field Laboratory (SSFL) in Simi Valley (Ventura County), California. The SSFL is a facility that formerly performed work for the Department of Energy.

2.0 DATA REVIEW AND EVALUATION

The review of the radiological survey and laboratory data was performed based on guidance provided by the Environmental Protection Agency (EPA 2000) and the National Institute of Science and Technology (NIST 2006). The data review included developing tables of data and summary statistics along with preparing visual representations of the data.

The data review and evaluation focused on radionuclides associated with activities at the SSFL that could be present in surface soil. The radionuclides of concern for this investigation are cesium-137 (Cs-137), strontium-90 (Sr-90), and plutonium-239 and plutonium-240 (Pu-239/240). Naturally occurring radionuclides were also included as part of the evaluation as a control. Actinium-228 (Ac-228) represents the radionuclides in the thorium decay series, and bismuth-214 (Bi-214) represents the radionuclides in the uranium decay series. A survey of radiation levels was performed for the Sterling project to identify areas of potentially elevated radioactivity. Surface soil samples were collected based on the results of the radiation survey and analyzed in a radiochemistry laboratory for the radionuclides of concern.

Table 1 lists the maximum, minimum, and average concentrations for the radionuclides of concern based on several studies. The results for the Sterling project are included, along with results for two other surveys performed at sites adjacent to the SSFL: the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy survey (B-B Survey, McLaren/Hart 1995) and the Runkle Canyon survey (Miller Brooks 2003, DMA 2005). In addition, four background surveys are also included. The background studies provide information on local distributions of radionuclides (Brandeis-Bardin background study [B-B Bkgd]), radionuclide concentrations across the country (U.S.), and at other sites in California (Lawrence Livermore National Laboratory [LLNL] and the former McClellan Air Force Base [McAFB]).

Graphs were prepared to visually compare the average concentrations and the ranges of concentrations reported in each of the surveys. Figures 1, 2, 3, 4, and 5 show comparisons for Sr-90, Cs-37, Pu-239/240, thorium and uranium series radionuclides, and gross alpha and gross beta radioactivity, respectively. The graphs show that the results of the Sterling project investigation are comparable to background radionuclide concentrations and results from other surveys performed in the areas surrounding the SSFL.

Figure 1 (Sr-90) shows that Runkle Canyon has the widest range of concentrations, followed by the national background. The Brandeis-Bardin survey and background study have low average concentrations combined with narrow ranges of concentrations. In fact, the maximum reported Sr-90 concentration at Brandeis-Bardin is below the detection limit for Sr-90 for the Sterling Project. This indicates that the analytical methods used by the laboratories are different, so comparisons to the Brandeis-Bardin surveys are difficult to interpret.

Table 1 Summary Statistics

Survey Description	Maximum (pCi/g)	Minimum (pCi/g)	Average (pCi/g)
Cs-137			
U.S.	3.5	0.1	0.7
LLNL	0.9	0.027	0.12
McAFB	0.35	0	0.13
B-B Bkgd	0.46	0.03	0.14
B-B Survey	0.39	0	0.15
Runkle Canyon	0.3	0	0.1
Sterling	0.38	0.002	0.13
Sr-90			
U.S.	4	0.2	0.7
McAFB	1.08	0	0.31
B-B Bkgd	0.13	0.01	0.08
B-B Survey	0.24	0	0.05
Runkle Canyon	12	0	1.4
Sterling	0.82	-0.59	0.15
Pu-239/240			
U.S.	0.04	0.009	0.025
LLNL	8.7	0.037	1.8
McAFB	0.036	0	0.002
B-B Bkgd	0.07	0	0.006
B-B Survey	0.22	0	0.015
Sterling	0.03	-0.002	0.0092
Naturally Occurring Radionuclides			
Thorium Series U.S.	3.5	0.1	0.95
Thorium Series Sterling	1.5	0.22	0.91
Uranium Series U.S.	4.3	0.1	1.1
Uranium Series Sterling	2.6	0.48	1
Gross Alpha U.S.	60	1.4	14
Gross Alpha Sterling	41	0.08	16
Gross Beta U.S.	60	3.7	20
Gross Beta Sterling	49	2.1	19

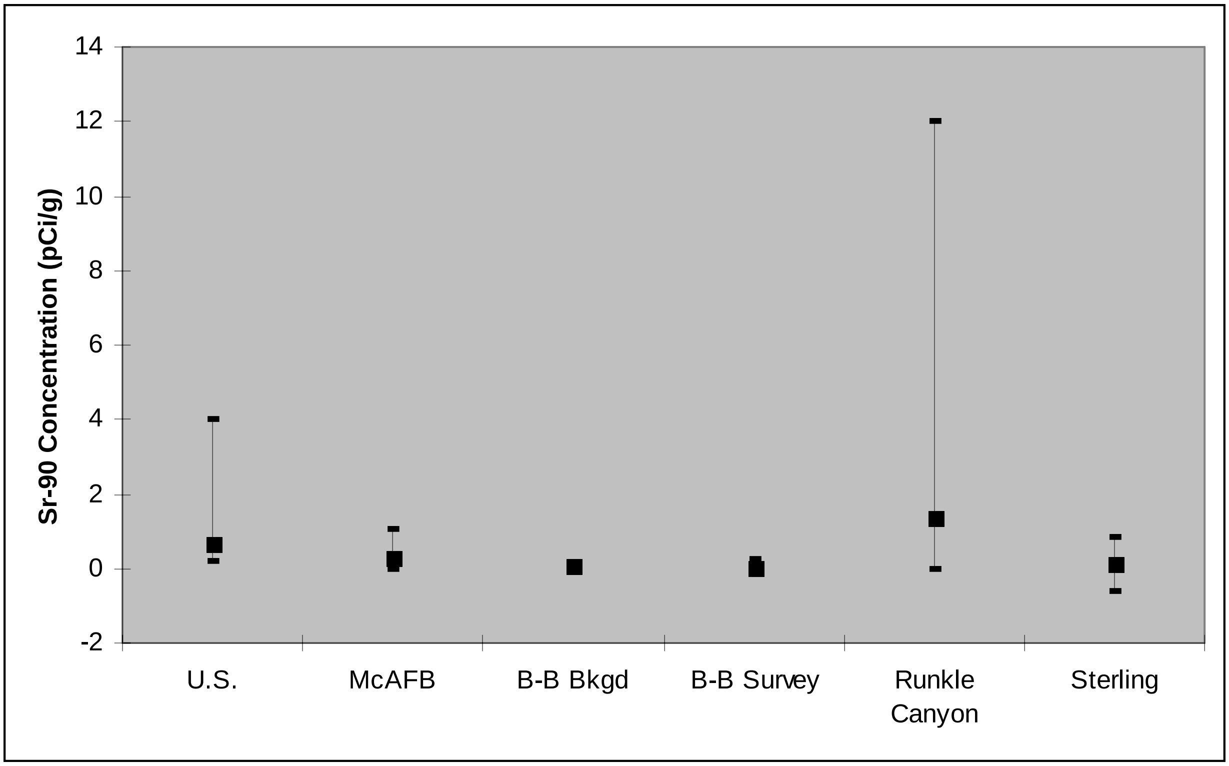

Figure 1 Comparison of Strontium-90 Concentrations

Figure 2 (Cs-137) shows that the U.S. background has the widest range of concentrations. The other surveys all have similar average concentrations and ranges. The majority of Cs-137 in the environment results from the atmospheric testing of nuclear weapons, which was stopped in 1963. The Cs-137 was distributed fairly uniformly on the surface of the earth, where the Cs-137 typically attaches to the fine, clay-sized particles in the soil. Areas that are paved or rocky do not provide as many surfaces for the Cs-137 to attach to, so some of the Cs-137 runs off and becomes concentrated in sediments or along the edges of paved or rocky areas. This results in higher variability (i.e., broader ranges) in Cs-137 concentrations. Areas with rough terrain, such as the western portion of the Sterling project, are expected to have greater variability in Cs-137 background although the average concentration is not expected to change.

Figure 3 (Pu-239/240) shows that both the LLNL and Brandeis-Bardin surveys have ranges of plutonium concentrations that extend off the graph. The Sterling project plutonium results are similar to the results seen in the other surveys.

Figures 4 and 5 compare the naturally occurring radionuclides for the Sterling project with the national background. These comparisons are included primarily as a control to document the quality of the laboratory analyses. The results for the Sterling project are comparable to the national background concentrations for naturally occurring radionuclides.

Attachments 1, 2, and 3 to this technical memorandum provide a more detailed analysis of the data review and evaluation of the radiological survey and laboratory analysis performed for the Sterling project.

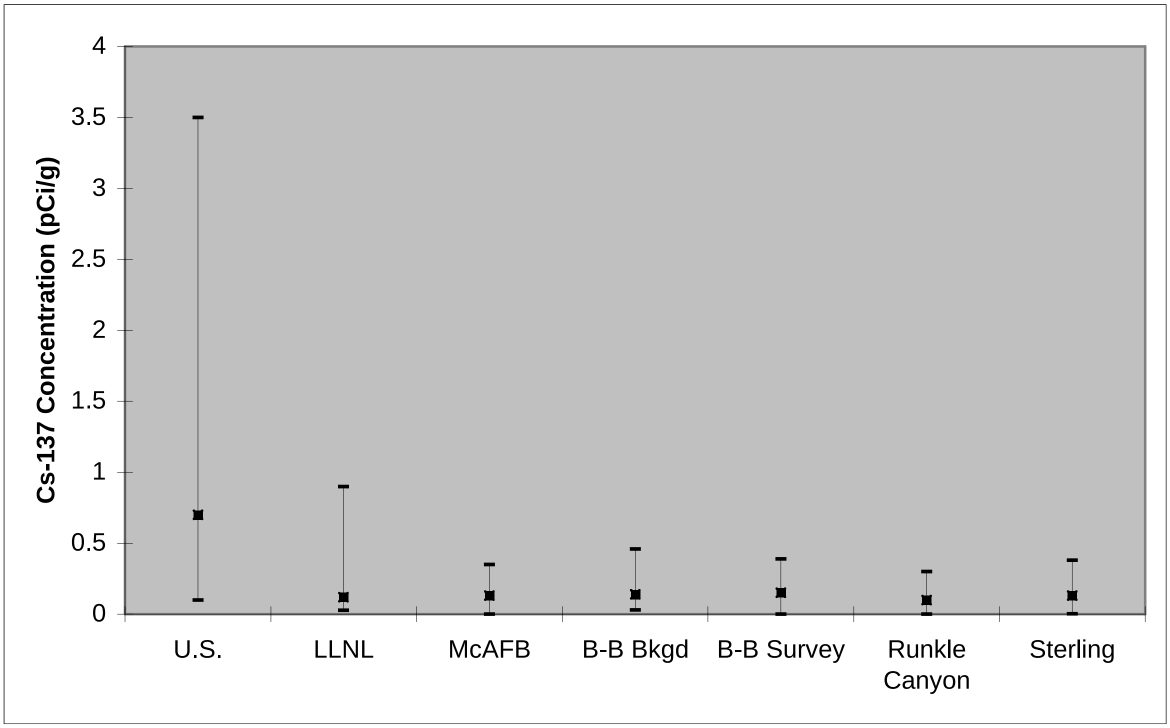

Figure 2 Comparison of Cesium-137 Concentrations

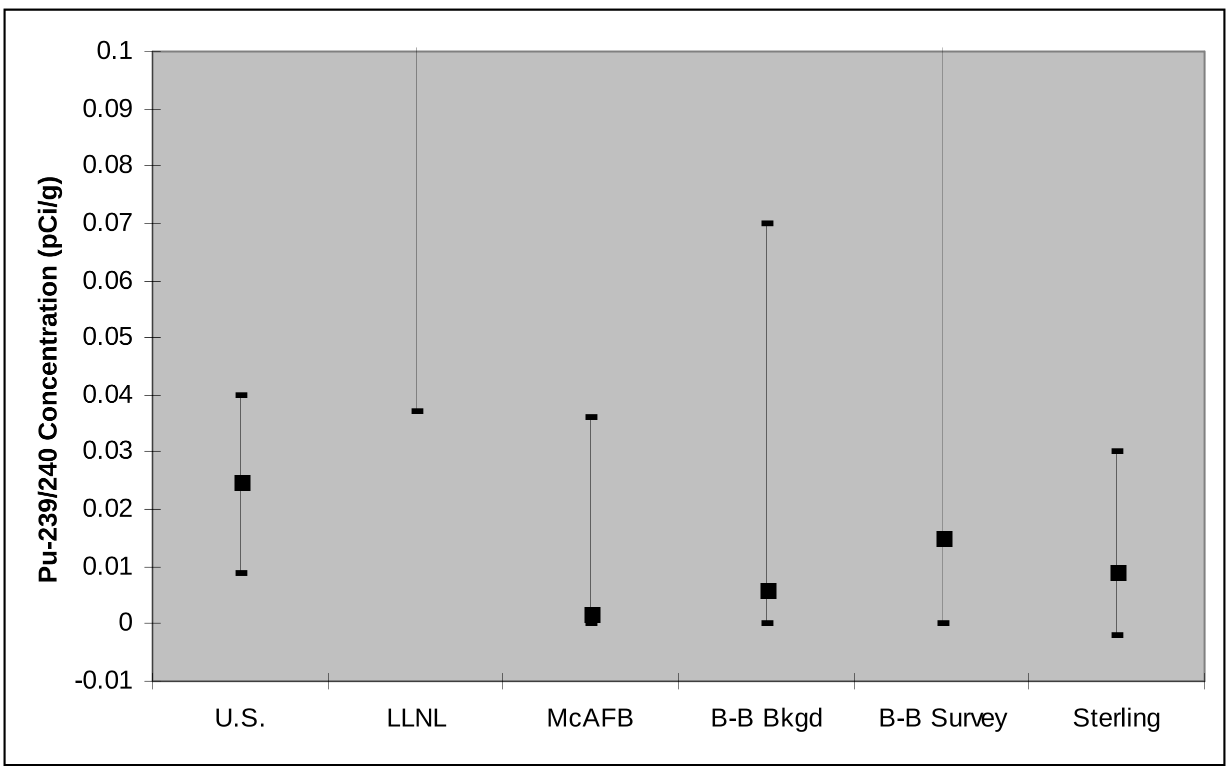

Figure 3 Comparison of Plutonium-239/240 Concentrations

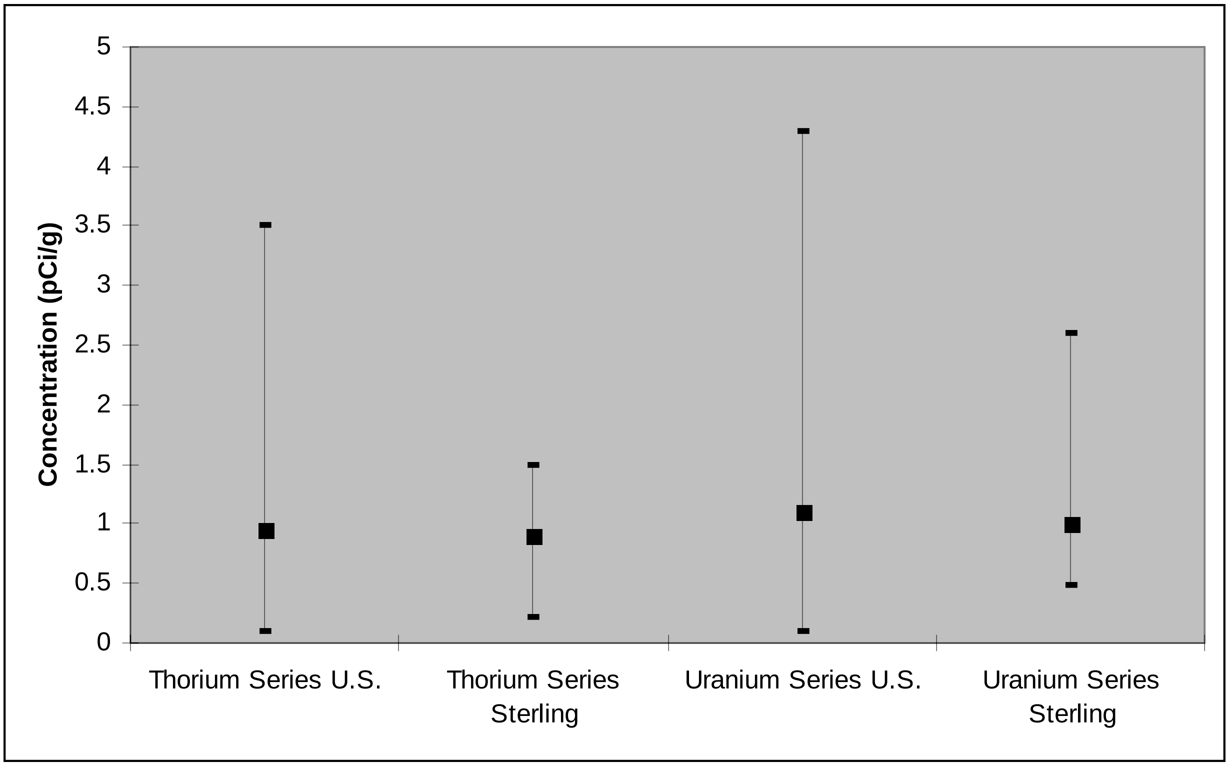

Figure 4 Comparison of Natural Decay Series Radionuclide Concentrations

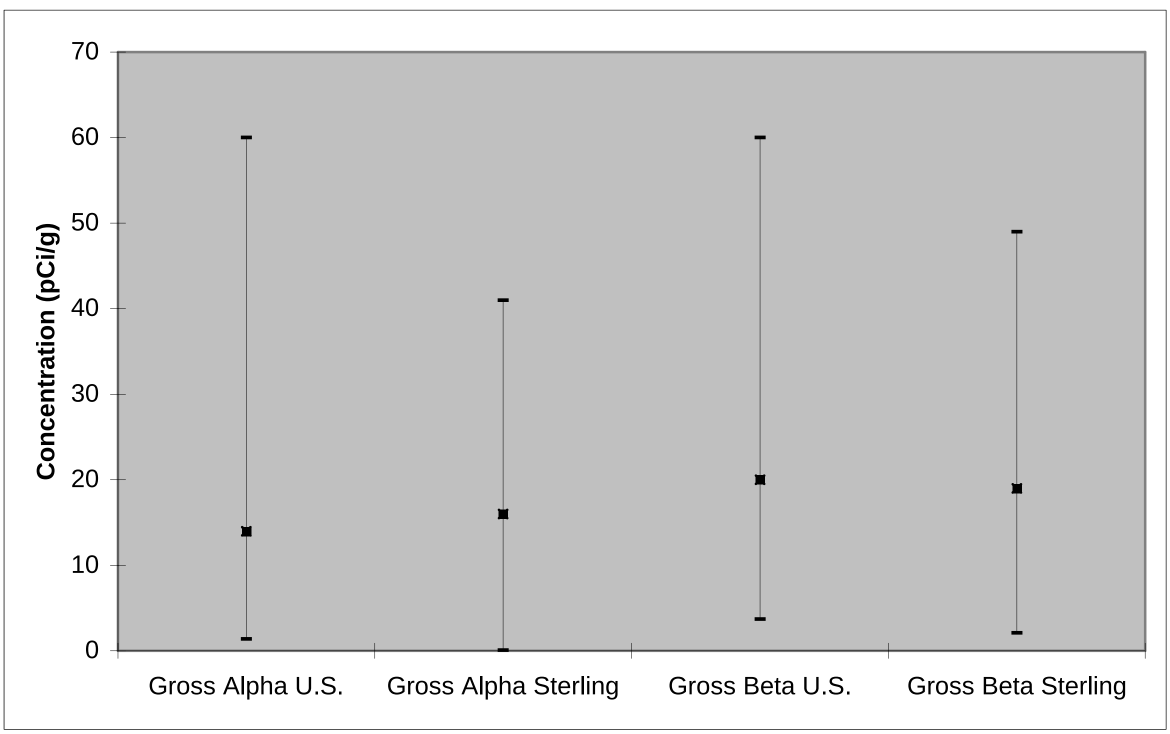

Figure 5 Comparison of Gross Alpha and Gross Beta Concentrations

3.0 SUMMARY AND CONCLUSIONS

Cabrera recommends that no additional radiological investigations be performed. It is unlikely that concentrations of the radionuclides of concern at the West Hill Project site result from activities at the SSFL. Based on the data available, it appears unlikely that any radioactivity has migrated from the SSFL onto the Sterling Property. Laboratory results, including those farthest west in the creek (i.e., LCR-48 and LCR-40), did not indicate any radionuclide concentrations above the referenced background values.

Attachment 1

Detailed Review and Evaluation

Of Radiological Survey and Laboratory Results

for the Sterling Project

1.0 PURPOSE

The purpose of this technical memorandum is to document the review and evaluation of existing radiological data. These data were collected to determine whether activities at the SSFL had impacted the soil in the area of the Sterling Project. Cabrera was tasked with the following activities, which are documented in this memorandum:

- Review radiological survey and laboratory analysis data (Sections 2.1 and 2.2),
- Confirm QA/QC and methodology with the analytical laboratory (Section 2.5), and
- Statistically evaluate radiological data, including a comparison with background levels of radioactivity (Section 3.0).

2.0 DATA REVIEW

The Sterling Project Radiological Study consisted of a screening survey followed by collection and laboratory analysis of soil samples. The screening survey was performed to provide qualitative information used to direct the soil sampling activities. The review of radiological data was divided into four sections. Section 2.1 discusses the review of the Sterling Project radiological screening survey. Section 2.2 discusses the review of the laboratory data collected as part of the Sterling Project radiological study. Section 2.3 presents a review of radiological surveys performed at other sites adjacent to the SSFL. Finally, Section 2.4 presents information on background levels of radioactivity and background radionuclide concentrations for the Unites States and areas around the SSFL.

The review of the radiological survey and laboratory data was performed based on guidance provided by the Environmental Protection Agency (EPA 2000) and the National Institute of Science and Technology (NIST 2006). The data review included developing tables of data and summary statistics along with preparing visual representations of the data.

2.1 Review of Sterling Project Screening Survey Data

The existing survey data consist of qualitative exposure rate measurements performed on a systematic grid. The grid consists of 100 foot by 100 foot squares, and is divided into three areas: West, North, and South. The site was surveyed between October 14, and November 18, 2005, using a Geiger-Mueller (GM) survey instrument.[1] During the survey, the highest and lowest contact exposure rate readings were recorded for each accessible grid. Approximately half of the grid (100 out of 220 squares) in the West area was along the boundary of the developable area. These grids were considered inaccessible and were not monitored. Representatives from the California Department of Toxic Substances Control (DTSC) were present during survey activities and confirmed the screening survey results using a similar survey instrument.

Posting plots of the lowest (Figure 3-1) and highest (Figure 3-2) exposure rate readings in each square were prepared. Posting plots show the results at the location the data were collected.

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[1] The survey instrument was a Victoreen Model 190 Survey and Count Reader with a Victoreen Model 110D GM Pancake Probe with a 15 cm2 thin window for detecting alpha (greater than 3.5 MeV), beta (greater than 35 keV), and photon (gamma and x-rays greater than 6 keV) radiation.

Colors were added to the posting plots to help identify trends in the data. Each color represents one standard deviation, with the mean value at the boundary between light blue and light green.

Summary statistics were calculated for the exposure rate measurement results. Table 3-1 lists the mean, standard deviation, median (i.e., middle value), minimum, and maximum exposure rate readings for the West, North, and South areas, as well as for all the areas combined. Summary statistics are provided for both the "Low" and "High" sets of exposure rate readings. The median values are similar to the mean values (i.e., less than one standard deviation of the mean separates the values). This shows the data distribution is symmetrical, without too much skewness (i.e., more results with high values than would be expected from a normal distribution). The mean value for the "High" values for the West area is higher than the mean value in the North and South areas. This indicates the exposure rates are higher in the western area than in the northern and southern areas, and supports the interpretation of the posting plots.

2.2 Review of Sterling Project Laboratory Data

The laboratory results consist of gamma spectroscopy, gross alpha, and gross beta results for forty-one (41) soil samples. Fifteen (15) of the samples were prepared for further analysis by gas-proportional counting for Sr-90, and by alpha spectrometry for Pu-238 and Pu-239/240. The number of soil samples collected in each area is based upon the qualitative data provided by the screening survey results.

Fifteen samples were collected from the West area, ten from the North area, and seven from the South area. In addition, there were seven samples collected from the creeks running through the site, along with two samples of concrete (i.e., CONC-1 and CONC-2) from a pile of debris. Samples analyzed by gamma spectrometry were dried, sealed, and allowed to stand for twenty-one days to allow for in-growth of radon progeny prior to counting. Gross alpha and gross beta measurements were performed by spreading 100 milligrams of sample in a thin layer and counting using a gas-proportional counter. Alpha spectrometry analyses for isotopic plutonium were performed by chemically separating the plutonium from a 3-gram soil sample and counting using a solid-state detector. Strontium-90 analyses were performed by chemically separating the strontium from the soil and then counting with a gas-proportional counter.

Radionuclides of concern were selected based on the Preliminary Endangerment Assessment Workplan (PEA, Allwest 2005) and results of similar surveys performed in the areas surrounding the SSFL (DMA 2005, McLaren/Hart 1995, Miller Brooks 2003, QST 1999). Two of these previous reports focused on Sr-90 (i.e., DMA 2005, Miller Brooks 2003). The other previous reports discussed Cs-137 and tritium in addition to Sr-90, and the McLaren/Hart report included Pu-238, Pu-239/240, and I-129. The radionuclides selected for detailed analysis in this report are Sr-90, Pu-238, Pu-239/240, and Cs-137. Because fluctuations in natural radiation background can impact the interpretation of survey and sample results, naturally occurring radionuclides were also included in this review. The uranium series radionuclides are represented by Bi-214, and the thorium series radionuclides are represented by Ac-228, which are both naturally occurring.

Histograms were prepared for each of the radionuclides of concern. The histograms (Figures 3-3 through 3-8) indicate some skewness in all of the distributions. Figure 3-5 indicates a possible lognormal[2] distribution for the cesium-137 concentrations.

Cumulative frequency distributions (CFDs) were prepared for each of the radionuclides of concern. The CFDs are used to identify potential outliers[2] from the data distribution. If all of the data are consistent with a normal distribution, the CFD will appear as a straight line. If the data describe some other continuous distribution (e.g., lognormal, Weibull) the data will appear as a curve. Gaps, jumps, or intersecting lines are indications of outliers and multiple distributions, and may indicate the presence of residual radioactivity in excess of background. The CFDs are presented in Figures 3-9 through 3-14. Figure 3-9 is a fairly straight line with a few small jumps, and indicates that all the actinium-228 data belong to a single distribution that is fairly consistent with the assumptions of a normal distribution. Figure 3-10 shows a fairly smooth curve for Bismuth, indicating that the data are probably associated with a single distribution that is not consistent with the assumptions of a normal distribution, with the possible exception of the maximum value. The remaining CFDs (i.e. Figure 3-9, 3-11, and 3-12) indicate the presence of relatively few potential outliers.

Summary statistics were calculated for each of the radionuclides of concern for each of the West, North, South, and Creek areas, as well as for the combined data set. All of the summary statistics are shown in Table 3-2. Similar to the exposure rate results, the mean and median values are similar for all of the areas indicating little or no skewness. The coefficient of variation (CV= standard deviation / mean × 100%) is presented in the summary statistics for all data.

2.3 Review of Other Local Survey Laboratory Data

Several surveys have been performed at three sites adjacent to the SSFL: the Brandeis-Bardin Institute, the Santa Monica Mountains Conservancy, and Runkle Canyon. The results of surveys at these sites provide information on radionuclide concentrations and radiation levels in areas adjacent to the SSFL. The survey at the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy included a study of local background for the radionuclides of concern (see Section 2.4 and Table 3-3).

The Cs-137 results at the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy ranged from a minimum reported concentration of 0.039 pCi/g to a maximum reported concentration of 0.385 pCi/g, with an average of 0.15 pCi/g. The Cs-137 concentrations in Runkle Canyon ranged from a detection limit of 0.08 pCi/g to a maximum of 0.3 pCi/g.

The Sr-90 results at the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy ranged from a minimum reported concentration 0f 0.01 pCi/g to a maximum reported concentration of 0.24 pCi/g, with an average of 0.05 pCi/g. The Sr-90 concentrations in Runkle Canyon ranged from a detection limit of 0.8 pCi/g to 12 pCi/g.

The Pu-238 results at the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy ranged from a minimum reported concentration of 0.055 pCi/g to a maximum reported concentration of 0.22 pCi/g, with an average of 0.1 pCi/g. One Pu-239/240 result was

[2] Outliers are values that are unexpected when compared to other members of the distribution, for example very high or very low values may be identified as outliers.

above the detection limit, 0.015 pCi/g. The detection limit for Pu-239/240 ranged from 0.01 to 0.09 pCi/g. The Runkle Canyon survey did not include analyses for isotopic plutonium.

2.4 Background Radioactivity

Background radioactivity consists of a combination of cosmic and cosmogenic (i.e., originating from outer space), terrestrial (i.e., originating from the Earth), and ubiquitous manmade radionuclides and radioactivity (e.g., X-rays, nuclear medicine, consumer products, nuclear fuel cycle and fallout). Cosmic and cosmogenic radioactivity contributes approximately 8% of the average total effective dose equivalent for people living in the United States. Gamma radiation from terrestrial radionuclides also contributes approximately 8% of the annual dose. Inhalation of radon gas and progeny (also from terrestrial radionuclides) contributes more than 50% of the annual dose. Ubiquitous man-made radionuclides are primarily of interest for discussions about Sr-90, Cs-137, and Pu-239/240, which are related to nuclear power and fallout. Manmade radionuclides in the environment are responsible for less than 1% of the mean annual effective dose equivalent in the United States (NCRP 1987, NRC 1994).

Concentrations of terrestrial radionuclides in soil vary greatly. Table 3-3 lists the mean concentration in U.S. soil, along with the range of concentrations, for the terrestrial and man-made radionuclides of concern. Although the ranges in the table are typical, larger variations exist in certain areas (e.g., areas with granite, mountain areas, Sierra Nevada). The mean annual dose from background terrestrial radiation in the United States is estimated to be 28 millirem per year, with a range from 22 to 38 mrem per year (NCRP 1987). If we assume an exposure time of 4000 hours per year (i.e., 80 hours per week for 50 weeks) the background dose rate is 7 microrem per hour, with a range from 5.5 to 9.5 microrem per hour.

If we assume secular equilibrium for the members of the uranium and thorium decay series (i.e., all radionuclides have equal concentrations), we can calculate an expected gross alpha and gross beta background based on terrestrial radionuclides. The thorium decay series emits six alpha particles and four beta particles. The uranium decay series emits eight alpha particles and six beta particles. Potassium-40 also emits one beta particle. If we use the mean background concentrations in Table 3-3, the expected gross alpha background is 14 pCi/g (ranging from a minimum of 1.4 to a maximum of 60.2 pCi/g) and the expected gross beta background is 20 pCi/g (ranging from a minimum of 3.7 to a maximum of 60.3 pCi/g).

Concentrations of ubiquitous man-made radionuclides in the environment result from atmospheric testing of nuclear weapons. The majority of the man-made radionuclides are present in undisturbed surface soils.

Cosmic radiation levels vary with altitude, and are considered a constant source of external dose at the site. In general, the annual dose rate from cosmic radiation is approximately equal to the annual dose rate contributed by gamma radiation from terrestrial radionuclides (i.e., approximately 8%, NCRP 1987, NRC 1994).

2.5 Data Quality

Cabrera performed a review of the quality of the radiological screening survey and laboratory data. The purpose of the review was to determine if the data quality supports the intended use of the data.

Quality control data were provided with the laboratory data. Performance evaluation (PE) samples (i.e., known concentration) were analyzed with each batch of samples for gamma spectroscopy, alpha spectrometry, strontium-90, gross alpha, and gross beta. The results of the PE samples were within tolerance limits established by the laboratory. Blanks were performed for each batch of samples for gross alpha and gross beta. The results for the blanks were within tolerance limits established by the laboratory.

The detection limits for the terrestrial radionuclides using gamma spectroscopy were 0.5 pCi/g, and the cesium-137 detection limit was 0.05 pCi/g. These detection limits are below the background concentrations listed in Table 3-3, so the method is acceptable for comparison to background. The detection limit for Sr-90 was approximately 0.22 pCi/g, which is below the mean background concentrations listed in Table 3-3. The detection limits for gross alpha and gross beta reported by the laboratory were also below the expected background concentrations calculated in Section 2.4 and listed in Table 3-3.

The detection limits for plutonium isotopes using alpha spectrometry were between 0.01 and 0.02 pCi/g, depending on the chemical recovery. This value exceeds the mean background concentration for Pu-238 listed in Table 3-3, and is approximately equal to the background concentrations for Pu-239/240. The only way to decrease the detection limit is to increase the amount of soil analyzed. However, increasing the amount of soil analyzed introduces chemical interferences that limit the detection limit. It was determined that alpha spectrometry represents the best available method for evaluating isotopic plutonium in soil.

The screening survey results were recorded using units for exposure rate. Exposure rates are primarily used to perform health and safety surveys to determine if radiation levels are acceptable for workers, and are not used to demonstrate compliance with environmental regulations. Exposure refers to the number of ionizations occurring in a unit mass of air due to the transfer of energy from a gamma or X radiation field emitted by a radioactive source. The screening survey was performed using a Geiger-Mueller (GM) detector and detected all types of ionizing radiation, not just gamma and X-rays. The measurements for this survey were performed at ground surface, where exposure rates are typically recorded at a height of one meter above the ground. Survey instruments are typically calibrated with a single radionuclide that is expected to provide the majority of the external dose in the survey area (i.e., Cs-137 for nuclear facilities or Ra-226 for environmental applications), and do not account for mixtures of radionuclides that could contribute to exposure. The exposure rates used to record the results of the screening level survey should not be compared with documented exposure rates because of differences in the way the measurements were performed. However, the exposure rate measurements still provide a qualitative relative measure of radiation levels in different areas of the site, since the radiation meter performs an internal calculation to convert the counts actually measured by the detector into the exposure rate units of microrem per hour.

3.0 STATISTICAL EVALUATION

A statistical evaluation of the data was performed to assist in the identification of locations with elevated concentrations of radionuclides of concern or levels of radioactivity. Identification of such areas of elevated activity could indicate that the area had been impacted by radiological activities at the SSFL. The screening survey was performed to provide a qualitative indication of areas with elevated radiation levels, while the more sensitive soil analysis measurements were used to determine if radionuclides were present with concentrations exceeding expected background levels. Because the data collection objectives were different, the results of the screening survey and the laboratory results were evaluated independently.

3.1 Evaluation of Screening Survey Results

The review of the screening survey data (Section 2.1) indicated that levels of radioactivity in the West area were higher than levels of radioactivity in the North or South areas. To test the observation that the relative exposure rate readings were higher in the West, a Kruskal-Wallis analysis of variance (ANOVA) on Ranks test was run on the exposure rate readings from the North, West and South areas. This test was followed by a pair wise method for isolating the group(s) that differs from the others (Dunn's method). The exposure rates measured in the West were significantly higher than the exposure rates measured in the North and South areas.

The review of laboratory data (Section 2.2) indicated that the highest average concentrations for Ac-228, Bi-214, Cs-137, and Pu-239/240 were from samples in the West area. The highest average Sr-90 and Pu-238 concentrations were found in the North area, and the highest average Gross Alpha and Gross Beta concentrations were found in the South area. The Kruskal-Wallis ANOVA was performed to determine if higher concentrations of naturally occurring Th-232 and Ra-226 in the West area (as measured by the daughter products) are the cause of the elevated exposure rates. The naturally occurring radionuclide concentrations in the West area are not significantly higher than radionuclide concentrations in the North and South. However, the numbers of sample analyses (i.e., 37 gamma spectroscopy results above the detection limit and 15 alpha spectrometry results compared to 274 exposure rate measurements) reduce the ability of the statistical tests to demonstrate a significant difference.

The slightly elevated exposure rate readings in the West resulted in more samples being collected in the West (15 samples for gamma spectroscopy and 9 samples for plutonium and Sr-90) than in the North (10 samples for gamma spectroscopy and 3 samples for plutonium and Sr-90), South (7 samples for gamma spectroscopy and 3 samples for plutonium and Sr-90) and Creek (7 samples for gamma spectroscopy) areas.

3.2 Evaluation of Laboratory Analysis Results

The statistical evaluation of laboratory results consists of a simple comparison of individual results to the referenced background data concentrations and previous survey results performed in areas adjacent to the SSFL. Any results for the radionuclides of concern outside the referenced range of background concentrations (see Table 3-3) provide evidence that the area has been impacted by radioactivity or radionuclides.

3.2.1 Radionuclides of Concern

The Sr-90 laboratory results are consistent with the referenced background ranges shown in Table 3-3. The average concentration for the Sterling project is less than the average concentrations reported in most of the other background and survey studies. The average and range for Sr-90 reported for the Brandeis-Bardin background and survey studies indicates that the analytical methods are significantly different. Comparisons between the Sterling project and the Brandeis-Bardin studies are probably not meaningful because of these differences. The maximum Sr-90 concentration (0.82 pCi/g at G9-W) is less than the upper bound of the national range (4.0 pCi/g) but exceeds the upper bound of the Brandeis-Bardin background study (0.13 pCi/g). The maximum concentration exceeds the Brandeis-Bardin Institute maximum result (0.24 pCi/g), but is less than the maximum Sr-90 concentration reported at Runkle Canyon (12 pCi/g).

The Cs-137 results are consistent with the referenced background ranges shown in Table 3-3. The average Cs-137 concentration for the Sterling project is less than the average U.S. background, and is essentially equal to the average Cs-137 concentration reported in other studies. The maximum Cs-137 concentration (0.37 pCi/g at N8-W) appears to be consistent with the other Cs-137 laboratory data collected for the Sterling Project. This value is less than the upper bound of the national range (3.5 pCi/g) and the Lawrence Livermore range (0.9 pCi/g) and the Brandeis-Bardin maximum background value of 0.46 pCi/g. The maximum concentration is less than the Brandeis-Bardin Institute maximum survey result (0.39 pCi/g).

The isotopic plutonium results are consistent with the referenced background ranges shown in Table 3-3. All of the Pu-238 results were below the detection limit of approximately 0.015 pCi/g. Four of the Pu-239/240 concentrations were reported above the detection limit, but below the upper bound of all the background ranges listed in Table 3-3.

3.2.2 Naturally Occurring Radionuclides

The actinium-228 results are consistent with the referenced background information. The average concentration is below the referenced average background concentrations. The maximum value of 1.5 pCi/g for sample N8-W is only two standard deviations above the mean and well within the referenced range of values for soils in the United States.

The bismuth-214 results are consistent with the referenced background information. The average concentration is at or below the referenced average background concentrations, and all of the results are below the upper bound of the background values (i.e., 4.3 pCi/g).

The gross alpha and gross beta results are consistent with the referenced background information. The average concentrations are essentially equal to the average background concentrations calculated for the U.S. All of the reported concentrations are less than the upper bound of the expected range of gross alpha and gross beta calculated in Section 2.3.

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Attachment 2
Tables

Table 3-1 Survey Data Summary Statistics

	Lowest Reading (microrem per hour)	Highest Reading (microrem per hour)
North		
Mean	9.7	21.6
Standard Deviation	3.4	3.8
Median	9.9	21.9
Minimum	1.8	10.2
Maximum	18.5	28.3
South		
Mean	15.8	22.8
Standard Deviation	3.9	2.9
Median	15.9	23.3
Minimum	6.8	13.5
Maximum	23.7	27.6
West		
Mean	13.8	24.8
Standard Deviation	3.9	2.8
Median	14.1	25.2
Minimum	4.5	15.2
Maximum	23.1	29.3
All		
Mean	12.9	23.2
Standard Deviation	4.4	3.5
Median	12.6	23.75
Minimum	1.8	10.2
Maximum	23.7	29.3

Table 3-2 Laboratory Data Summary Statistics

	*Ac-228	*Bi-214	Cs-137	Sr-90	Pu-238	Pu-239/240	Alpha	Beta
North								
Average	0.80	0.92	0.094	0.17	0.0013	0.0033	16.5	21.4
St Dev	0.30	0.24	0.076	0.12	0.0040	0.0023	11.1	10.5
Median	0.83	0.92	0.072	0.16	0.002	0.002	12.8	19.8
Minimum	0.45	0.63	0.0020	0.064	-0.003	0.002	3.8	2.1
Maximum	1.3	1.3	0.26	0.3	0.005	0.006	38.1	43.2
South								
Average	0.92	1.0	0.081	0.084	0.00067	0.011	19.2	23.9
St Dev	0.30	0.33	0.060	0.37	0.0023	0.011	10.7	11.7
Median	0.90	1.0	0.055	0.038	0.002	0.016	16.8	20.3
Minimum	0.44	0.66	0.031	-0.26	-0.002	-0.002	7.6	16.0
Maximum	1.3	1.7	0.19	0.47	0.002	0.02	41.3	49.1
West								
Average	1.0	1.1	0.16	0.16	0.00056	0.011	17.9	18.7
St Dev	0.29	0.35	0.13	0.41	0.0024	0.0085	9.6	9.9
Median	1.0	0.99	0.17	0.12	0.00	0.01	15.6	15.6
Minimum	0.48	0.67	0.013	-0.59	-0.003	-0.001	7.0	8.4
Maximum	1.5	1.8	0.037	0.82	0.004	0.03	38.4	42.1
Creeks								
Average	0.84	0.96	0.052	-0.763	0.005	0.000	9.1	10.8
St Dev	0.30	0.69	0.012	-0.018	0.002	0.000	5.7	3.3
Median	0.85	0.74	0.054	-0.306	0.000	0.000	10.6	10.7
Minimum	0.22	0.48	0.037	-1.998	0.000	0.000	0.080	6.6
Maximum	1.3	2.6	0.069	-0.018	0.016	0.000	19.0	18.4
All								
Average	0.91	1.0	0.11	0.15	0.00073	0.0092	15.8	18.5
St Dev	0.30	0.41	0.11	0.34	0.0025	0.0083	9.8	10.1
Median	0.89	0.96	0.073	0.12	0.00	0.006	13	16.5
Minimum	0.22	0.48	0.0020	-0.59	-0.0030	-0.002	0.080	2.1
Maximum	1.5	2.6	0.037	0.82	0.01	0.03	41	49.1
Count	37	37	38	15	15	15	41	41

***** Ac-228 represents the thorium series radionuclides, and Bi-214 represents the uranium series radionuclides, which are both naturally occurring.

Table 3-3 Documented Background Concentrations

Radionuclide	Source	Reference Location	Average Concentration (pCi/g)	Range (pCi/g)	Reference
Actinium-228	Natural	U.S.	0.95	0.1 to 3.5	UNSCEAR 2000
Bismuth-214	Natural	U.S.	1.1	0.1 to 4.3	UNSCEAR 2000
Potassium-40	Natural	U.S.	10	2.7 to 20	UNSCEAR 2000
Cesium-137	Man-made	U.S.	0.7	0.1 to 3.5	EPA 1998
	Man-made	Lawrence Livermore	0.12	0.027 to 0.9	EPA 1998
	Man-made	McClellan AFB	0.13	< L_C* to 0.35	Cabrera 2004
	Man-made	Brandeis-Bardin	0.14	0.03 to 0.46	McLaren/Hart 1995
Strontium-90	Man-made	U.S.	0.7	0.2 to 4.0	EPA 1998
	Man-made	McClellan AFB	0.31	< L_C to 1.08	Cabrera 2004
	Man-made	Brandeis-Bardin	0.080	0.01 to 0.13	McLaren/Hart 1995
Pu-238	Man-made	U.S.	0.001	5×10^{-4} to 2×10^{-3}	EPA 1998
	Man-made	Lawrence Livermore	0.29	<0.03 to 1.23	EPA 1998
	Man-made	McClellan AFB	0.0004	< L_c to 0.018	Cabrera 2004
	Man-made	Brandeis-Bardin	<0.02	<0.005 to <0.02	McLaren/Hart 1995
Pu-239/240	Man-made	U.S.	0.025	9×10^{-3} to 0.04	EPA 1998
	Man-made	Lawrence Livermore	1.8	0.037 – 8.7	EPA 1998
	Man-made	McClellan AFB	0.002	< L_C to 0.036	Cabrera 2004
	Man-made	Brandeis-Bardin	<0.07	<0.006 to <0.07	McLaren/Hart 1995
Gross Alpha	Natural	U.S.	14	1.4 to 60.2	Calculated Section 2.4
Gross Beta	Natural	U.S.	20	3.7 to 60.3	Calculated Section 2.4

* Less than the critical level, which is the 95% upper confidence limit for the background distribution assuming Poisson counting statistics.

Attachment 3
Figures

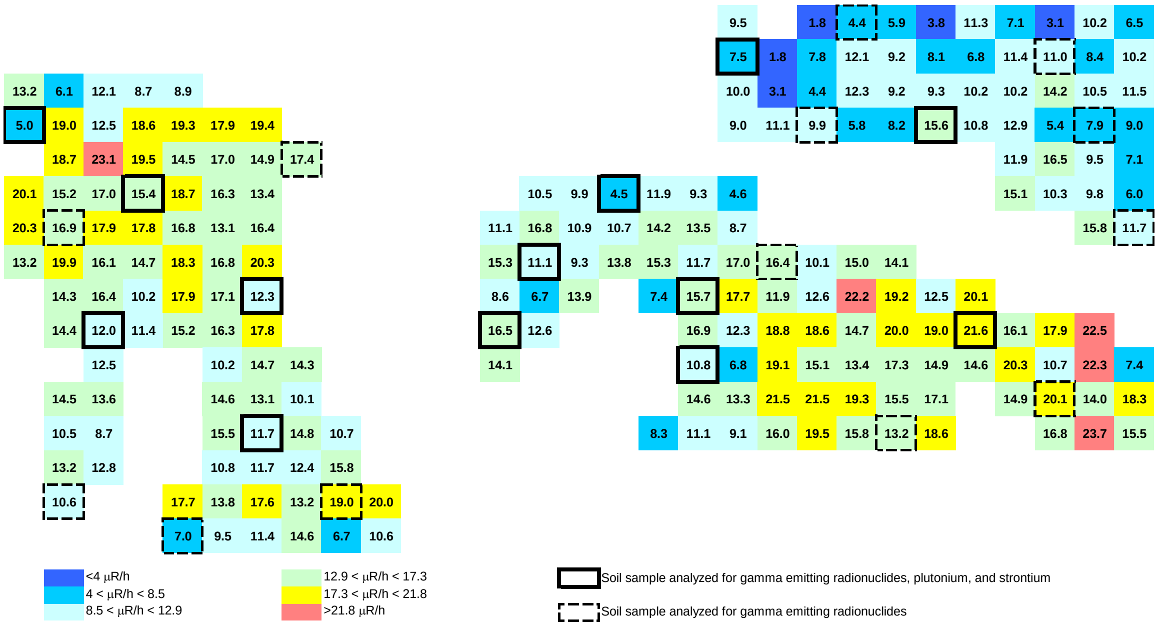


Figure 3-1 Posting Plot of Lowest Exposure Rate Readings in Each Grid Square

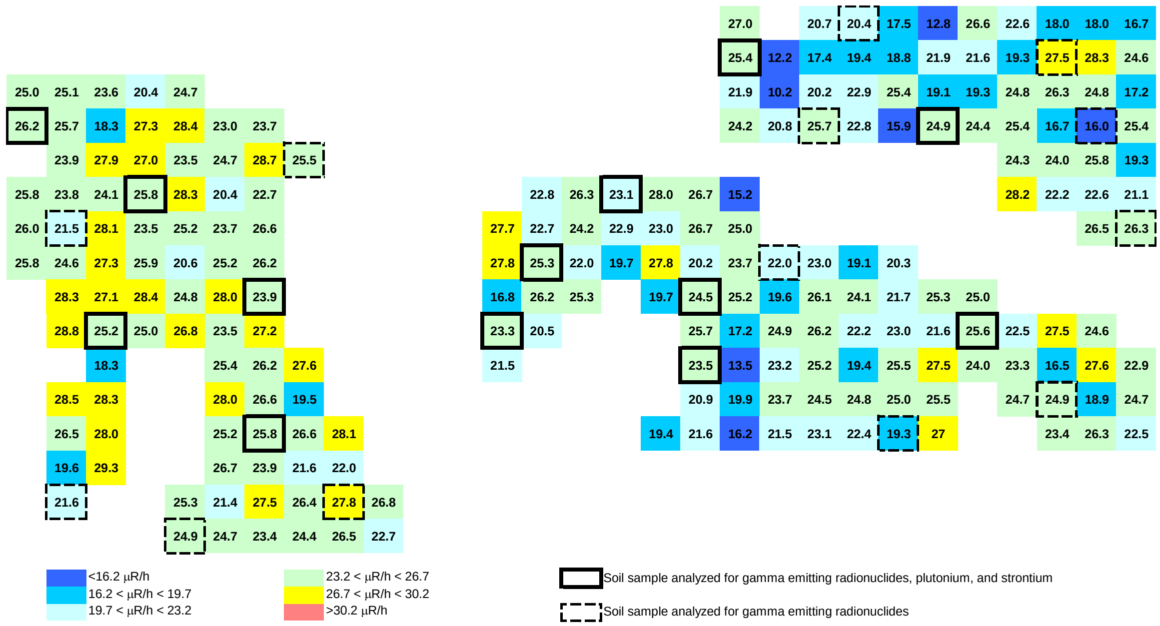


Figure 3-2 Posting Plot of the Highest Exposure Rate Readings in Each Grid Square

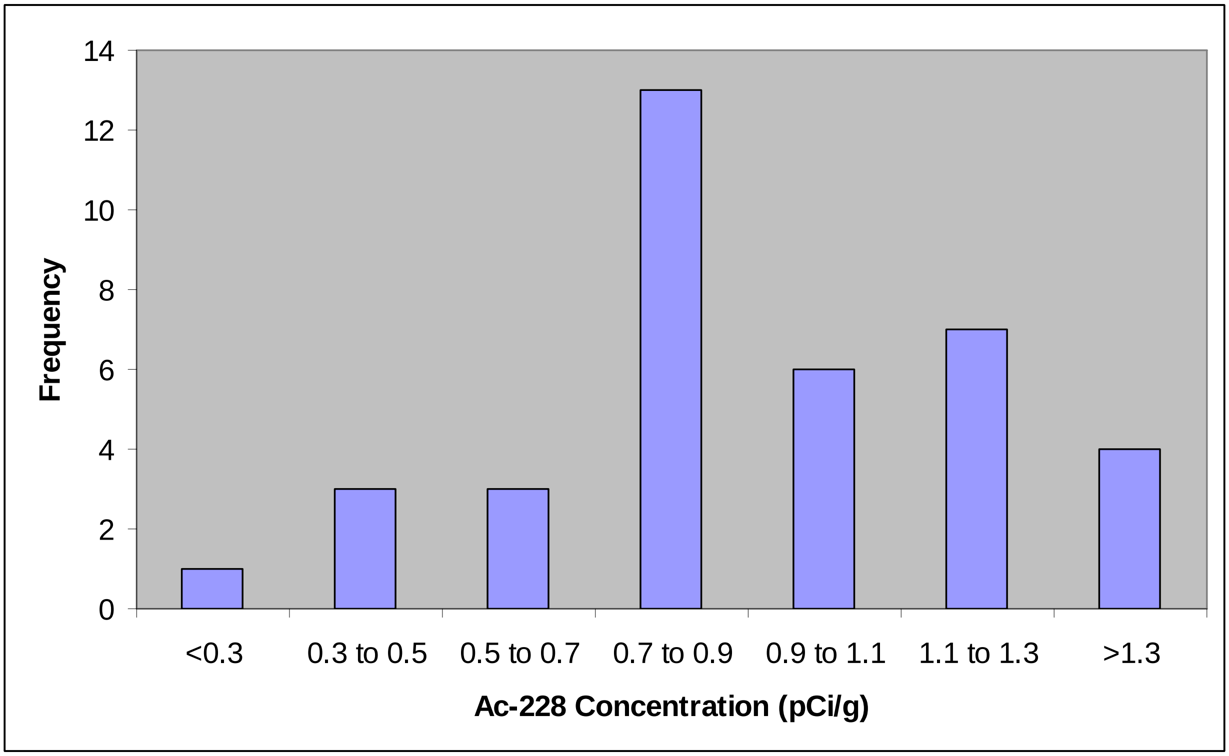


Figure 3-3 Histogram of Actinium-228 Laboratory Results

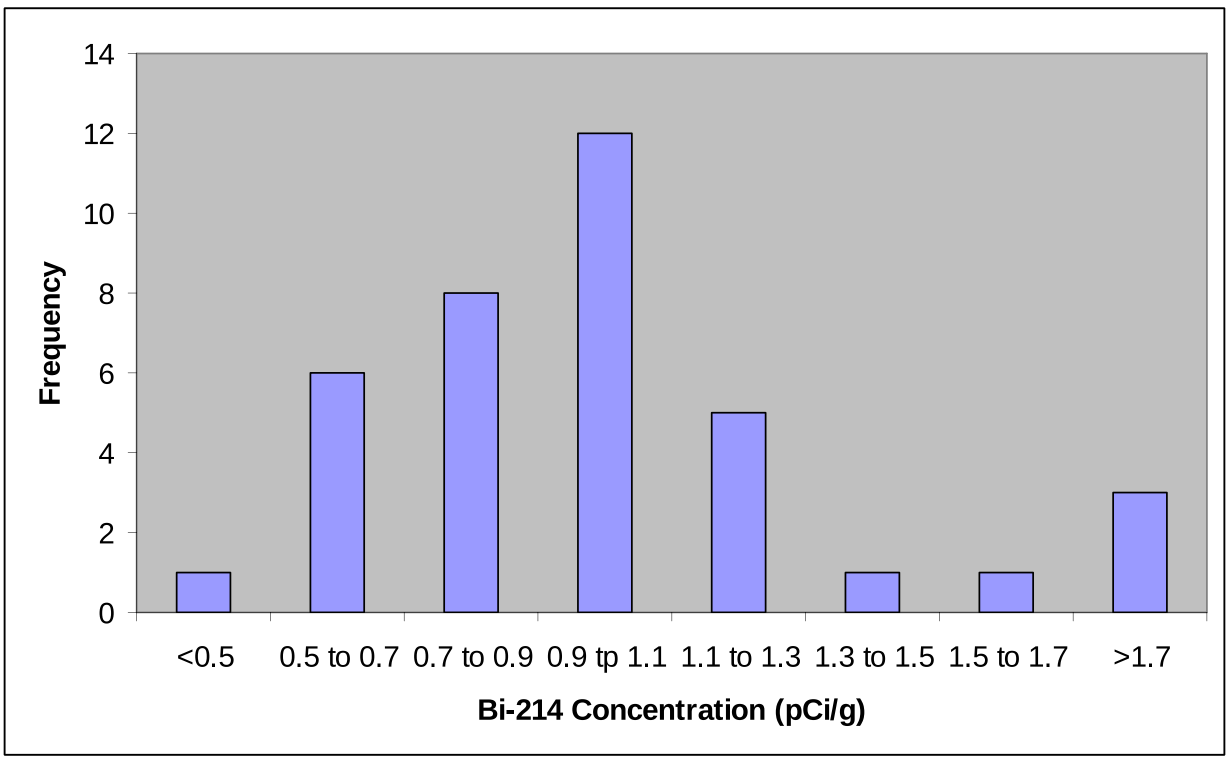


Figure 3-4 Histogram of Bismuth-214 Laboratory Results

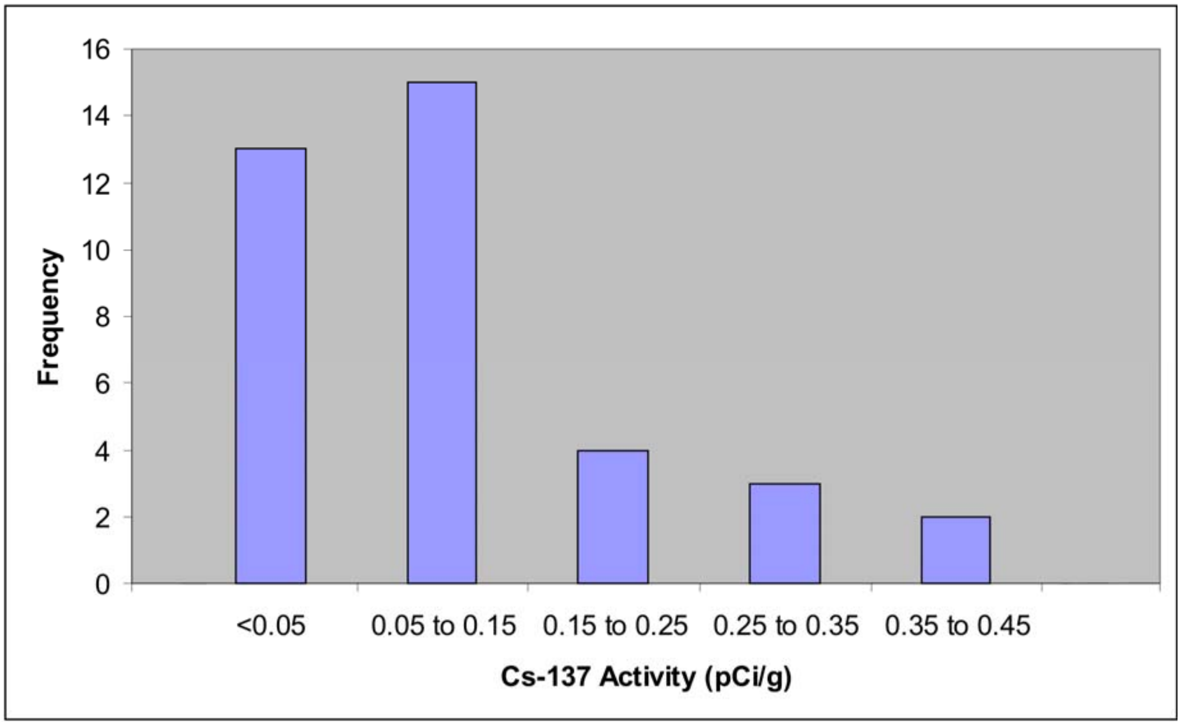


Figure 3-5 Histogram of Cesium-137 Laboratory Results

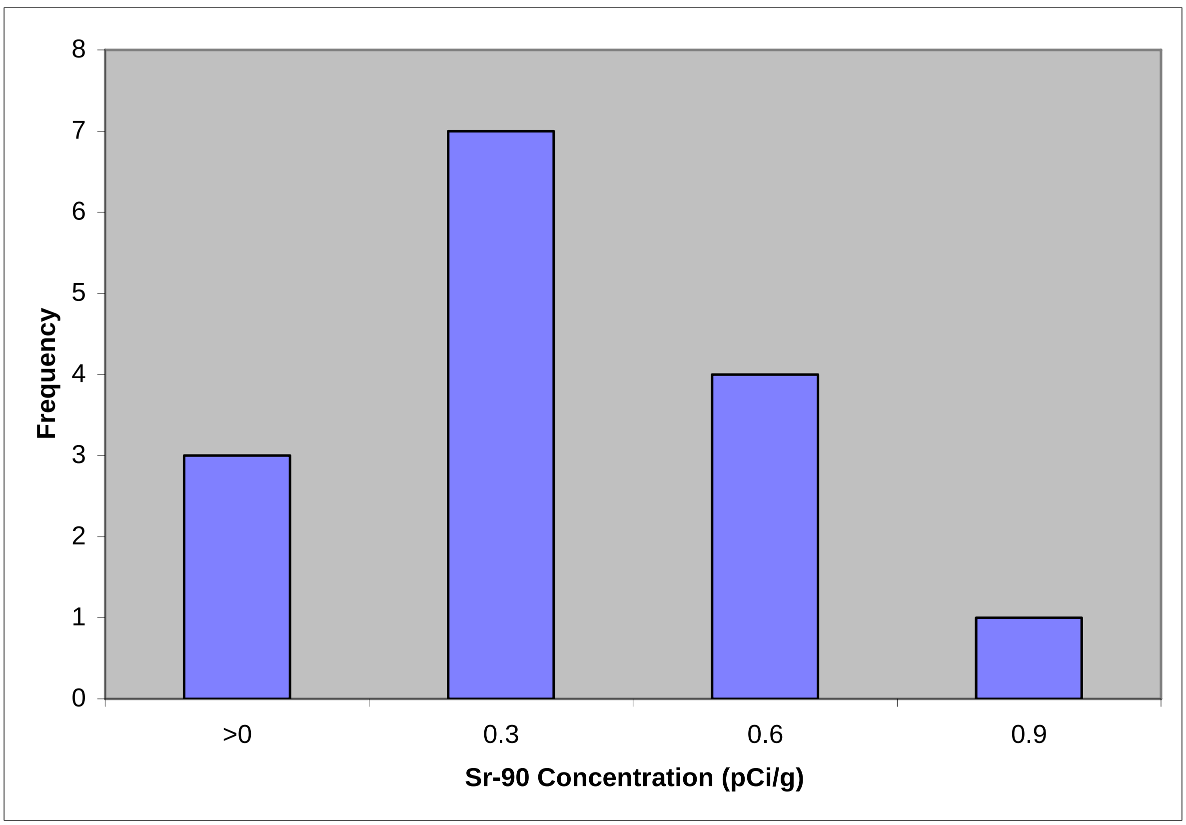


Figure 3-6 Histogram of Strontium-90 Laboratory Results

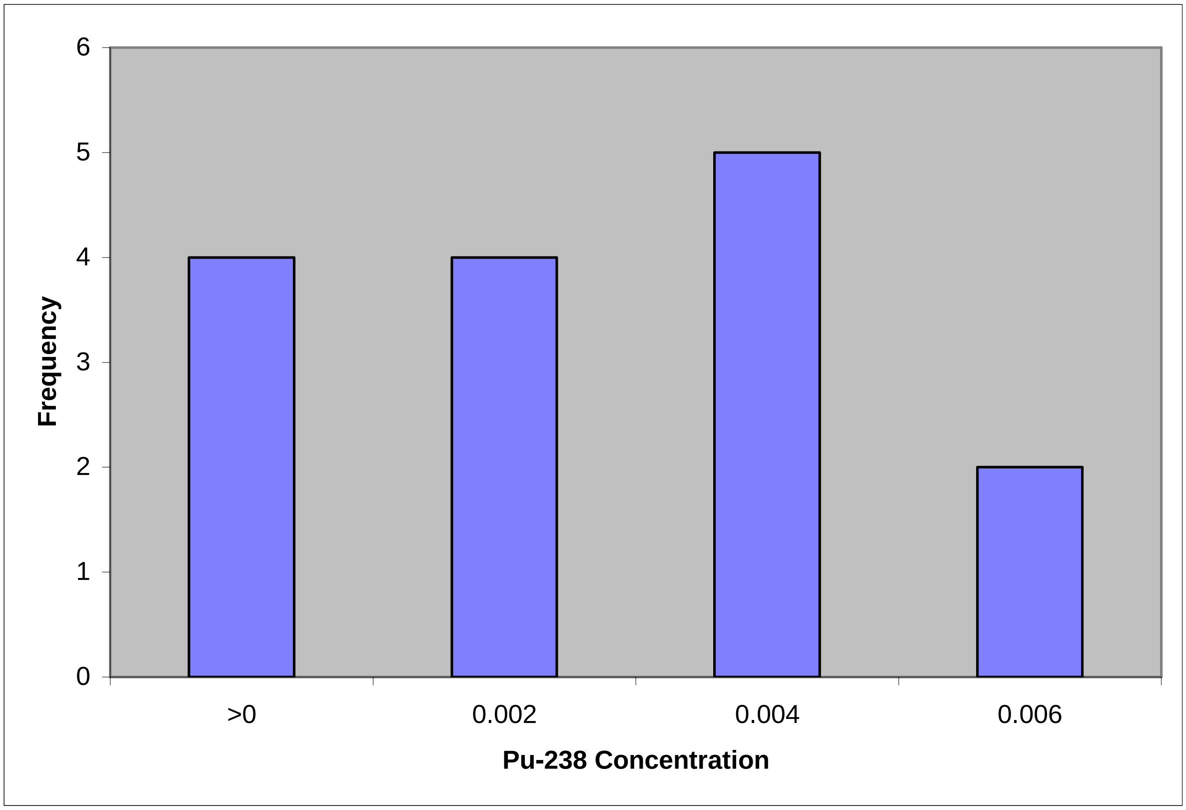


Figure 3-7 Histogram of Plutonium-238 Laboratory Results

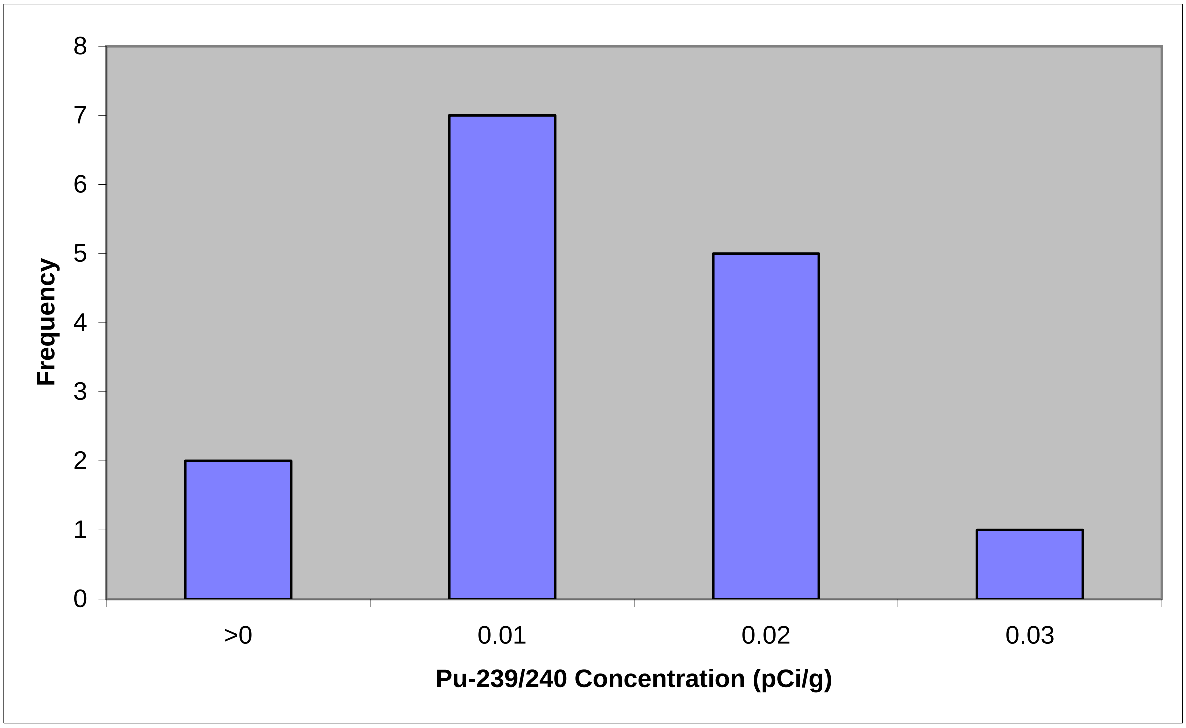


Figure 3-8 Histogram of Plutonium-239/240 Laboratory Results

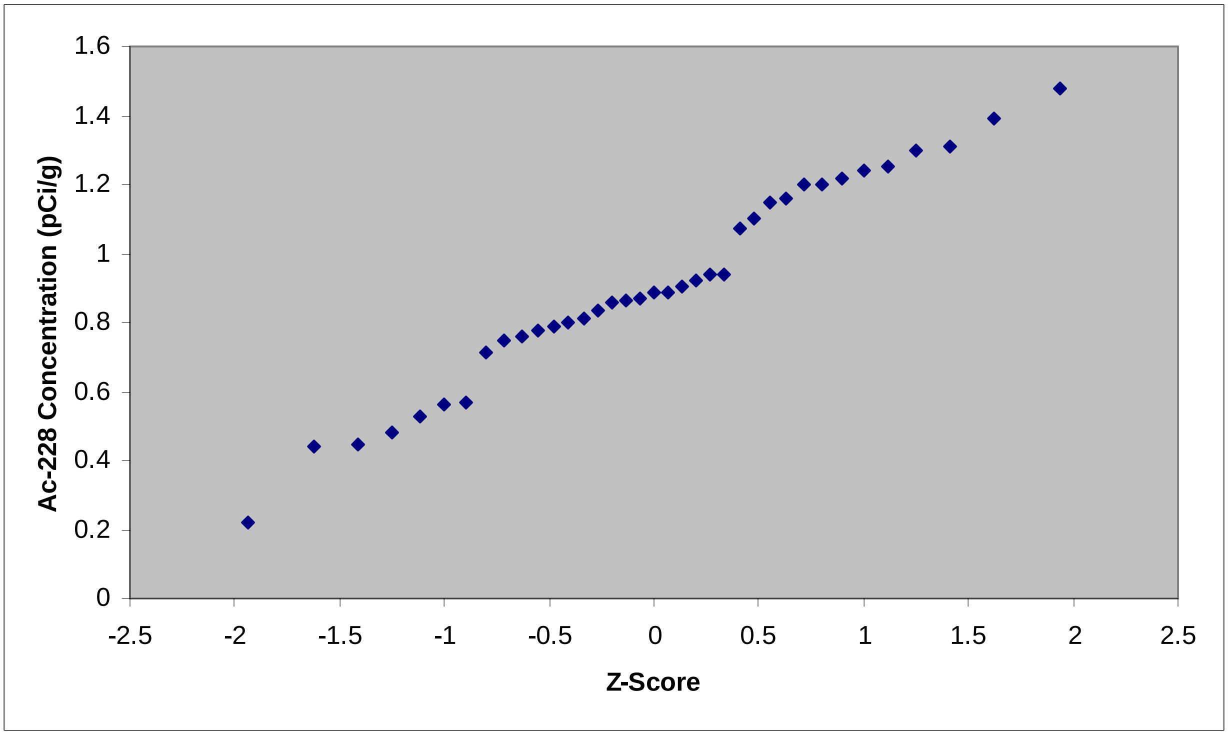


Figure 3-9 Cumulative Frequency Distribution of Actinium-228 Laboratory Results

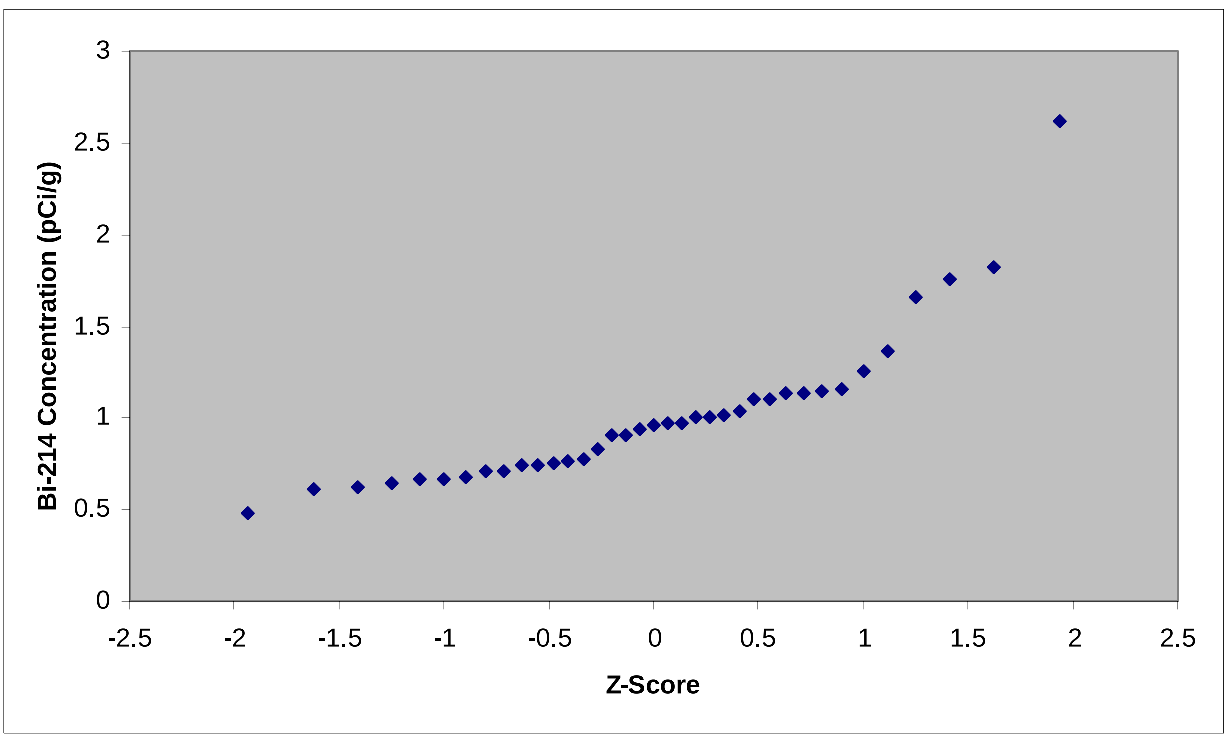


Figure 3-10 Cumulative Frequency Distribution of Bismuth-214 Laboratory Results

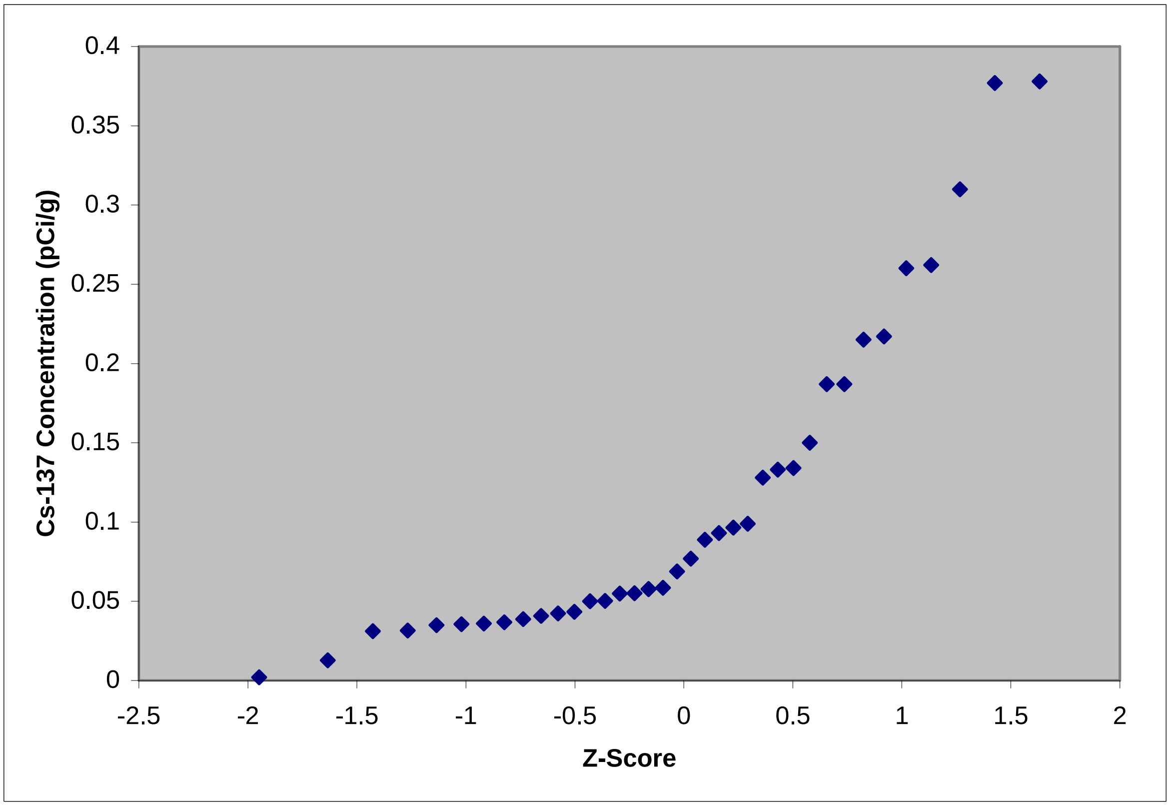


Figure 3-11 Cumulative Frequency Distribution of Cesium-137 Laboratory Results

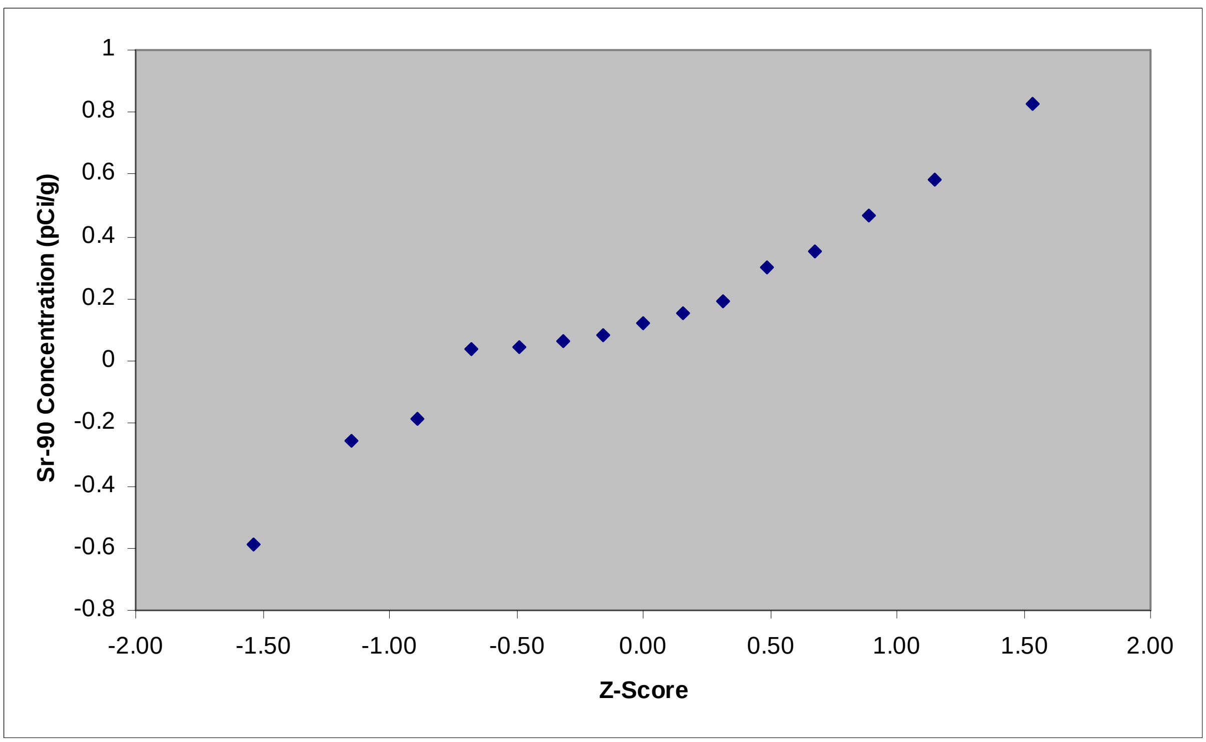


Figure 3-12 Cumulative Frequency Distribution of Strontium-90 Laboratory Results

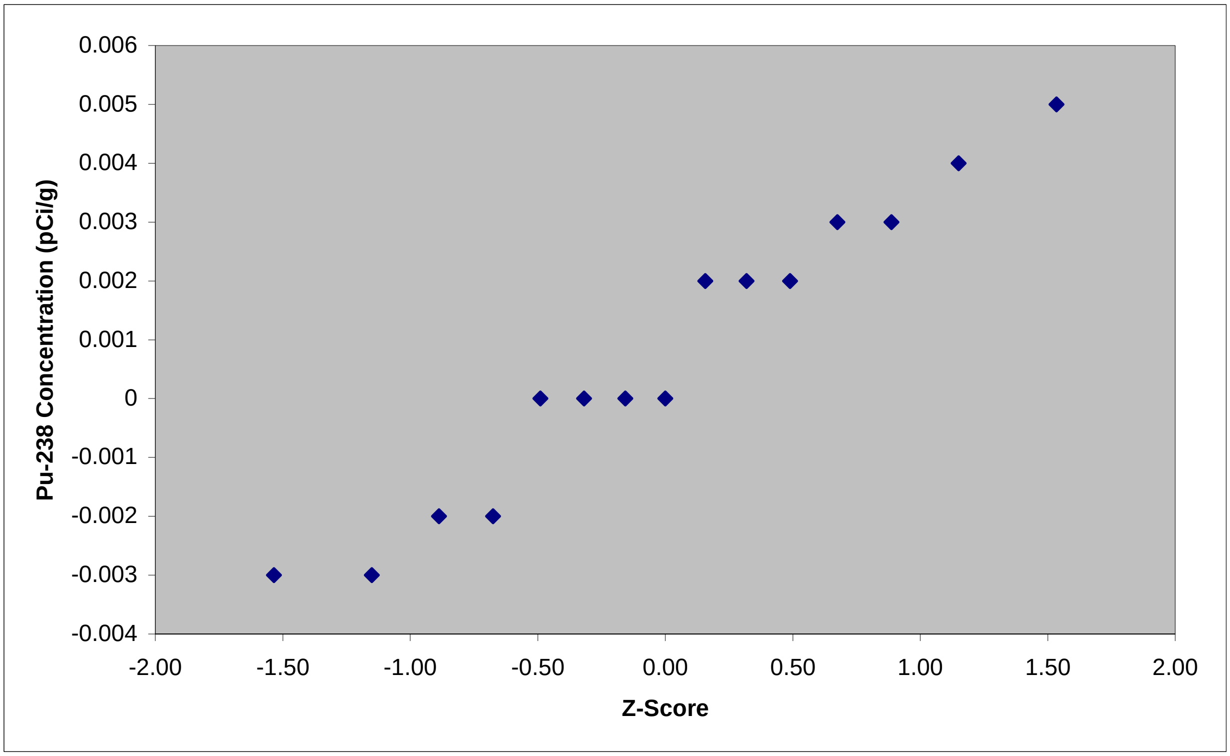


Figure 3-13 Cumulative Frequency Distribution of Plutonium-238 Laboratory Results

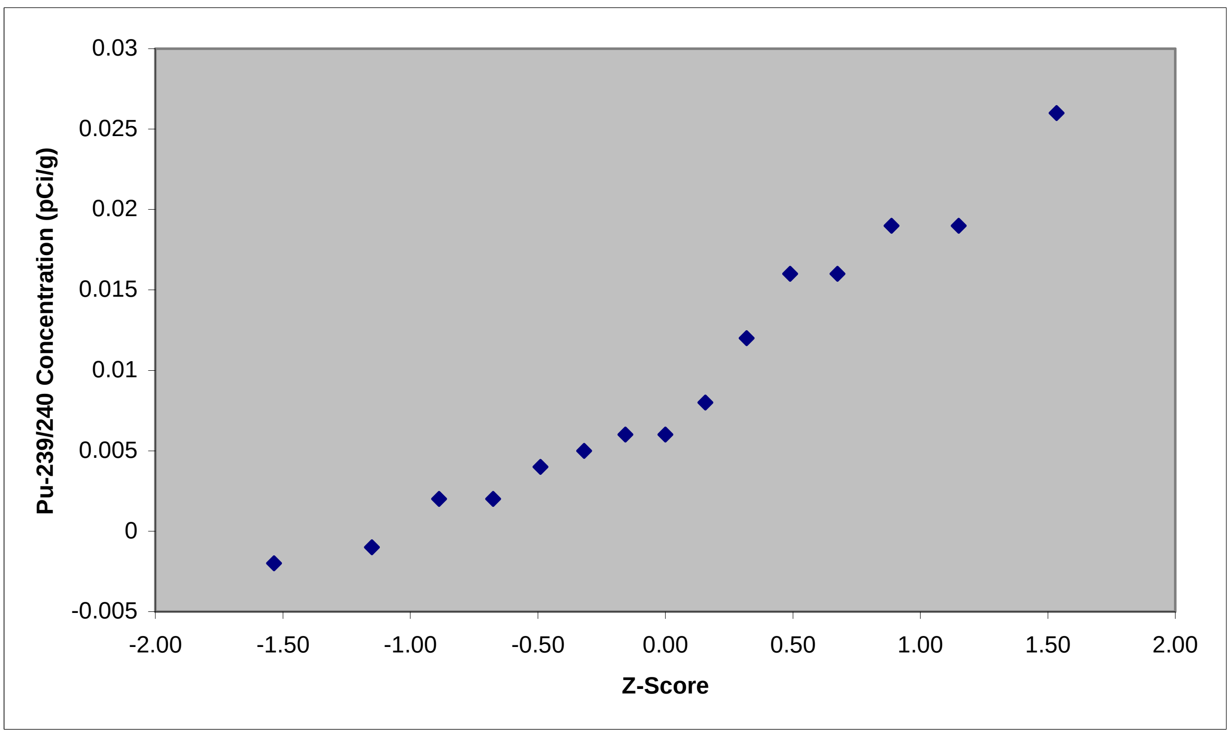


Figure 3-14 Cumulative Frequency Distribution of Plutonium-239/240 Laboratory Results

Figure 3 – 14, Victoreen Model 190 and Probe 489-110D Technical Specifications

Order online

View catalog

Specifications

Survey and Count Rate Meter (Model 190)

Operating ranges (dependent on selected probe)

Toggles and selects rate units:

µR/hr	mR/hr	R/hr
CPM	CPS	
µSv/hr	mSv/hr	
DPM	Bq/cm2	µCi/cm2

and the complementary units in the integrate mode:

µR	mR	R
CTS	D	
µSv	mSv	
Bq	µCi	

with the integrated time value in seconds

Accuracy Within 10% of reading between 10% to 100% of full scale indication on any range, exclusive of typical energy dependence. Accuracy is probe dependent

Detector GM Pancake Probe (see probe specifications to follow)

Adapter module Contains calibration data and high voltage settings for a specified probe. The module is available with an MHV connector

***Note:** Additional adapter modules can be purchased for use with multiple probes. Specify Model 190060 for MHV adapter module*

By using multiple replaceable probe adaptor modules, each module can be assigned to a specific probe. The module's EEPROM stores the calibration factors for a specific probe. When plugged into a Model 190 Survey and Count Rate Meter, it automatically sets the high voltage and activates the calibration data set for the specific probe. By using modules married to specific probes, the user has the convenience of using only one Model 190 with multiple probes for survey work

Log Logs 211 data points and sequentially labels data points. (Data retrieval requires the Infrared Communicator, Model 190-1A). With the communicator, alphanumerics up to 16 characters can be programmed into the Model 190 to name the locations of individual data points to be collected. The location name is displayed when the Log button is pressed. Press the Log button again, and the data point is stored

Battery condition Automatically indicates when battery is low

Power requirements Four 9 V batteries, 200 hours operation

Warm up time 15 second diagnostic check

Check source Model 450UCS ^{238}U, 0.064 µCi check source, 2 x 2 yellow card

Environmental

Relative humidity 0 to 95%, non-condensing

Temperature range - 10° to + 60°C

Housing material Molded ABS plastic, splash-proof case

Dimensions (survey meter only) 3.75 (w) x 2.1 (d) x 9.2 in (h) (9.2 x 5 x 23.4 cm)

Weight (survey meter only) 1.56 lb (0.7 kg)

Optional accessories

Infrared Communicator (Model 190-1A), additional features can be activated, such as log mode, alarm setpoint, energy specific calibrations, and default setting changes. Features and pushbuttons can also be locked-out to set up the Model 190 in a user defined mode of operation

Note: The Model 190EX Survey and Count Rate Meter with pancake probe is calibrated to NIST standards. The 190 and probe are calibrated in mR/h or µSv/h units as a standard. The Model 190EX unit pancake probe is not weatherproof. The end user may calibrate in additional radiation units using the Infrared Communicator, Model 190-1A

GM Pancake Probe (Model 489-110D)

Detector Halogen-quenched "Pancake" GM tube

Radiation detected Alpha above 3.5 MeV, beta above 35 keV and gamma above 6 keV

Operating voltage 900 V; compatible with all GM survey meters

Window 15 cm² (1.75 in Ø) mica, 1.4 to 2.0 mg/cm² thick

Typical background 30 CPM

Sensitivity 3500 CPM/mR/hr

Protective screen Stainless steel, hexagonal pattern providing 86% open area

Housing material ABS plastic

Cable Shielded cord; approximately 9.50 ft long MHV coaxial connector

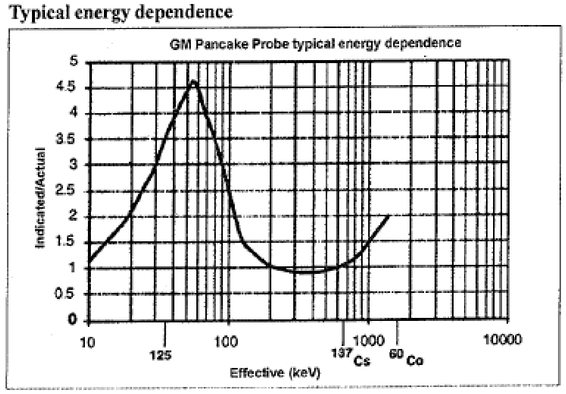
Dimensions

Detector housing 2.50 (w) x 0.875 (d) x 4.25 in (h) (6.36 x 2.2 x 10.8 cm)

Handle 1 in Ø x 6.25 in (d) (2.5 x 16.5 cm) (excluding connector)

Weight (pancake probe only) 0.625 lb (0.28 kg)

Typical energy dependence



Efficiency The GM Pancake Probe, Model 489-110D efficiency is shown below. In a recent performance check, the numbers shown represent typical results obtained:

Isotope	%Efficiency
^{14}C	5
^{99}Tc	12
^{137}Cs	24
^{90}Sr	59
^{36}Cl	26
^{241}Am	8
^{129}I	2
^{230}Th	15
^{239}Pu	12

Note: The efficiency formula used to calculate the % Efficiency is: Eff % = (CPM x 100) / DPM

Available model(s)

190EX 190 Meter with GM Pancake Probe on Telescoping Assembly

CE **Tested.** **Meets applicable standards.**

For more information, receive our full product catalog, or order online, contact **Radiation Management Services** business of **Fluke Biomedical**: 440.248.9300 or www.flukebiomedical.com/rms.

Specifications are subject to change without notice

190EX-ds rev 4 07 mar 05