United State Environmental Protection Agency

Office of Emergency Management
National Decontamination Team
Erlanger, Kentucky 41018

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Radiological Ground Survey of the Kiskimere Site in Pennsylvania

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Table of Contents

Executive Summary iv

Acronyms and Abbreviations vi

1.0 Introduction 1

2.0 Background and Survey Area Description 2

3.0 Background Radiation 4

4.0 Survey Equipment and Data Collection Procedures 6

4.1 Radiation Detectors 6
4.2 Data Recording and Verification 7

5.0 Data Analysis 7

6.0 Results 8

6.1 Measurement Results 8
6.3 Electronic Data 17
Appendix I Thorium-232 Decay Series (4n) 18
Pu-241 Decay Scheme 19

References 20

Executive Summary

The United States Environmental Protection Agency (EPA), Office of Emergency Management (OEM), National Decontamination Team (NDT) manages the Airborne Spectrophotometric Environmental Collection Technology (ASPECT) program. This program provides emergency response support to chemical and radiological incidents. It may also be used for characterization of environments containing naturally occurring radioactive materials (NORM) or man-made radioactive materials. Additionally the ASPECT radiation detection equipment can be mounted on ground based vehicles and used for surveys. This was the case for this survey which deployed equipment mounted to Kawasaki all-terrain vehicles.

The Kiskimere Groundwater Investigation site consists of a residential neighborhood which has the potential to be impacted by several past and ongoing cleanups in the area. Adjacent to the Kiskimere neighborhood to the north is the Shallow Land Disposal Area (SLDA) and the Parks Township site which is wholly fenced. In addition, the Apollo Plant which was site of a nuclear cleanup in the 1990's is located southeast of the Kiskimere neighborhood. The Apollo Plant was one source of the buried waste located at the SLDA.

The SLDA Site in Parks Township, Pennsylvania is an approximately 44 acre site that was used in part, for disposal of radioactive wastes from the nearby Apollo nuclear fuel fabrication facility in accordance with existing regulations at the time. The radioactively contaminated wastes were buried in a series of trenches on the site and covered with soil. Contaminants of concern include Am-241, Uranium ranging from depleted to highly enriched, Pu-239, Pu-241, Ra-228 and Thorium-232.

Multiple detector systems were deployed for this survey – two systems were deployed on Kawasaki Mules; each comprised of four sodium iodide (NaI) log detectors (2"X4"X16") detectors. In addition, portions of the survey used a Lanthanum Bromide ($LaBr_3$(Ce)) detector and a FIDLER (Field Instrument for Detection of Low Energy Radiation) detector.

The survey area consisted of the area surrounding the SLDA site, the area behind the Vascular Imaging complex and the Kiskimere neighborhood. Nearly 20,000 individual one second spectra were collected by the RSX NaI detector systems and analyzed. In addition, three outfalls were surveyed directly with a LaBr detector; one area was surveyed with a FIDLER detector connected to a Violinist spectroscopy system. Unlike the other survey areas, these detectors were left in place for ten to fifteen minutes to increase sensitivity.

Overall, preliminary indications are that detections made were consistent with background levels of NORM. This survey was conducted on the areas immediately surrounding the site and at the outfalls at or near the Kiskiminetas River. No detections were made of the americium, uranium or plutonium isotopes; detections of thorium and its daughters appear to be at or near normal background values.

As indicated in Image 1, there was an increase in count rates behind the Vascular Imaging complex due primarily to topography conditions. These count rates subsided as the survey progressed away from the rapid elevation change of the hillside. Spectral analysis indicates that the increased count rate was due to the proximity of the hillside. Additional in-situ FIDLER spectroscopy corroborates that assessment. Overall the survey found no off-site elevated readings attributable to the site operations.

Acronyms and Abbreviations

ASPECT	Airborne Spectral Photometric Environmental Collection Technology
Bi	bismuth
cps	counts per second
DOE	Department of Energy
EPA	Environmental Protection Agency
eU	Equivalent Uranium based on ^{214}Bi region of interest
FOV	Field of view
ft	feet
GEM	Gamma Emergency Mapper
GPS	Global Positioning System
LaBr	Lanthanum Bromide (also La_2Br_3(Ce) detector)
K	potassium
MeV	Mega electron volts
MOU	memorandum of understanding
NaI(Tl)	sodium iodide thallium drifted detector
NORM	Naturally Occurring Radioactive Material
pCi	picocurie
Ra	radium
Rn	radon
TENORM	technologically enhanced naturally occurring radioactive material
Th	thorium
Tl	thallium
U	uranium

1.0 Introduction

The United States Environmental Protection Agency (EPA), Office of Emergency Management (OEM), National Decontamination Team manages the Airborne Spectrophotometric Environmental Collection Technology (ASPECT) program. This program provides emergency response support to chemical and radiological incidents. It may also be used for characterization of environments containing naturally occurring radioactive materials (NORM). Additionally the ASPECT radiation detection equipment can be mounted on ground based vehicles and used for surveys. This was the case for this survey which deployed equipment mounted to Kawasaki all-terrain vehicles.

The Shallow Land Disposal Area Site in Parks Township, Pennsylvania is an approximately 44 acre site that was used in part, for disposal of radioactive wastes from the nearby Apollo nuclear fuel fabrication facility in accordance with existing regulations at the time. The radioactively contaminated wastes were buried in a series of trenches on the site and covered with soil. Contaminants of concern include Am-241, Uranium ranging from depleted to highly enriched, Pu-239, Pu-241, Ra-228 and Thorium-232. Although detection of plutonium isotopes is physically challenging due to their low photon yield, americium-241 is present with all domestically produced plutonium in relatively significant amounts. Thus any indication of Am-241 would have been indicative of possible plutonium contamination as well. Americium however is also challenging to detect as its primary photon emissions occur at on 60 keV and are fairly easily shielded but is still much more readily detected than plutonium. Thorium-232 is relatively easy to detect due to its multiple energetic photon emissions.

This survey was conducted at the request of Region 3 to assess potential off-site contamination of surrounding areas due to runoff or weathering of onsite contamination. Public roadways were surveyed, as were areas immediately adjacent to the site boundary. In addition, access agreements were obtained from two nearby businesses. Due to the nature of the radiations associated with these radionuclides, these results will be indicative of the first few inches of soils. If there were any subsurface contamination, these surveys would not be capable of detecting it.

The objectives of this survey were:

1. Assess the potential off-site contamination originating from the site, with emphasis on Am-241 and Th-232.
2. Conduct environmental measurements on public roadways near the site.
3. Conduct environmental measurements of adjacent properties where access agreements were obtained.
4. Use LaBr and FIDLER detectors to increase sensitivity of surveys of outfalls and areas exhibiting higher count rates.

2.0 Background and Survey Area Description

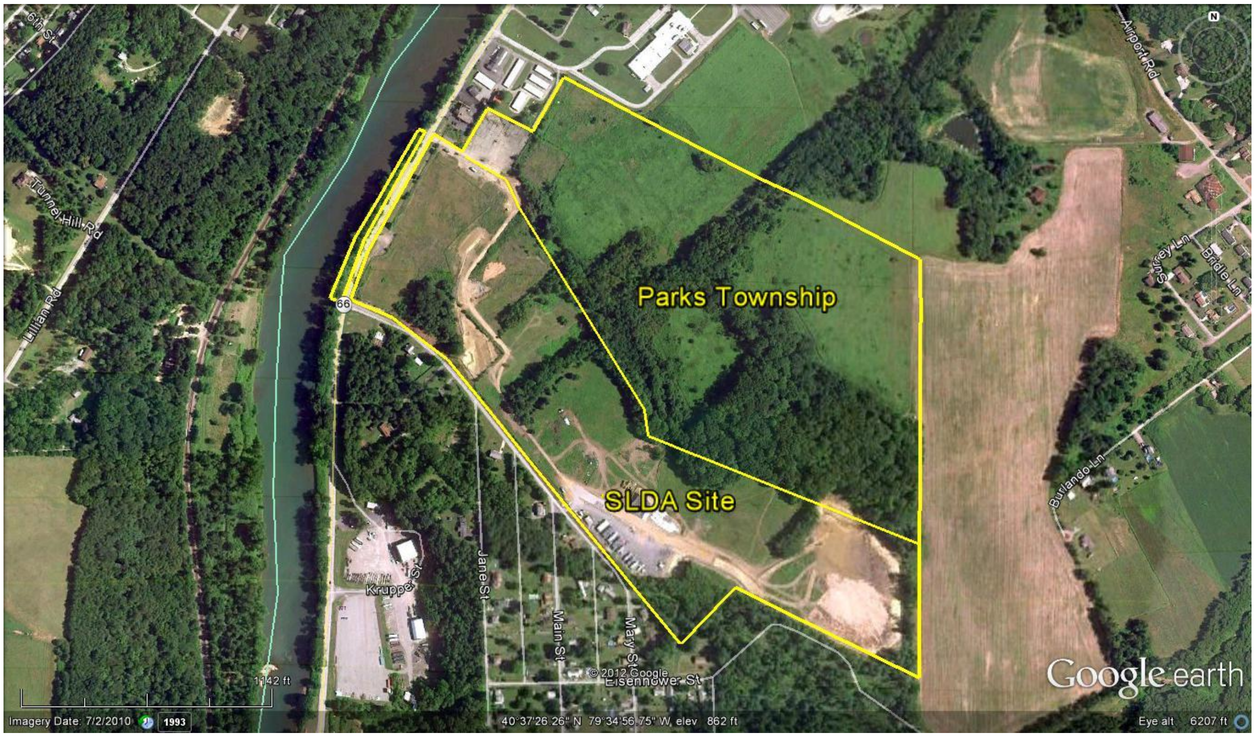


Image 1: Aerial image of the survey area.

The Shallow Land Disposal Area in Parks Township, Pennsylvania is an approximately 44 acre site that was used, in part, for disposal of radioactive wastes from the nearby Apollo nuclear fuel fabrication facility in accordance with existing regulations at the time. The radioactively contaminated wastes were buried in a series of trenches on the site and covered with soil. As part of this survey, public roadways were surveyed, as were areas immediately adjacent to the site boundary. In addition, access agreements were obtained from two nearby businesses and surveys were conducted on those properties as well. The following description is taken from the Record of Decision for the SLDA site.

"In 1957 the Apollo Nuclear Fabrication Facility began operation in Apollo, Pennsylvania und U.S. Atomic Energy Commission (AEC) license No. SNM-145. Between 1961 and 1970, Nuclear Materials and Equipment Corporation (NUMEC), who owned both the Apollo Facility and the SLDA, buried process and other wastes from the Apollo plant at the SLDA site. According to historical documents, these wastes were buried in accordance with AEC regulations 10 CFR 20.304, Disposal by Burial in Soil, which was subsequently rescinded in 1981. In 1967, NUMEC stock was bought by Atlantic Richfield Company (ARCO) and the use of the SLDA for radioactive waste disposal was discontinued after 1970. In 1971, the Babcock & Wilcox Company (B&W) acquired NUMEC.

Based on reports prepared by ARCO/B&W, and discussions with individuals familiar with disposal operations at SLDA, the waste materials were placed into a series of pits that were constructed adjacent to one another. From geophysical surveys performed at the site, these pits appear as linear trenches and are depicted on site drawings as trenches. These geophysical anomalies were labeled as “trenches 1 through 10”; this numbering scheme was based partially on the sequential construction and use of each trench (1 being the oldest trench and 9 being the most recently constructed trench in the upper trench area). Trench 10 is located in another part of the site and was used for disposal purposes throughout the 1960s and during 1970. Disposal activities at the SLDA site were reportedly terminated in 1970. Under NRC license SNM-2001, BWXT is required to properly maintain the site in order to ensure protection of workers and the public, and to eventually decommission the site in compliance with NRC regulations as part of its license termination activities.

The Shallow Land Disposal Area in Parks Township, Pennsylvania is an approximately 44 acre site that was used, in part, for disposal of radioactive wastes from the nearby Apollo nuclear fuel fabrication facility in accordance with existing regulations at the time. The radioactively contaminated wastes were buried in a series of trenches on the site and covered with soil. As part of this survey, public roadways were surveyed, as were areas immediately adjacent to the site boundary. In addition, access agreements were obtained from two nearby businesses and surveys were conducted on those properties as well.”

3.0 Background Radiation

Naturally occurring radioactive material (NORM) originates from cosmic radiation, cosmogenic radioactivity, and primordial radioactive elements that were created at the beginning of the earth about 4.5 billion years ago. Cosmic radiation consists of very high-energy particles from extraterrestrial sources such as the sun (mainly alpha particles and protons) and galactic radiation (mainly electrons and protons). Its intensity increases with altitude, doubling about every 6,000 ft, and with increasing latitude north and south of the equator. The cosmic radiation level at sea level is about 3.2 µR/h and nearly twice this level in locations such as Denver, CO.

Cosmogenic radioactivity results from cosmic radiation interacting with the earth's upper atmosphere. Since this is an ongoing process, a steady state has been established whereby cosmogenic radionuclides (e.g., ^{3}H and ^{14}C) are decaying at the same rate as they are produced. These sources of radioactivity were not a focus of this survey and were not included in the processing algorithms.

Primordial radioactive elements found in significant concentrations in the crustal material of the earth are potassium, uranium and thorium. Potassium is one of the most abundant elements in the Earth's crust (2.4% by mass). One out of every 10,000 potassium atoms is radioactive potassium-40 (^{40}K) with a half-life (the time it takes to decay to one half the original amount) of 1.3 billion years. For every 100 ^{40}K atoms that decay, 11 become Argon-40 (^{40}A) and emit a 1.46 MeV gamma-ray.

Uranium is ubiquitous in the natural environment and is found in soil at various concentrations with an average of about 1.2 pCi/g. Natural uranium consists of three isotopes with about 99.3% being uranium-238 (^{238}U), about 0.7% being uranium-235 (^{235}U), and a trace amount being uranium-234 (^{234}U).

Thorium-232 is the parent radionuclide of one of the 4 primordial decay chains. It is about four times more abundant in nature than uranium and also decays through a series of daughter products to a stable form of lead. The thorium content of rocks ranges between 0.9 pCi/g and 3.6 pCi/g with an average concentration of about 1.3 pCi/g.[1] It was the primary focus of this survey and is commonly measured as a significant component of the terrestrial component of natural background. The ninth daughter product, thallium-208 (^{208}Tl), is used to estimate the presence of thorium by its 2.61 MeV gamma-ray emission.

All these primordial radionuclides are present in varied concentrations in building materials which make-up part our naturally occurring radioactive background (Table 1)[2].

Table 1: Average concentrations of potassium, uranium and thorium in some building materials

Material	Potassium (pCi/g)	Uranium (pCi/g)	Thorium (pCi/g)
Granite	32	1.7	0.22
Sandstone	11.2	0.2	0.19
Cement	6.4	1.2	0.57
Limestone concrete	2.4	0.8	0.23
Sandstone concrete	10.4	0.3	0.23
Wallboard	2.4	0.4	0.32
By-product gypsum	0.2	5.0	1.78
Natural gypsum	4	0.4	0.2
Wood	90	-	-
Clay brick	18	3	1.2

Technologically enhanced naturally occurring radioactive material (TENORM) is NORM processed in such a manner that its concentration has been increased. TENORM is associated with varied industries including energy production, water filtration, fertilizer production, mining and metals production. Concentrations of radionuclides in TENORM are often orders of magnitude greater than the naturally occurring concentrations.

4.0 Survey Equipment and Data Collection Procedures

4.1 Radiation Detectors

The radiological detection technology used for ground-based measurements consisted of two RSX-4 Units (Radiation Solutions, Inc., 386 Watline Avenue, Mississauga, Ontario, Canada) (Image 2). Each unit was equipped with four 2”x4”x16” thallium-activated sodium iodide (NaI[Tl]) scintillation crystals. One unit was mounted in front of each of two Kawasaki Mules. A $LaBr_3$ detector was also carried on the mule and used to supplement the NaI detectors as well as to have a semi-portable instrument that could be carried to inaccessible areas (down steep slopes etc.).

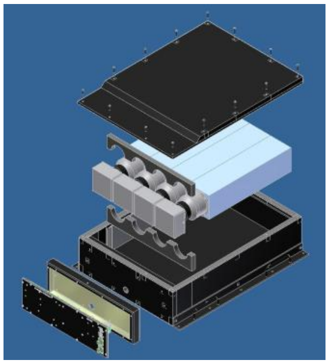


Image 2: RSX-4 unit showing four detector locations

The Radiation Solutions RSX-4 unit was designed for airborne detection and measurement of low-level gamma radiation from both naturally occurring and man-made sources. It can also be used for ground-based measurements as shown in the images below. These units use advanced digital signal processing and software techniques to produce spectral data equivalent to laboratory quality. The unit is a fully integrated system that includes an individual high resolution (1,024 channels) advanced digital spectrometer for each detector. A high level of self diagnostics and performance verification routines such as auto gain stabilization are implemented with an automatic error notification capability, helping to assure that the resulting maps and products are of high quality and accuracy.

Image 3: Equipment setup on the Kawasaki Mule

4.2 Data Recording and Verification

Radiological spectral data are collected every second along with GPS coordinates and other data reference information. These data are subject to quality checks within the Radiation Solutions internal processing algorithms (e.g. gain stabilization) to ensure a good signal. If no problems are detected, a green indicator light within the RadAssist software application notifies the user that all systems are good. A yellow light indicates a gain stabilization issue with a particular crystal. This can be fixed by waiting for another automatic gain stabilization process to occur or the user can disable the particular crystal. A red light indicates another problem and would delay the survey until it can be resolved.

5.0 Data Analysis

RadAssist Version 3.18.2.0 (Radiation Solutions, Inc., 386 Watline Avenue, Mississauga, Ontario, Canada) was used to produce bread-crumb maps of **Total count rate** (counts per second).

Total count rate products can be used to assess the wide range of radioactivity present in the environment. The spectral region of interest (ROI) ranged from 30 keV to 2,814 keV (channels 9 to 937). It measures gamma activity from all terrestrial sources including contributions from radon. Radon corrections were not performed and radon is not expected to significantly affect results due to the relatively short survey duration. Cosmic radiation is measured at 3,072 keV (Channel 1,023) and was excluded from the total count rate ROI.

Multi-Channel Analyzer (MCA) measurements were taken at two locations of greatest concern for a potential off-site release with a TSA Systems Inc. Violinist III. The Violinist III utilizes a FIDLER (Field Instrument for the Detection of Low-Energy Radiation). The FIDLER was specifically designed to detect the low-energy (17 keV and 60 keV) photons that are associated with plutonium and americium. The Violinist III provides a graphical MCA display of this energy range and converts the photon count from the FIDLER into plutonium and americium numerical surface concentrations.

The analyses at these two locations provided no differentiation above background to indicate that plutonium or americium were present on the soil surface. NOTE: Since these nuclides only emit low energy photons this instrument is not suitable for determining if there is buried material present.

6.0 Results

6.1 Measurement Results

Three RSX units were used in this ground survey. Two RSX-4 units were mounted to Kawasaki mules positioned at about 0.67 meters above the ground. One RSX-1 LaBr detector was used to supplement the NaI detector results and to reach areas with difficult access. In addition, a FIDLER probe was used to obtain an extended spectrum collection in an area that exhibited increased count rate due to ground topography as well as at the primary outfall from the site.

None of the surveys using the additional equipment indicated the presence of any radioactive materials other than NORM. The spectra from the outfalls and the base of the hillside are shown below. A background $LaBr_3$ spectrum from the spectroscopy software PeakEasy©[*] is included for comparison purposes. All survey results were consistent with background levels of the naturally occurring thorium and uranium decay chains (including Ra-228). There were no significant detections of Am-241. No soil samples were taken during this survey.

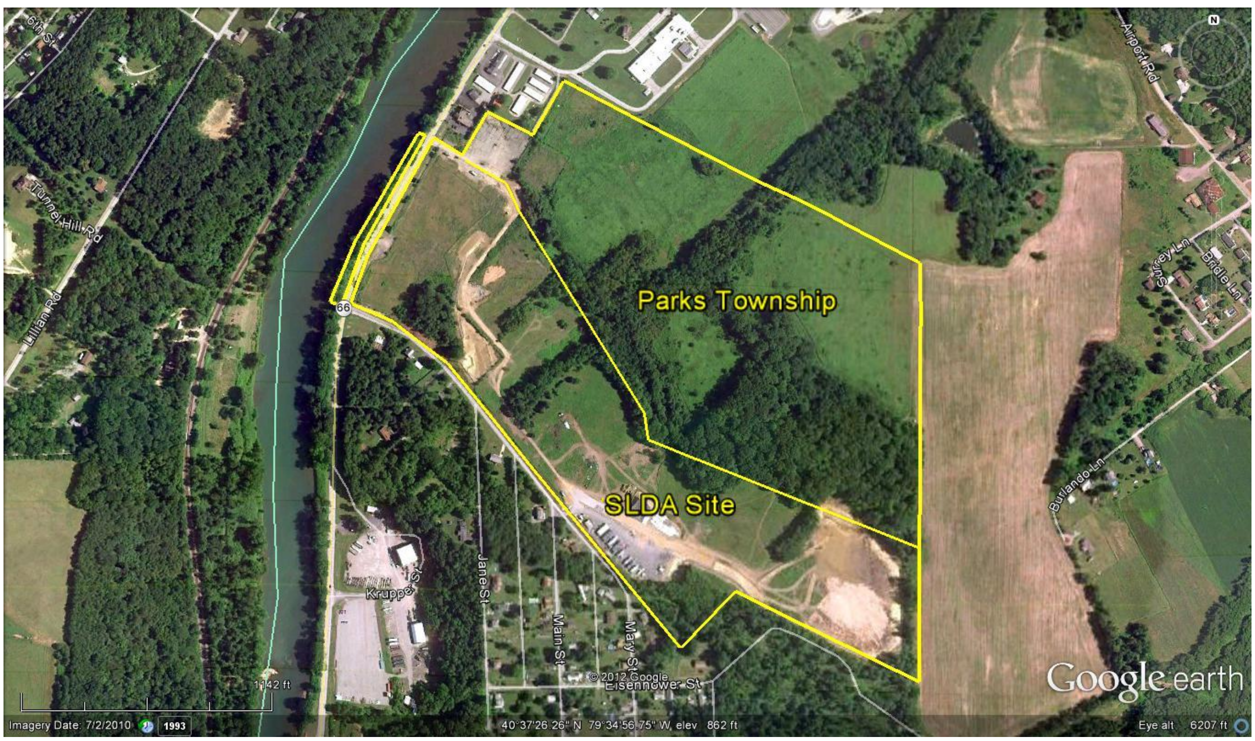


Image 4
The SLDA site

[*] PeakEasy Software created by Los Alamos National Laboratory. Version 4.02released February 27, 2012.

Image 5
LaBr survey at the River Outfall

Image 6
Sampling at Outfall 001

Image 7
$LaBr_3$ measurement at Kiskimere Outfall

Image 8
FIDLER, $LaBr_3$ and NaI detectors at Outfall 001

Image 9
Hillside Sampling Location

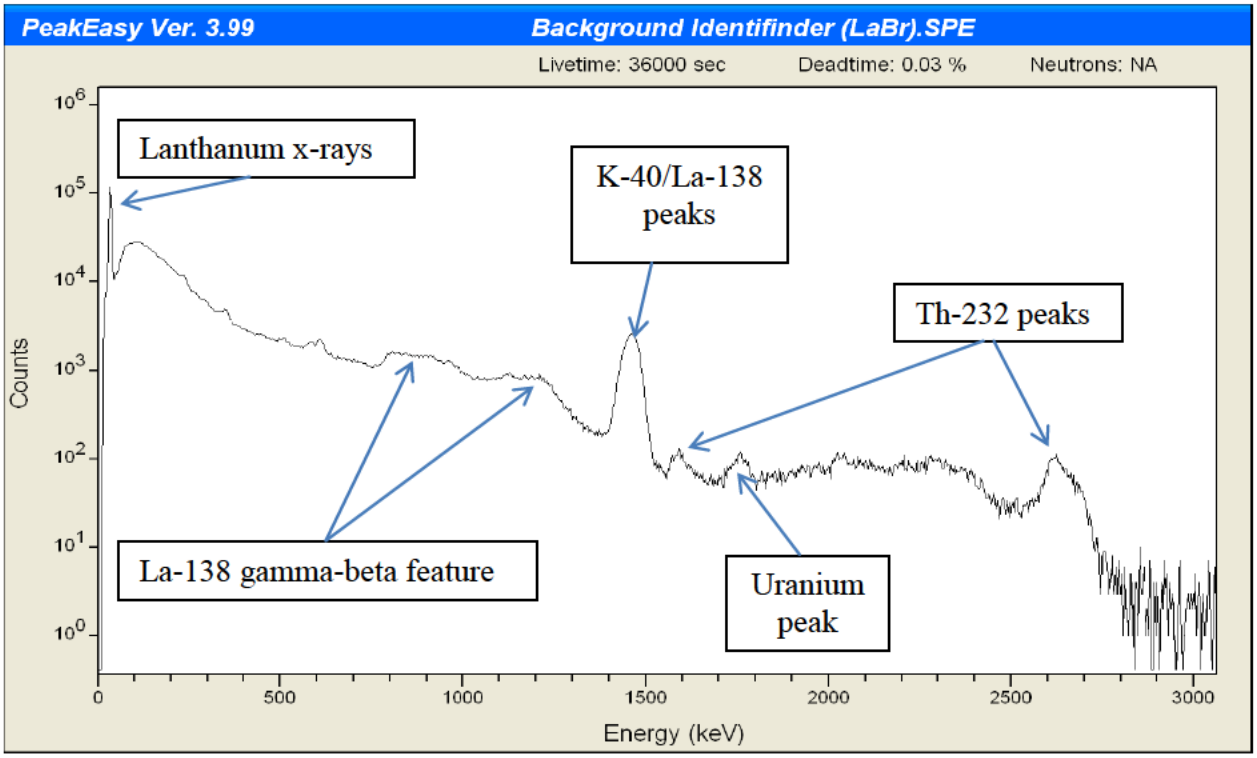


Figure 1
Background spectrum for LaBr detector
from PeakEasy software.

Figure 1 above is an example background spectrum for a Lanthanum bromide detector. The peaks due to internal contamination from La-138 as well as peaks from naturally occurring uranium, potassium and thorium are the only notable signature in all of the spectra.

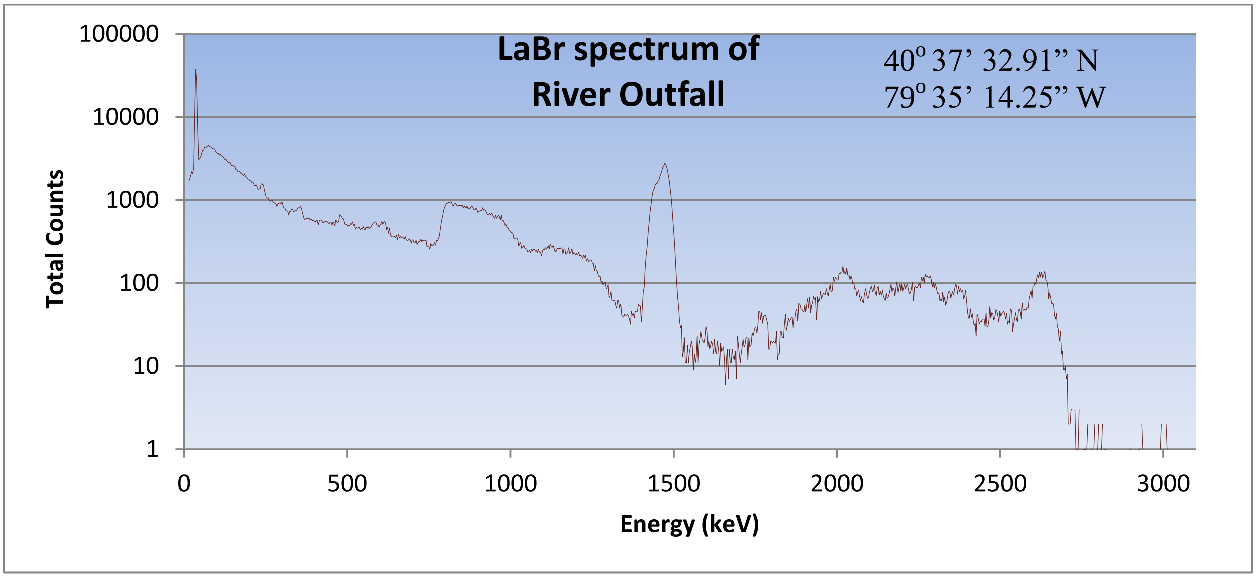


Figure 2
LaBr Spectrum at River outfall.

The above spectrum is from a 10 minute count at the storm outfall near the river. The spectrum exhibits only peaks expected from natural background and from the detector. No features clearly indicated the presence of off-site contamination from site operations. The same is true for all extended collections at the three outfalls measured.

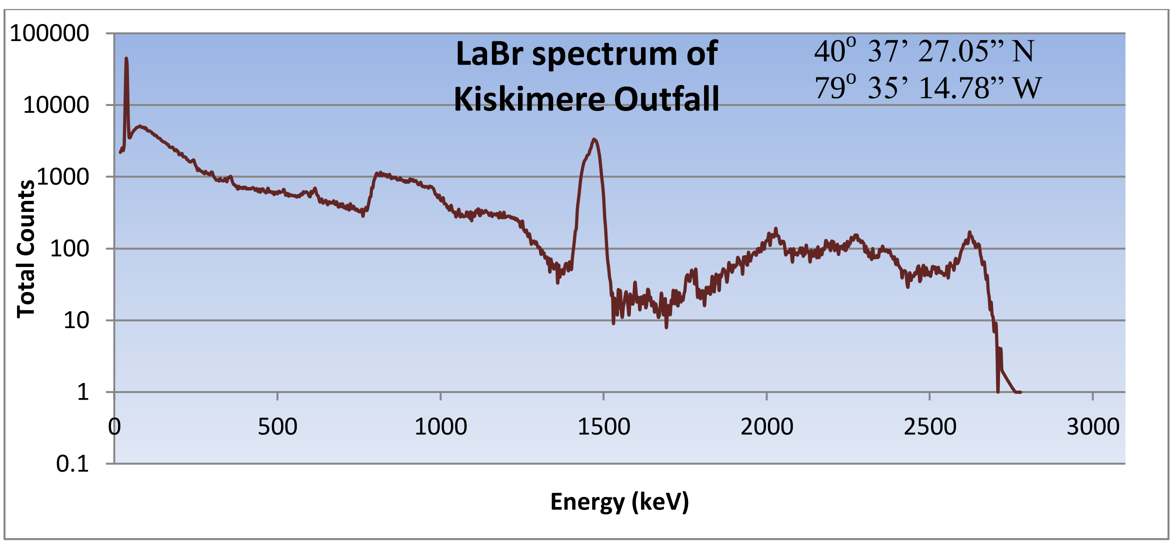


Figure 3
LaBr spectrum at Kiskimere Outfall

The above spectrum is from a 10 minute count at the Kiskimere outfall. The spectrum exhibits only peaks expected from natural background and from the detector. No features clearly indicated the presence of off-site contamination from site operations.

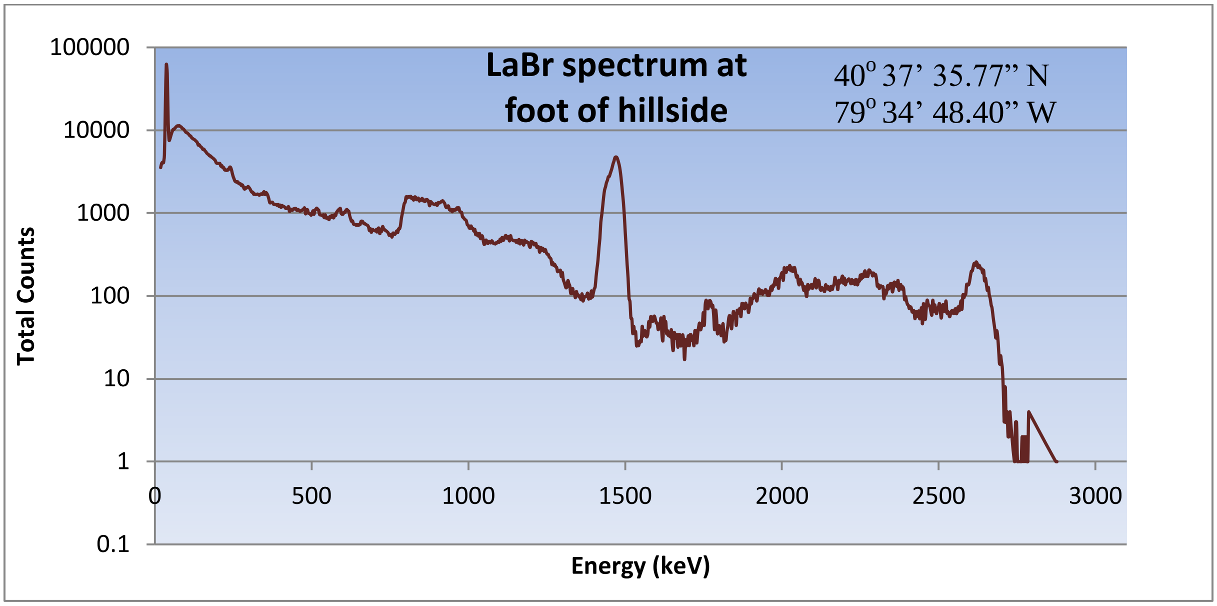


Figure 4
LaBr spectrum at the foot of the hillside

The above spectrum is from a 10 minute count at the hillside where the highest count rates were noted by the RSX-4 units. While the count rates were elevated, the spectrum exhibits only peaks expected from natural background and from the detector. This is indicative of a topography issue where the hillside contributes additional counts to the detector than would be typically detected from a flat terrain. No features clearly indicated the presence of off-site contamination from site operations.

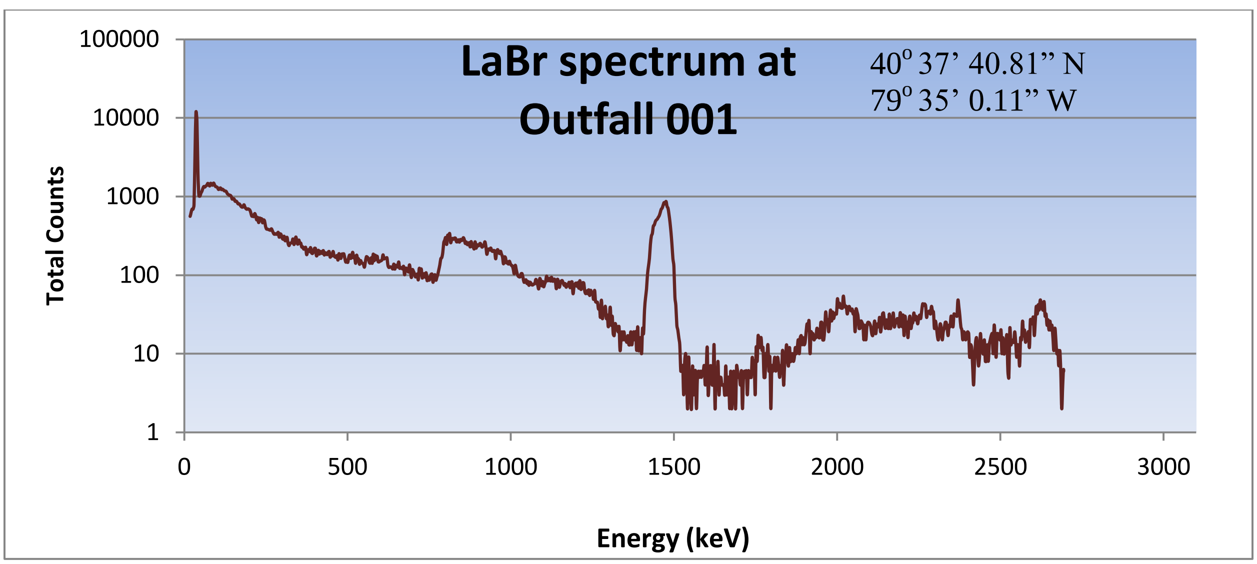


Figure 5
LaBr spectrum at Outfall 001

The above spectrum is from an approximately 5 minute count at Outfall 001. The spectrum exhibits only peaks expected from natural background and from the detector. No features clearly indicated the presence of off-site contamination from site operations.

6.2.2 Total Count Rate Maps

These maps represent the total gamma radiation count rate*. It is a basic tool that identifies areas with higher radiation levels relative to other locations. This product should not be used for risk assessment purposes or making public health decisions. Any location showing a large change in count rate might warrant a more detailed assessment. No areas on this map clearly indicated the presence of Am-241off-site contamination from the SLDA site. As indicated in the figure below, there was an increase in count rates behind the Vascular Imaging complex. These count rates subsided as the survey progressed away from the rapid elevation change of the hillside. Spectral analysis indicates that the increased count rate was due to NORM and the proximity to the hillside. Additional *in-situ* FIDLER spectroscopy corroborates that assessment. Overall the survey found no clear elevated off-site readings attributable to the site operations.

* The region of interest was channels 9 to 937 (30 keV to 2814 keV).

Image 10
Total Count Rate Map
Total Count Rate Map of Surveyed Areas

Parameter: Total Counts (cps)

< 3900.0	7500.0 : 8400.0
3900.0 : 4800.0	8400.0 : 9300.0
4800.0 : 5700.0	9300.0 : 10200.
5700.0 : 6600.0	10200. : 11100.
6600.0 : 7500.0	> 11100.

ASPECT Program

Ground Parameters

1 per second acquisition rate
Total Counts ROI = 9 to 937
RSX4 Unit
4 NaI detectors

The background rate in an apparently unaffected area was approximately 4000 counts per second. For this reason, the data was plotted with a range approximately one to three times background levels. Very few data points exhibited total count rates near twice the background rate. All of these were attributed to the topography of the area (steep hillside). No areas were found that exceeded the three times background threshold.

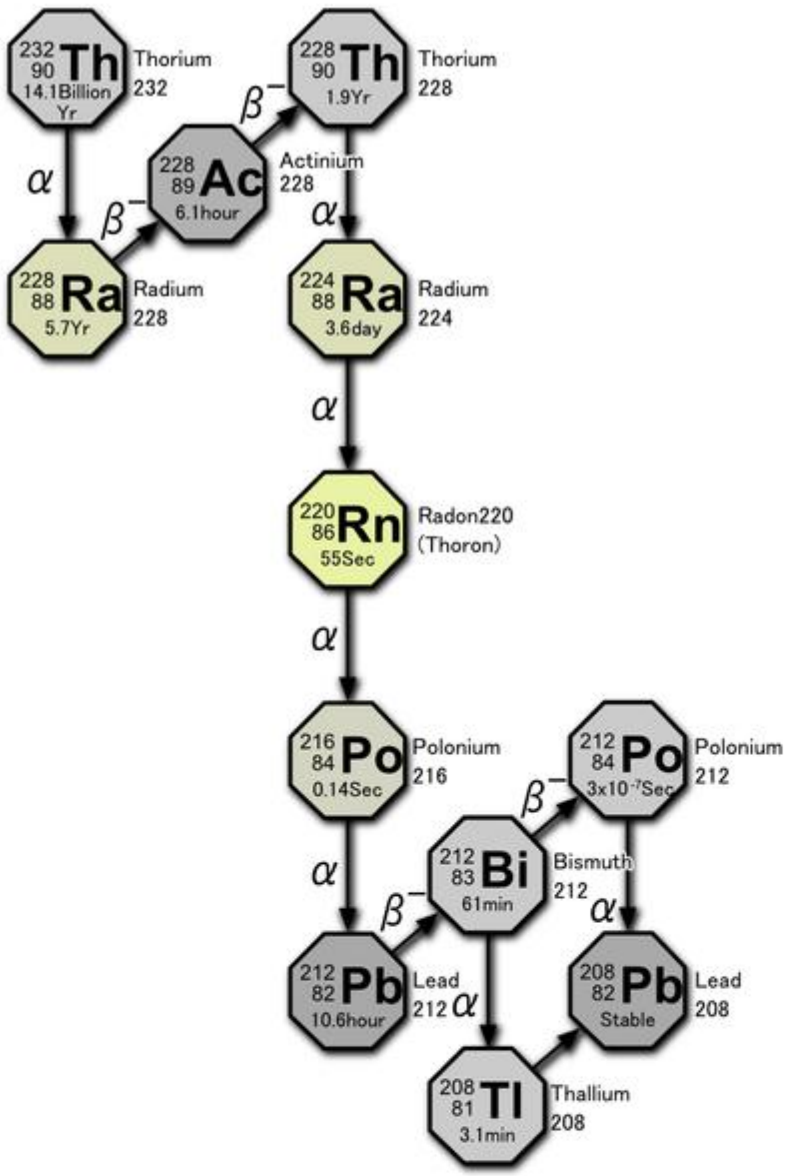
6.3 Electronic Data

Access to the electronic data and Google Earth files can be provided by contacting:

Richard Rupert
On-Scene Coordinator
EPA Region 3
Rupert.Richard@epa.gov

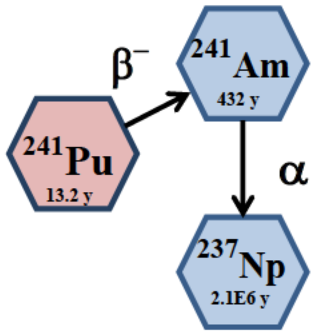
8.0 Appendices

Appendix I
Thorium-232 Decay Series (4n)*



* Image obtained from http://upload.wikimedia.org/wikipedia/commons/1/1c/Decay_chain%284n%2CThorium_series%29.PNG, accessed on September 25, 2010

Pu-241 Decay Scheme



References

[1] Eisenbud, M. Environmental Radioactivity; From Natural, Industrial, and Military Sources. 3rd Edition. Academic Press, Inc., New York, NY. 1987.

[2] National Council on Radiation Protection and Measurements. [1987]. Exposure of the Population in the United States and Canada from Natural Background Radiation. Bethesda, MD. NCRP Report 94.