



AN AERIAL RADIOLOGICAL SURVEY OF THE

# **BROWNS FERRY NUCLEAR POWER STATION**

AND SURROUNDING AREA

DECATUR, ALABAMA

DATE OF SURVEY: JULY 1985

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## ABSTRACT

An aerial radiological survey was conducted during the period 12 July to 17 July 1985 over a 97-square-kilometer (37-square-mile) area centered on the Browns Ferry Nuclear Power Station located near Decatur, Alabama. The survey was conducted at a nominal altitude of 46 meters (150 feet) with line spacings of 76 meters (250 feet). A contour map of the terrestrial gamma exposure rate plus the cosmic exposure rate extrapolated to 1 meter above ground level was prepared and overlaid on an aerial photograph and a USGS topographic map of the area. The terrestrial exposure rates north and east of Wheeler Lake ranged from approximately 11 to 18 microroentgens per hour ( $\mu\text{R}/\text{h}$ ), while the area south and west of the lake ranged from approximately 9 to 11  $\mu\text{R}/\text{h}$ . Two areas of increased exposure rate were evident. One of these areas was associated with the main units of the reactor facility, while the other was associated with a temporary radiological waste holding area inside the plant's protected area. A machine-aided search of the data for man-made sources of radiation indicated the presence of a third area within the plant facility. This area is utilized as a temporary low-level radioactive waste storage site. All three areas indicated the presence of Co-60.

Soil samples and ion chamber measurements were obtained at four locations to support the aerial data. In addition, soil samples were also taken at six locations along the shore of Wheeler Lake.

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## 1.0 INTRODUCTION

The United States Department of Energy (DOE) maintains a Remote Sensing Laboratory (RSL) in Las Vegas, Nevada and an extension facility in Washington, D.C. The RSL is operated for the DOE by EG&G Energy Measurements, Inc. (EG&G/EM), a contractor of the DOE. One of the major functions of the RSL is to manage an aerial surveillance program called the Aerial Measuring System (AMS).

Since its inception in 1958, the AMS has continued a nationwide effort to document baseline radiological conditions surrounding energy-related sites of interest. These sites include power plants, manufacturing and processing plants, and research laboratories employing nuclear materials. At the request of federal or state agencies, and by direction of the DOE, the AMS is deployed for various aerial survey operations.

An aerial gamma survey was conducted from 12 July through 17 July 1985 over the Browns Ferry Nuclear Power Station and surrounding area (Figure 1). The survey covered a 97-square-kilometer (37-square-mile) area centered on the plant. The purpose of the survey was to map the gamma environment of the area surrounding the Browns Ferry facility. The survey was performed at the request of the United States Nuclear Regulatory Commission.

## 2.0 SITE DESCRIPTION

The Browns Ferry facility is located in Limestone County, Alabama, 14.5 kilometers (9 miles) northwest of the town of Decatur, Alabama. The Browns Ferry Nuclear Power Station is operated by the Tennessee Valley Authority. The plant is situated on Wheeler Lake which supplies the cooling water. The majority of the land surrounding the facility is cultivated and fairly level with 61-meter (200-foot) maximum elevation changes.

Large-area aerial photographic imagery of the plant was obtained in September 1985, and many oblique photographs of the site were taken during the survey.

Browns Ferry and the surrounding area were previously surveyed in May 1973.<sup>1</sup> No attempt will be made in this report to compare these two surveys due to the extreme differences in data collection and analysis methodology and mission parameters.

## 3.0 NATURAL BACKGROUND

Natural background radiation originates from radioactive elements present in the earth, airborne radon, and cosmic rays entering the earth's atmosphere from space.

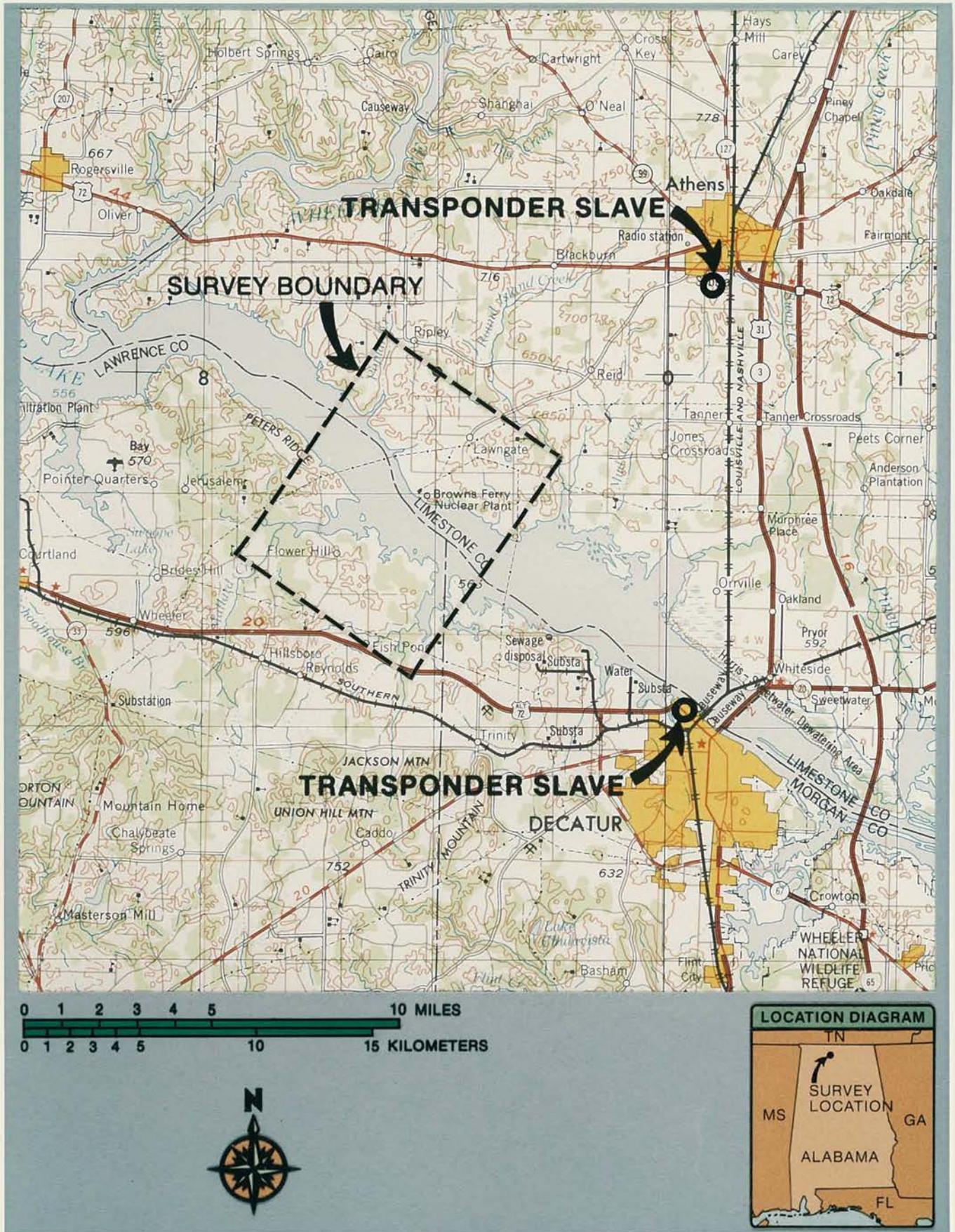
The natural terrestrial radiation levels depend upon the type of soil and bedrock immediately below and surrounding the point of measurement. Within cities, the levels are also dependent on the nature of the street and building materials. The gamma radiation originates primarily from the uranium decay chain, the thorium decay chain, and radioactive potassium. Local concentrations of these nuclides produce radiation levels at the surface of the earth typically ranging from 1 to 15  $\mu\text{R/h}$  (9 to 130 mrem/y).<sup>2</sup> Some areas with high uranium and/or thorium concentrations in the surface minerals exhibit even higher radiation levels, especially in the western states.

One member of both the uranium and thorium radioactive decay chains is an isotope of radon, a noble gas, which can both diffuse through the soil and travel through the air to other locations. Therefore, the level of airborne radiation due to these radon isotopes and their daughter products at any specific location depends on a variety of factors, including meteorological conditions, mineral content of the soil, and soil permeability. Typically, airborne radiation contributes from 1 to 10 percent of the natural background radiation levels.

Cosmic rays, the space component, interact with elements of the earth's atmosphere and soil. These interactions produce an additional natural source of gamma radiation. Radiation levels due to cosmic rays vary with altitude and geomagnetic latitude. Typically, values range from 3.3  $\mu\text{R/h}$  at sea level in Florida to 12  $\mu\text{R/h}$  at an altitude of 3 kilometers (1.9 miles) in Colorado.<sup>3</sup>

## 4.0 SURVEY PLAN

The survey was designed to cover approximately 97-square-kilometers (37-square-miles) surrounding the Browns Ferry Nuclear Power Station site (Figure 1). The gamma ray spectral data were processed to provide both a qualitative and quantitative analysis, where applicable, of the radionuclides in the survey area. The steering computer was programmed to set up a series of parallel flight lines to cover the area surrounding



**Figure 1.** GENERAL VIEW OF THE BROWNS FERRY NUCLEAR POWER STATION AND SURROUNDING AREA SHOWING THE PLANT, SURVEY BOUNDARY, AND URS TRANSPONDER LOCATIONS FOR THE JULY 1985 SURVEY

the site. For this survey all lines were flown in a northeast-southwest direction at a nominal altitude of 46 meters (150 feet) above ground level (AGL), a line spacing of 76 meters (250 feet), and a speed of 36 meters/second (70 knots).

## 5.0 SURVEY EQUIPMENT

A Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 2) was used for the low altitude survey. The aircraft carried a crew of two and a lightweight version of the Radiation and Environmental Data Acquisition and Recorder system, Model IV (REDAR IV). Two pods—each containing four 10.2 cm × 10.2 cm × 40.6 cm (4 in. × 4 in. × 16 in.) log-type thallium-activated sodium iodide, NaI(Tl), gamma detectors as well as one 10.2 cm × 10.2 cm cylindrical gamma detector of the same material—were mounted on the sides of the helicopter. The smaller detector extends the effective dynamic range of the REDAR IV system, which is useful in areas exhibiting enhanced levels of radiation.

The preamplifier signal from each detector was calibrated with a Na-22 source. Normalized outputs of each detector were combined in a four-way summing amplifier for each array. The outputs of each array were matched and combined in a two-way summing amplifier. Finally, the signal was adjusted in the analog-to-digital converter (ADC) so that the calibration peaks appeared in preselected channels of the multichannel analyzer of the REDAR IV system.

### 5.1 REDAR IV System

The REDAR IV is a multi-microprocessor, portable data acquisition and real-time analysis system. It has been designed to operate in the severe environments associated with platforms such as helicopters, fixed-wing aircraft, and various ground-based vehicles. The system displays to the operator all required radiation and system information, in real time, via CRT displays and multiple LED readouts. All pertinent data are recorded on magnetic cartridge tapes for post-mission analysis on minicomputer systems.

The system employs five Z-80 microprocessors with AM9511 arithmetic processing chips to perform the data collection and display, real-time data analysis, navigational calculations and data



Figure 2. MBB BO-105 HELICOPTER WITH DETECTOR PODS

recording, all of which are under operator control. The system allows access to the main processor bus through both serial and parallel data ports under control of the control processor.

The system consists of the following subsystems:

1. Two independent radiation data collection systems
2. A general purpose data I/O system
3. A digital magnetic tape recording system
4. A CRT display system
5. A real-time data analysis system
6. A microwave ranging system with steering calculation and display

The REDAR processing system block diagram is shown in Figure 3.

Each radiation data collection system consists of a multichannel analyzer which collects 1024 channels of gamma ray spectral data (4.0 keV/channel) once every second during the survey operation. The 1024 channels of data are sent to the single channel processor and then compressed into 256 channels. Table 1 summarizes the spectral data compression performed by REDAR IV.

The spectrum is divided into three partitions with the appropriate energy coefficient to make the width of the photopeaks approximately the same in each partition. The resolution of NaI(Tl) crystals varies with energy, permitting the compression of the spectral data without compromising photopeak identification and stripping techniques. In the first partition (channels 0-75), the data are not compressed to permit stripping of low energy photopeaks, such as the 60 keV photopeak from

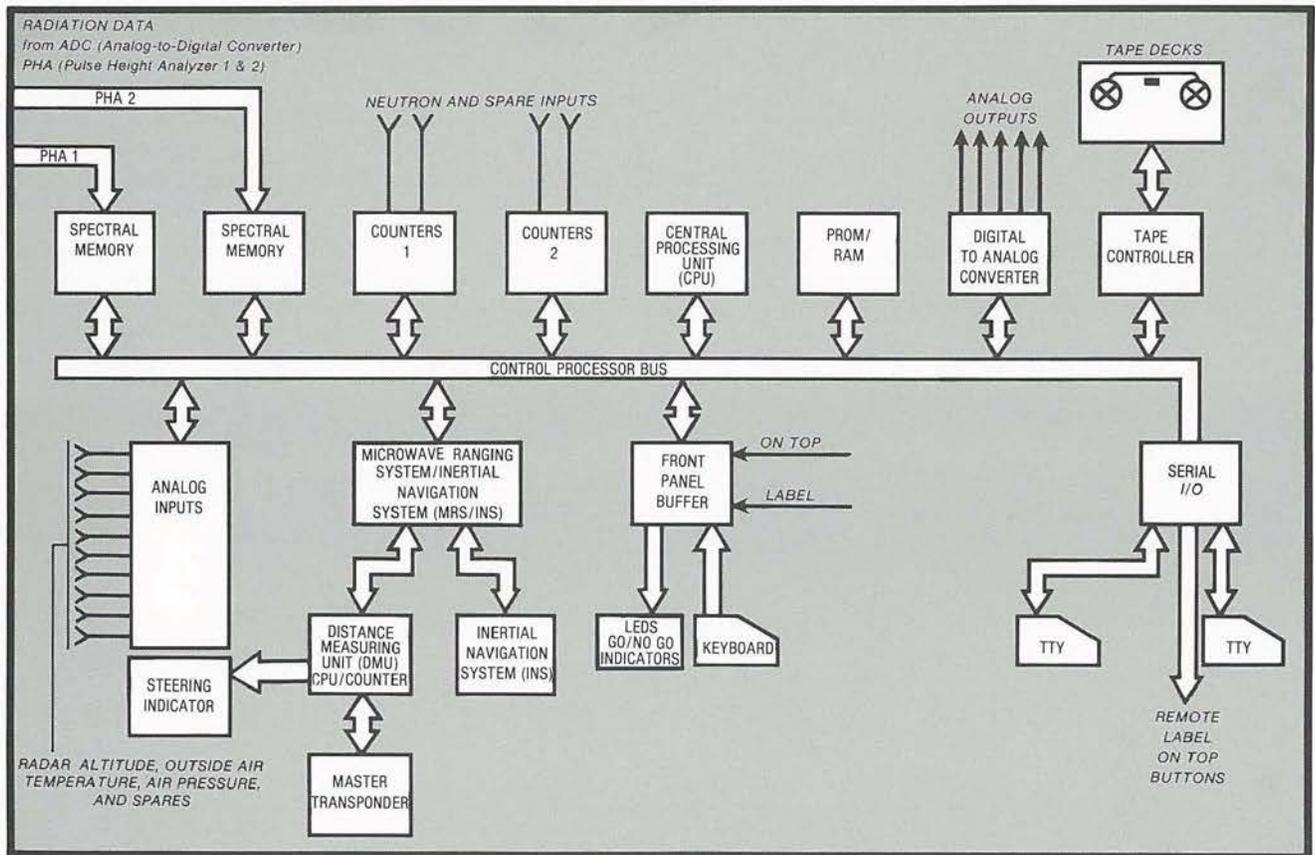


Figure 3. REDAR PROCESSOR SYSTEM BLOCK DIAGRAM

Am-241. The spectral compression technique reduces the amount of data storage required by a factor of four.

The 256 channels of spectral data are continuously recorded every second. The REDAR IV system has two sets of spectral memories; each memory can accumulate four individual spectra. The two

memories are operated in a flip-flop mode, every 4 seconds, for continuous data accumulation. While one memory is being used to store data, the data in the other memory are being transferred to magnetic tape.

The REDAR IV data acquisition system is shown in Figure 4.

$E_{\gamma}$ (keV)	Channel Input	Energy Coefficient $\Delta E$ (keV/channel)	Compressed Channel Output
0 - 300	0 - 75	4	0 - 75
304 - 1620	76 - 405	12	76 - 185
1624 - 4068	406 - 1017	36	186 - 253
4072 - 4088	1018 - 1022	N/A	254
>4088 - Analog Cutoff	1023	N/A	255
	1024	Unused	256

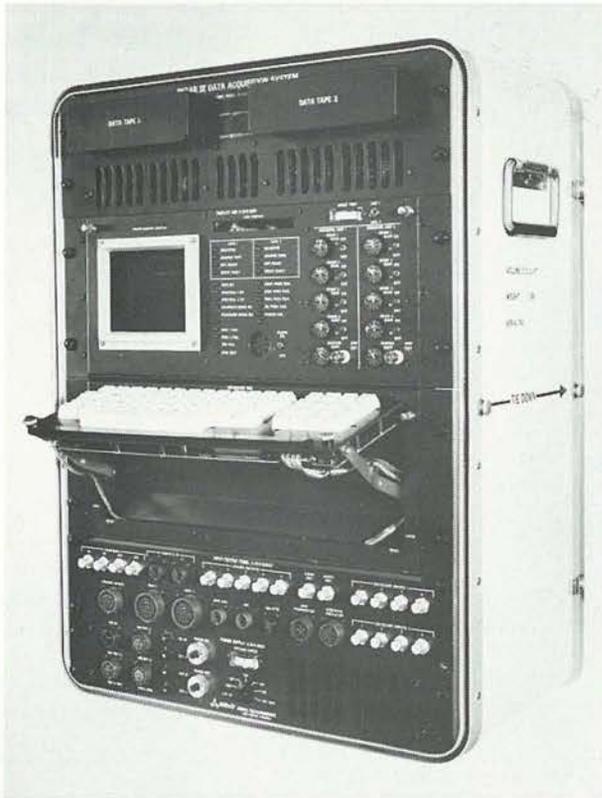


Figure 4. REDAR DATA ACQUISITION SYSTEM

## 5.2 Helicopter Positioning Method

The helicopter position was established using two systems: an ultrahigh frequency ranging system (URS) and an AL-101 radar altimeter.

The URS master station, mounted in the helicopter, interrogated two remote transponder slaves located outside the survey area (the locations of the transponder slaves are indicated in Figure 1). By measuring the roundtrip propagation time between the master and remote stations, the master unit computed the distance to each. The distances were recorded on magnetic tape with the radiation data once each second. Simultaneously these distances were converted to position coordinates for the steering indicator to direct the aircraft along the predetermined flight lines.

The radar altimeter similarly measured the time lag for the return of a pulsed signal and converted this delay to aircraft altitude. For altitudes up to 1500 meters (4,950 feet) the accuracy was  $\pm 0.6$  meter or  $\pm 2$  percent, whichever was greater. These data were also recorded on magnetic tape

so that any variation in gamma signal strength caused by altitude fluctuations could be compensated.

The detectors and electronics systems which accumulated and recorded the data are described in considerable detail in a separate publication.<sup>4</sup>

## 6.0 DATA PROCESSING EQUIPMENT

Data processing was begun in the field with the Radiation and Environmental Data Analyzer and Computer (REDAC) system. This system consists of a computer analysis laboratory mounted in a mobile van (Figure 5). During the survey operations, the van and aircraft were based at Mountain Lakes Aviation located in Pryor, Alabama.



Figure 5. MOBILE COMPUTER PROCESSING LABORATORY

The REDAC system consists primarily of a 16-bit CPU with 512 kilobytes of memory and floating point processor; two discs with a total of 1.1 gigabytes of storage; two 800/1600-byte-per-inch, 9-track, 1/2-inch tape drives; two 4-track, 1/4-inch cartridge tape drives for reading REDAR tapes; a 36-inch-wide carriage incremental plotter; a multi-speed printer; a system CRT display; and three alpha/graphics CRT displays and hardcopy units. A block diagram of the system is shown in Figure 6. This system has an extensive series of software routines available for complete data processing in the field.

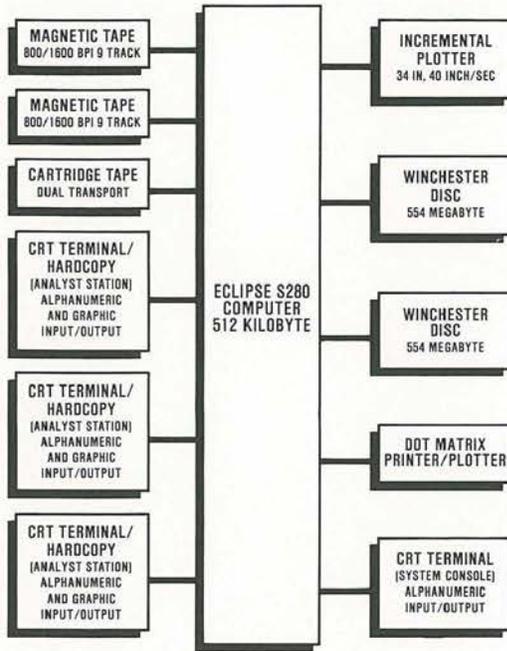


Figure 6. REDAC SYSTEM BLOCK DIAGRAM

Gamma spectral windows can be selected for any portion of the spectrum. Weighted combinations of such windows can be summed or subtracted and the results plotted as a function of time or distance. By the proper selection of windows and weighting factors, it is possible to extract the photopeak count rates for radioisotopes deposited on the terrain by human activity. Such isotopes disturb the spectral pattern of natural soil radioactivity. These photopeak count rates can then be converted to isotope concentrations or exposure rates. Spectral data can be summed over any portion of a survey flight line.

The spectral data can also be decompressed into a linear plot. The REDAC can display the spectral data or plot it on the incremental plotter for isotopic identification and documentation.

## 7.0 DATA ANALYSIS

The aerial radiation data consisted, in general, of contributions from the naturally-occurring radioelements, aircraft and detector background, and cosmic rays. For this survey, the major emphasis was placed on mapping the terrestrial gamma radiation in the surrounding area of the plant and locating and identifying any sources of man-made radiation, if they existed. Isopleth maps

were produced by processing the data using two different procedures: gross count procedure and man-made gross count extraction procedure.

### 7.1 Gross Count Procedure

The gross count method was based on the integral counting rate observed in that portion of the spectrum between 0.05 and 3.0 MeV. This count rate (measured at survey altitude) was converted to exposure rate (microrentgens/hour) at 1 meter above ground level by application of a predetermined conversion factor. This factor assumes a uniformly distributed source covering an area which is large compared with the field-of-view of the detector (approximately 100 to 200 meters at the survey altitude of 46 meters). The exposure rate values could be one or two orders of magnitude higher for a source localized in a small area.

### 7.2 Man-Made Gross Count Extraction Procedure

The man-made gross count (MMGC) extraction algorithm is designed to sense the presence of changes in spectral shape. Large changes in gross counting rates from natural radiation usually produce only small changes in spectral shape because the natural emitters change in more or less a constant ratio as the detector moves from one location to another. The algorithm senses counts in the lower portion of the spectrum in excess of those predicted on the premise that these counts bear a constant ratio to counts in the upper portion. Since the algorithm is designed to be most sensitive to man-made nuclides, the spectrum dividing line is chosen at an energy (1.4 MeV) above which most long-lived, man-made nuclides do not emit gamma rays. It is analytically expressed in MeV as:

$$MMGC = \sum_{E=0.05}^{1.39} (\text{counts})_E - K \sum_{E=1.40}^{3.00} (\text{counts})_E$$

The counts in the upper energy window (1.40 to 3.00 MeV) are multiplied by a constant K, so as to equal the counts in the lower energy window (0.05 to 1.39 MeV). Hence, the resultant MMGC is equal to zero for areas containing normal background radiation.

The man-made gross count algorithm is general and will respond to a wide range of nuclides. The result of using this generality is less than optimum sensitivity to specific nuclides. If the search nuclide is known, more sensitive algorithms can be devised.

## 8.0 GROUND-BASED MEASUREMENTS

Exposure rates were measured and soil samples obtained at four locations during the Browns Ferry survey to support the integrity of the aerial results. The locations for the ground-based measurements were chosen to be in areas which were assumed to exhibit only a normal background radiation level and away from any obvious anomalies. A Reuter-Stokes pressurized ionization chamber was used for each exposure measurement at a 1-meter height at the center of a 120-meter (396-foot) diameter measurement area. Soil samples, to a depth of 15.0 cm, were also obtained at the center and at four points of the compass on the circumference of the circular area. The soil samples were dried and their gamma activities measured using a germanium-based detector system located at EG&G/EM's Santa Barbara laboratory. Detailed descriptions of the systems and procedures used for soil sample data collection and analyses are outlined in separate publications.<sup>5,6,7</sup>

Additionally, six soil samples were collected along the shoreline of Wheeler Lake, upstream and downstream from the plant, in an effort to verify that no man-made isotopes were concentrated on the shoreline. A soil sample was also collected at one of the benchmark sites sampled during the May 1973 survey. Sample preparations and analyses were the same as previously described.

## 9.0 DISCUSSION OF RESULTS

### 9.1 Terrestrial Gamma Exposure Rate Contour Map

The principal result obtained from the gamma survey of the Browns Ferry Nuclear Power Station is the terrestrial gamma exposure rate contour map (Figure 7) of the 97-square-kilometer (37-square-mile) area surrounding the plant. The map represents the measured terrestrial gamma exposure rate plus an estimated cosmic component

(3.8  $\mu\text{R/h}$ ) at 1 meter above the earth's surface. The highly variable airborne radon daughter component is not included.

The exposures at 1 meter above the ground, shown on the map in Figure 7, range from a low of less than 4.75  $\mu\text{R/h}$  over Wheeler Lake up to 7.5  $\mu\text{R/h}$  along the shoreline. The general terrestrial gamma background ranged from approximately 11 to 18  $\mu\text{R/h}$  north and east of Wheeler Lake, while the exposure rates south and west of the lake ranged from approximately 9 to 11  $\mu\text{R/h}$ . Note that these exposure values include a cosmic contribution of 3.8  $\mu\text{R/h}$ . While the cosmic component is quite uniform, the varying terrestrial components from K-40, the U-238 series, and the Th-232 series cause most of the changes throughout the survey area.

Two anomalous areas of exposure rate can be observed over the facility on the terrestrial gamma exposure rate contour map in Figure 7. These areas are discussed in Section 9.3.

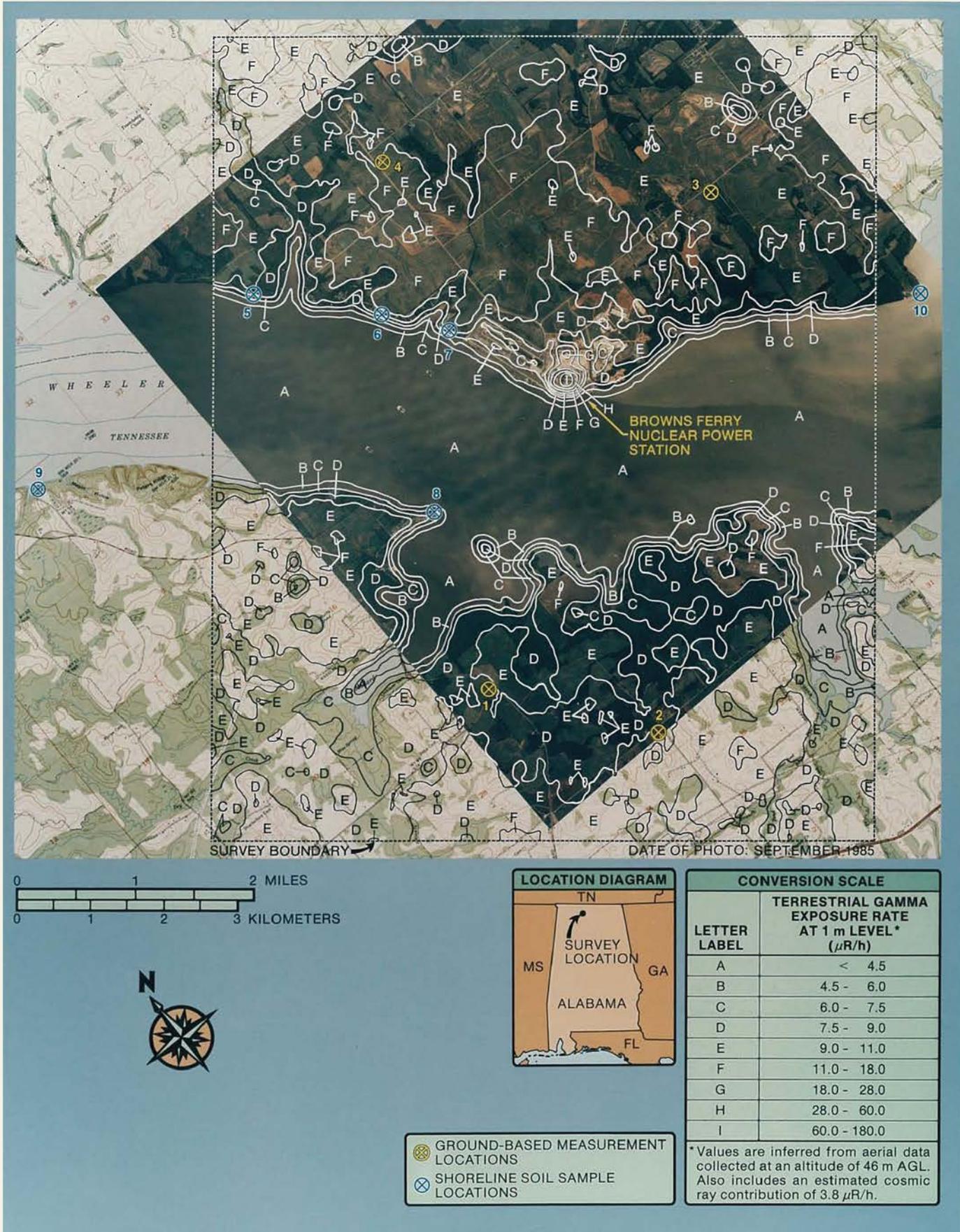
The background gamma energy spectra shown in Figures 8 and 9 illustrate that only natural radioisotopes (e.g., K-40, Bi-214, Tl-208) exist in the area outside the plant boundary, although in different quantities. Figure 8, which represents the area south and west of the lake, exhibits less natural radioactivity than does Figure 9, which represents the area north and east of the lake.

### 9.2 Exposure Rates From Airborne Radon Daughters

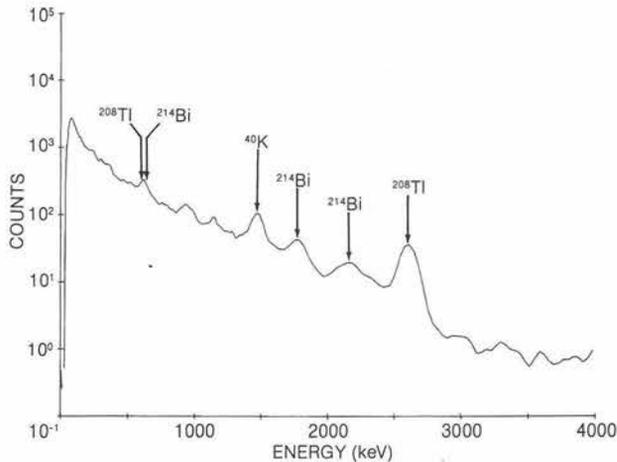
The computed background gamma count rates (cosmic, aircraft, and radon contributions) varied over a range from 640 to 1710 counts per second (cps) during the survey period. Since the aircraft and cosmic fractions of background are about 500 cps, the radon contribution ranges from 140 to 1210 cps at the 46-meter survey altitude. These count rates imply exposures from airborne radon at the ground level of from less than 0.1 to 0.8  $\mu\text{R/h}$ . The uncertainty is about 50 percent of these values.

### 9.3 Man-Made Gross Count Contour Map

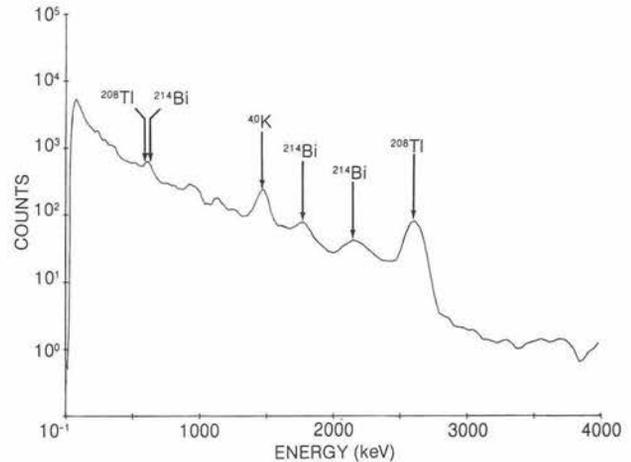
The MMGC algorithm (discussed in Section 7.2) was used to search the Browns Ferry aerial survey data for man-made gamma emitters. The results



**Figure 7. TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1985 OVER THE BROWNS FERRY NUCLEAR POWER STATION AND SURROUNDING AREA**



**Figure 8.** GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE NATURAL BACKGROUND IN THE SURVEY AREA SOUTH AND WEST OF WHEELER LAKE



**Figure 9.** GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE NATURAL BACKGROUND IN THE SURVEY AREA NORTH AND EAST OF WHEELER LAKE

of this analysis are represented in Figure 10 in the form of contours of man-made radiation. The data in Figure 10 are the net gross counts above background in the window 0.05 to 1.39 MeV. As indicated, three areas of man-made radiation are apparent in the data. Anomalous areas were also apparent in the terrestrial gamma contour map (Figure 7). Area 1 was an expected location and falls directly over the main units of the plant. Figure 11 is a net (source minus background) spectrum taken from Area 1; Co-60 is the predominant isotope. Area 2 is northeast (plant north) of the main units at Browns Ferry inside the security (protected area) fence. It is beyond the transformer field in what appears to be a median area of grass and bare soil. This anomalous area was unexpected and through conversations with plant personnel it was determined that this source of man-made radiation was associated with a van parked in the area that contained two boxes of radiological waste being held and prepared for shipment. One of the items was a reactor water cleanup pump impeller. The van and contents were shipped off plant in November 1985.<sup>8</sup> Figure 12 is a net spectrum taken from Area 2; Co-60 is the predominant isotope. Area 3, east of Area 2 but still within the plant boundary, is the temporary low-level radiological waste storage site. Figure 13 is a net spectrum taken from that area and, again, Co-60 is the predominant isotope. This area of man-made radiation was not evident in the terrestrial gamma exposure rate contour map (Figure 7), thus demonstrating the sensitivity of the MMGC algorithm.

#### 9.4 Ground-Based Measurements

Ion chamber measurements and soil samples were collected at four sites within the survey boundaries during the aerial survey. The site locations (numbers 1 through 4) are labeled in Figure 7. The soil samples were dried and counted on a calibrated gamma spectrometer in the laboratory. The soil analysis exposure rates were computed from the primary isotopic concentrations in the soil samples and included the effect of soil moisture. The calculated soil exposure rate values are compared with the ion chamber measurements and the aerial measurements in Table 2. These exposure values represent the terrestrial plus the cosmic components only.

The isotopic and ion chamber measurements generally agree with the aerial measurement interval at each site. There are several contributors to differences among the measurement methods:

1. The aerial data were not taken at exactly the same places and times as the ground data.
2. Each one-second data point obtained with the airborne system covers an area several thousand times as large as a measurement made at 1 meter, such as with a survey meter, and several million times as large as a typical soil sample.
3. Since only a limited number of soil samples were taken, statistical deviations are significant.
4. The ground cover reduces the computed isotopic exposure by as much as 5 percent.



**Figure 10.** MAN-MADE RADIATION GROSS COUNT CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1985 OVER THE BROWNS FERRY NUCLEAR POWER STATION AND SURROUNDING AREA

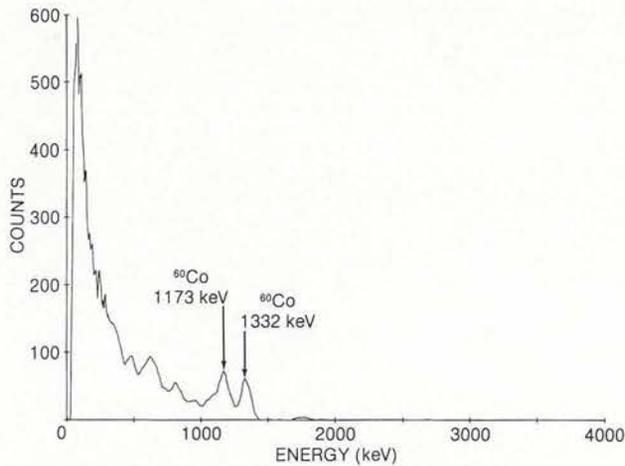


Figure 11. NET GAMMA RAY SPECTRUM OF AREA 1

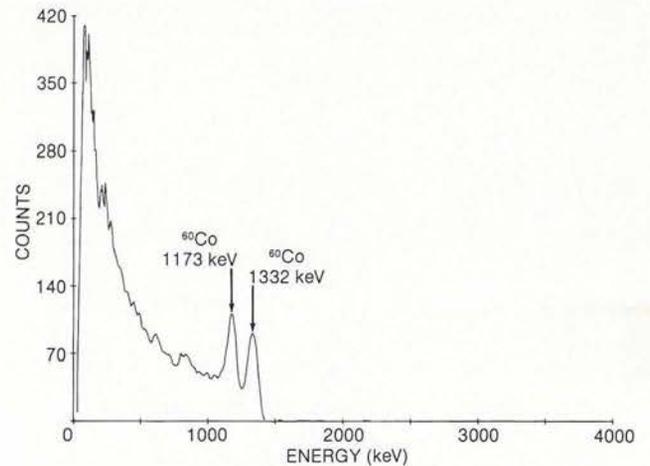


Figure 12. NET GAMMA RAY SPECTRUM OF AREA 2

Table 3 presents the results of the soil sample analyses.

The locations of the six samples collected along the shoreline of Wheeler Lake (locations 5 through 10) are indicated in Figure 7. The data from the soil sample analyses are presented in Table 4. No attempt is made to correlate this data with the aerial data due to the fact that these samples were

collected on the shoreline and the aerial data from those areas have water (Wheeler Lake) averaged into a large portion of the detector's field-of-view and do not represent true terrestrial exposure rates. The analyses do indicate that there are no high concentrations of man-made isotopes present. There are, however, varying concentrations of naturally-occurring elements that can be accounted for by runoff and deposition along the shoreline.

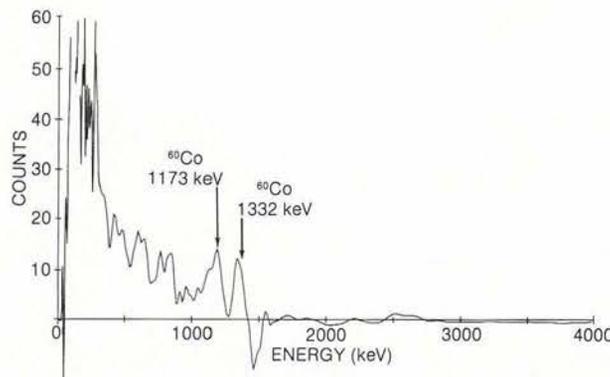


Figure 13. NET GAMMA RAY SPECTRUM OF AREA 3

Sample Location <sup>1</sup>	Exposure Rate ( $\mu\text{R/h}$ at 1 Meter Above Ground Level)		
	Soil Analysis <sup>2</sup>	Ion Chamber <sup>3</sup>	Inferred Aerial Data <sup>2</sup>
1	$9.0 \pm 0.4$	$8.5 \pm 0.5$	7.5 - 9.0
2	$8.2 \pm 1.0$	$7.8 \pm 0.5$	7.5 - 9.0
3	$10.5 \pm 0.6$	$9.9 \pm 0.5$	9.0 - 11.0
4	$10.1 \pm 1$	( <sup>4</sup> )	11.0 - 18.0

<sup>1</sup> See site locations in Figure 7.

<sup>2</sup> Includes a cosmic contribution of  $3.8 \mu\text{R/h}$ .

<sup>3</sup> Reuter-Stokes Model RSS-111, Serial No. Z528.

<sup>4</sup> No ion chamber data available.

Site <sup>1</sup>	Soil Sample Analysis (Average Values)				
	Soil Moisture (%)	U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)
1	$9.1 \pm 0.9$	$3.1 \pm 0.1$	$9.9 \pm 0.4$	$0.08 \pm 0.05$	$3.6 \pm 0.7$
2	$10.0 \pm 3.0$	$2.7 \pm 0.4$	$7.9 \pm 1.2$	$0.35 \pm 0.13$	$3.8 \pm 0.8$
3	$12.0 \pm 0.6$	$4.1 \pm 0.3$	$12.4 \pm 0.9$	$0.43 \pm 0.04$	$5.7 \pm 0.5$
4	$10.0 \pm 1.0$	$4.1 \pm 0.3$	$13.0 \pm 2.0$	$0.15 \pm 0.13$	$4.3 \pm 0.6$

<sup>1</sup> See site locations in Figure 7.

Site <sup>1</sup>	Soil Sample Analysis (Average Values)				
	Soil Moisture (%)	U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)
5	7.2	$4.1 \pm 0.2$	$9.8 \pm 0.5$	$0.26 \pm 0.02$	$6.0 \pm 0.5$
6	18.8	$4.8 \pm 0.2$	$15.6 \pm 0.8$	$0.015 \pm 0.005$	$4.4 \pm 0.4$
7	12.8	$5.2 \pm 0.2$	$20.0 \pm 1.0$	$0.051 \pm 0.006$	$5.8 \pm 0.4$
8	14	$1.6 \pm 0.07$	$2.9 \pm 0.2$	( <sup>2</sup> )	$0.3 \pm 0.1$
9	19	$1.1 \pm 0.07$	$2.5 \pm 0.2$	$0.015 \pm 0.003$	$1.0 \pm 0.2$
10	4.4	$0.65 \pm 0.05$	$1.3 \pm 0.1$	$0.008 \pm 0.003$	$0.36 \pm 0.07$

<sup>1</sup> See site locations in Figure 7.

<sup>2</sup> No output value.

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