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October 31, 2002

IT-MC-CK10-0264
Project No. 796887

Mr. Lee Coker
U.S. Army Corps of Engineers, Mobile District
Attn: EN-GE/Lee Coker
109 St. Joseph Street
Mobile, Alabama 36602

Contract: **Contract No. DACA21-96-D-0018/CK10**
Fort McClellan, Alabama

Subject: **Draft Airborne Radiological Survey – Main Post and Pelham Range, Walkover Radiological Survey at Rideout Field and Anomaly Surveys on Main Post and Pelham Range, and Groundwater Investigation – Burial Mound at Rideout Field**

Dear Mr. Coker:

I am enclosing one copy of the subject document. This document presents the results of airborne and walkover radiological surveys conducted at the Main Post and Pelham Range as well as the results of a groundwater investigation conducted at the Burial Mound at Rideout Field – Pelham Range. These investigations are summarized in the following paragraphs.

Summary of Radiological Investigations at Pelham Range and Main Post, Fort McClellan

In October 2001, IT conducted an airborne radiological survey on the Main Post and Pelham Range and subsequently investigated select anomalies identified in the airborne data in an effort to locate and characterize areas of elevated radioactivity at Fort McClellan. Additionally, IT collected groundwater samples at the Burial Mound at Rideout Field to characterize site geology and hydrogeology and to determine if man-made radionuclides have impacted groundwater. The radiological investigations were conducted under contract to the U.S. Army Corps of Engineers in accordance with Contract Number DACA21-96-D-0018, Task Order CK10.

Airborne Radiological Survey – Main Post and Pelham Range

IT contracted Fugro Airborne Surveys to perform a helicopter-borne gamma-ray spectrometer survey to identify cesium-137 (Cs-137) and cobalt-60 (Co-60) sources within an approximately 470-acre area on the Main Post and a 4,900-acre area on Pelham Range. The instrumentation included a sodium iodide gamma-ray detector to measure the radioactive properties of the areas, a global positioning system to provide accurate navigation information, altimeters to monitor flying heights, and temperature and pressure sensors. System source checks and reference line

data were collected before and after each survey flight.

Maps of the Cs-137, Co-60, total exposure and low-energy to high-energy ratios were prepared. These parameters were used to prioritize anomalous areas for follow-up ground surveys by providing information for the differentiation between naturally occurring and man-made elevated responses.

The airborne survey positively identified three Cs-137 and Co-60 sources, including one on the Main Post (Anomaly M1) and two on Pelham Range (Anomalies P1 and P2). The airborne survey also identified four other anomalies for follow-up evaluation (one on the Main Post [Anomaly M2] and three on Pelham Range [Anomalies P3 through P5]). Anomaly M1 on the Main Post was located near the community center and M2 on Iron Mountain. Anomaly M2 was selected based on historical land use. Anomalies P1 and P2 on Pelham Range were coincident with ATG's radiological waste removal location at Rideout Field. The waste removal activities were conducted concurrent with the airborne survey. The other anomalies at Pelham Range were selected based on historical land use and were near trails used to transport supplies and equipment during the same period as the radiological training. The results of the airborne radiological survey are summarized in a report included as Attachment A.

Walkover Radiological Survey at Rideout Field and Anomaly Surveys on Main Post and Pelham Range

Anomalies P1 and P2 identified during the airborne survey were selected for further evaluation using a walkover radiological survey. In the area of ATG's removal activities and closeout survey at Rideout Field, a small survey grid was established to investigate the anomalies. The grid survey was conducted in August 2002 using a Ludlum 2221 scaler/rate meter coupled with a Ludlum 44-10 2x2 sodium iodide detector sensitive to gamma radiation. Source checks were performed regularly. A global positioning system was used for survey control.

The removal action at Rideout Field that was being conducted by ATG at the same time as the airborne survey was completed prior to performing the follow-up ground survey. ATG also performed a final status survey providing documentation for release of the area from radiological control. To confirm that these activities were the source of the airborne anomalies, data collection grids were established encompassing airborne anomalies P1 and P2 as well as a small portion of the ATG final status survey area. The total count data acquired within ATG's survey area were assumed to be within closeout specifications and these data were compared to the newly acquired ground data.

The results of the gridded survey were within the expected range for the soil type at Pelham Range. These results were compared to the reference grids at both Rideout Field and the Main Post and were within acceptable closeout parameters as established by the ATG report.

To further characterize the other anomalies (M1, M2, and P3 – P5 from the airborne data and three additional anomalies [P6-P8] selected by IT based on slightly elevated airborne readings and historical land use), the Ludlum system was used to identify the gamma-ray peak location and an Exploranium GR-135 Identifier portable gamma spectrometer was used to identify the

gamma-emitting radioactive materials. The GR-135 contains a sodium iodide detector and software referencing a gamma-ray library. The instrument was stabilized and calibrated prior to and after each survey day.

The Pelham Range anomalies not associated with ATG's removal action (i.e., Anomalies P3 through P8) and Main Post Anomaly M2 were caused by naturally occurring radionuclides (e.g., potassium and uranium series radionuclides). IT investigated Main Post Anomaly M1 in February 2002 using a Ludlum 2221/44-10 sodium iodide detector and a Ludlum Model 19 microR meter. The ground survey of Anomaly M-1 confirmed the presence of Cs-137 identified during the airborne survey.

The total count data from the walkover survey at Rideout Field and the reference grids and graphical representation of the radiological spectra are presented in the report, included as Attachment B.

Groundwater Investigation – Burial Mound at Rideout Field

The work plan for the groundwater investigation at the Burial Mound at Rideout Field proposed installation of four monitoring wells in the residuum groundwater zone. However, groundwater was not encountered in residuum at three well locations near the Burial Mound. Therefore, three additional bedrock wells were installed to provide site-specific geological and hydrogeological data and to collect groundwater samples for laboratory analysis.

The groundwater samples were analyzed for gamma-emitting radionuclides (including Cs-137 and Co-60) and strontium-90. However, none of these radionuclides were detected in the samples. Only two naturally occurring radionuclides (bismuth-214 and lead-214) were detected in one of the samples. The detected radionuclide activities were well below the DOE guideline concentrations. The results of the groundwater investigation at the Burial Mound at Rideout Field are summarized in a report included as Attachment C.

Please review the subject document and provide either a letter of concurrence or written comments with suggested changes. At your request, I have distributed copies of this document as indicated below. If you have questions, or need further information, please contact me at (770) 663-1429 or Steve Moran at (865) 694-7361.

Sincerely,

Stephen H. Moran for
Jeanne A. Yacoub, P.E.
Project Manager

Attachments

Distribution: Lisa Holstein, FTMC (3 copies)
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Airborne Radiological Survey - Main Post and Pelham Range

Walkover Radiological Survey at Rideout Field and Anomaly Surveys on Main Post and Pelham Range

Groundwater Investigation - Burial Mound at Rideout Field

Fort McClellan
Calhoun County, Alabama

October 2002

Task Order CK10
Contract Number DACA21-96-D-0018

IT CORPORATION
A Member of The IT Group

US Army Corps of Engineers
Mobile District

Attachment A
Airborne Radiological Survey

Walkover Radiological Survey Report

Fort McClellan
Calhoun County, Alabama

Prepared for:

U.S. Army Corps of Engineers, Mobile District
109 St. Joseph Street
Mobile, Alabama 36602

Prepared by:

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Task Order CK10
Contract No. DACA21-96-D-0018
IT Project No. 796887

October 2002

Revision 0

FUGRO AIRBORNE SURVEYS

FUGRO

Report # 6014

AIRBORNE GAMMA-RAY SPECTROMETER SURVEY
FOR
IT CORPORATION
FT. MCCLELLAN, MAIN POST AND
PELHAM RANGE,
CALHOUN COUNTY, ALABAMA

1 October, 2002

Fugro Airborne Surveys, 2270 Argentia Road, Unit 2, Mississauga, Ontario, Canada. L5N 6A5
Phone: 1 905 812 0212, Fax: 1 905 812 1504

SUMMARY

A helicopter-borne gamma-ray spectrometer survey was carried out under contract to IT Corporation on two sites at the former U.S. Army installation, Fort McClellan, Calhoun County, Alabama by Fugro Airborne Surveys.

The purpose of the survey was to identify any detectable radiological sources, to determine the sources (cesium [^{137}Cs] or cobalt [^{60}Co]), and to define an anomalous area small enough to locate the radioactive sources on the ground. A 2048 cubic inch (cu in), sodium iodide (NaI) gamma-ray detector package attached to a 512 channel spectral analyzer, mounted in a twin engine helicopter was used to measure the radioactive properties of the survey areas. A Global Positioning System (GPS) electronic navigation system ensured accurate positioning of the data with respect to the base maps. Ancillary equipment included a video recorder pointed at the ground below the aircraft, laser altimeter, radar altimeter and temperature and pressure sensors.

The data were processed to produce ^{137}Cs and ^{60}Co, Total Exposure Rate and Low-energy to High-energy Ratio maps. Concentrations for the natural radiation windows; potassium (^{40}K), uranium (^{214}Bi) and thorium (^{208}Tl) were also produced and delivered with the digital data. These parameters were used to discriminate natural sources producing exposure rate anomalies from man-made sources. The natural radiation parameters could also be used to identify naturally occurring radioactive material (NORM) from industrial uses. Anomalous areas identified on the ratio and total exposure rate maps were viewed in the 512 channel spectrum to identify the isotopes producing anomalous radiation.

^{137}Cs and ^{60}Co anomalies were detected in the vicinity of Rideout field. This site was being excavated for the removal of contaminated material at the time of the airborne survey. One area with ^{137}Cs counts above background was identified in the Main Post Area. Other weakly elevated areas relative to local background were identified in other parts of the survey area. These will warrant follow-up if they correspond to likely areas of contamination based on historical land uses.

Exposure rates measured from the airborne survey will differ from measurements made by handheld spectrometers on the ground. Airborne measurements will vary from ground measurements with similar detectors due to the fact that the airborne measurement averages the contribution of gamma-rays from a much larger area. The geometry of the source, inhomogeneities in the sampled area and attenuation due to vegetation will also affect the airborne measurements. The results reflected in this report are expressed as gamma-ray counts where possible to avoid introducing inaccurate analysis due to the foregoing factors and in order to avoid assuming a particular source geometry. Geometric factors may cause an overestimate or underestimate of the ground concentration by one to two orders of magnitude.

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1. INTRODUCTION

During the 1960's radiological training was conducted at Ft. McClellan using ^{137}Cs and ^{60}Co sources. There is no record of the disposition of these sources. The purpose of the airborne gamma-ray spectrometer survey (AGS) was to identify any detectable radiological sources, what the sources are (^{137}Cs or ^{60}Co), and to define an anomalous area small enough to locate the sources on the ground.

A helicopter-borne gamma-ray spectrometer flyover was designed for this purpose using 2048 cu in of NaI detector, flown at a 33 ft. terrain clearance and a 33 ft. line spacing. The spectrometer was configured to record a 512 channel spectrum encompassing the gamma-ray spectrum from natural geological sources and the man-made isotopes of interest.

The original activity of the sources was between 2 and 4 Curies (Ci). The sources were manufactured in 1952. The current activity of an intact ^{60}Co source would be 10 to 20 mCi and an intact cesium source today would be 0.8 to 1.6 Ci. If located on surface, an amount corresponding to much less than one percent of the remaining source could be detected at the 33-ft. intended flying height.

Much of the Pelham Range and Main Post areas are forested. Tree heights are estimated at 70 to 100 feet. The contribution of the biomass may add an additional attenuation to gamma radiation equivalent to approximately 50 feet of flying height. Nevertheless, isolated pieces of the original sources at surface would be detectable at well over 150 feet in the air. Due to the strength of these sources, flying height and tree cover do not pose as much of a problem as burial. Soil and water strongly attenuate gamma-rays. Intact sources could be completely masked by burial at more than 18 inches. Tests with the type of equipment being used at Fort McClellan have shown that a 50 mCi source at 18 inches depth is detectable at 33 ft. flying heights with up to a 49 ft. lateral offset.

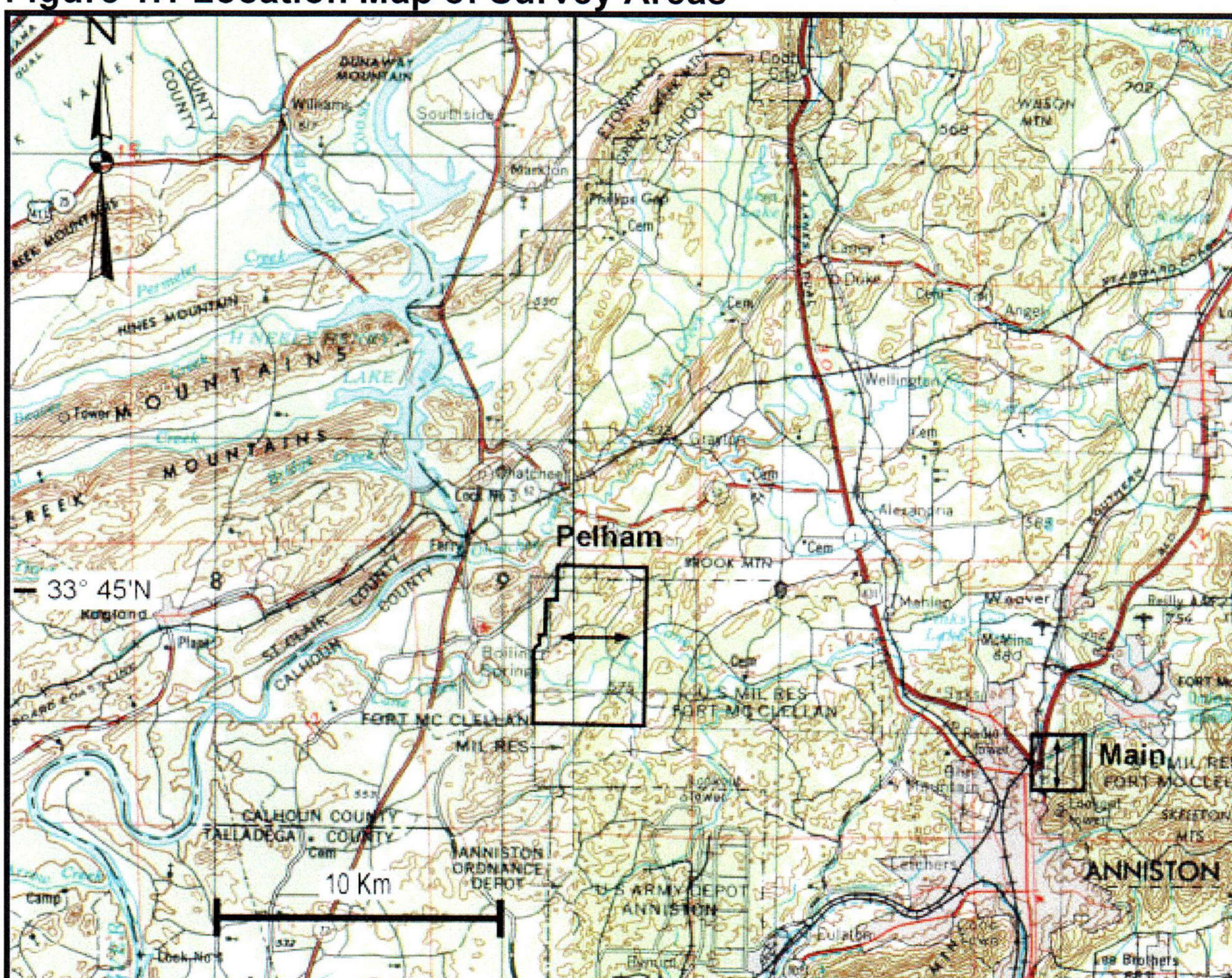
Widespread contamination relative to the footprint of the system, 8 inches thick, of less than .33 pCi/g is thought to be a realistic minimum detection limit for ^{137}Cs. At 40 nautical miles per hour (kts), the footprint of the system is an ellipse 60 ft by 125 ft at 30 ft flying height, and 200 ft by 265 ft at 100 ft flying height. Smaller areas with higher activities, such as could be caused by widespread pieces of broken sources, could realistically be detected. The detection limits will vary for other isotopes. These detection levels are based on theoretical attenuation values for soil density, biomass and atmospheric conditions. High levels of moisture in the soil could adversely affect these estimates.

Two areas within Ft. McClellan were covered by the AGS survey. Area one comprised 470 acres of the Main Post and the second area comprised 4,900 acres in the northwest portion of the Pelham Range (see Figure 1.1). The flyover began November 15, 2000 and was stopped without completion on December 19, 2000. Cold wet weather, wind and an aircraft engine failure combined to prevent completion of data acquisition in 2000. The

survey was re-started on October 5, 2001 and the flyover of both areas was completed on October 22.

The data acquired in November and December of 2000 were completely replaced by data acquired in the second mobilization in October 2001. Although the data acquired in the first mobilization were within specifications, surveying conditions in October of 2001 were drier and less windy than in the first mobilization. This was thought to result in more sensitivity in the data and allow better flight path coverage. All of the equipment specifications, personnel and results contained in this report relate to the second mobilization.

Figure 1.1 Location Map of Survey Areas



Pelham Range is hilly and mostly tree and bush covered except for approximately 900 acres in the Battle Drill Area. Figure 1.2 shows the battle Drill Area looking east with tree

C01

covered areas in the background. In some areas steep ridges posed a challenge to the pilot to maintain a stable flying height. Tree heights are approximately 70 to 100 ft in the Pelham Range area.

Figure 1.2 Pelham Range, Cleared Area

The Main Post survey area is almost entirely tree covered with up to 100 ft high trees.

The helicopter was based at the Anniston Municipal Airport. Anniston Executive Aviation, Inc. provided fuel and hangar space. The crew of three, consisting of the Pilot, Equipment Operator and AGS Data Specialist, stayed in Anniston, a 5 minutes drive from the airport.

The survey employed a 512-channel spectrometer with 2048 cu in of NaI crystal, radar and barometric altimeters, video camera, analog and digital recorders, and an electronic navigation system. The instrumentation was installed in a Eurocopter Twinstar AS355F1 helicopter, which was provided by Four Seasons Aviation Ltd. of Toronto, Canada. One spectrometer crystal package and the electronics were housed within the helicopter and a second spectrometer crystal package was located in a cargo basket on the passenger side of the aircraft (see Figure 1.3). A laser altimeter and a radar altimeter were attached to the helicopter landing skids using a transverse mounting bar.

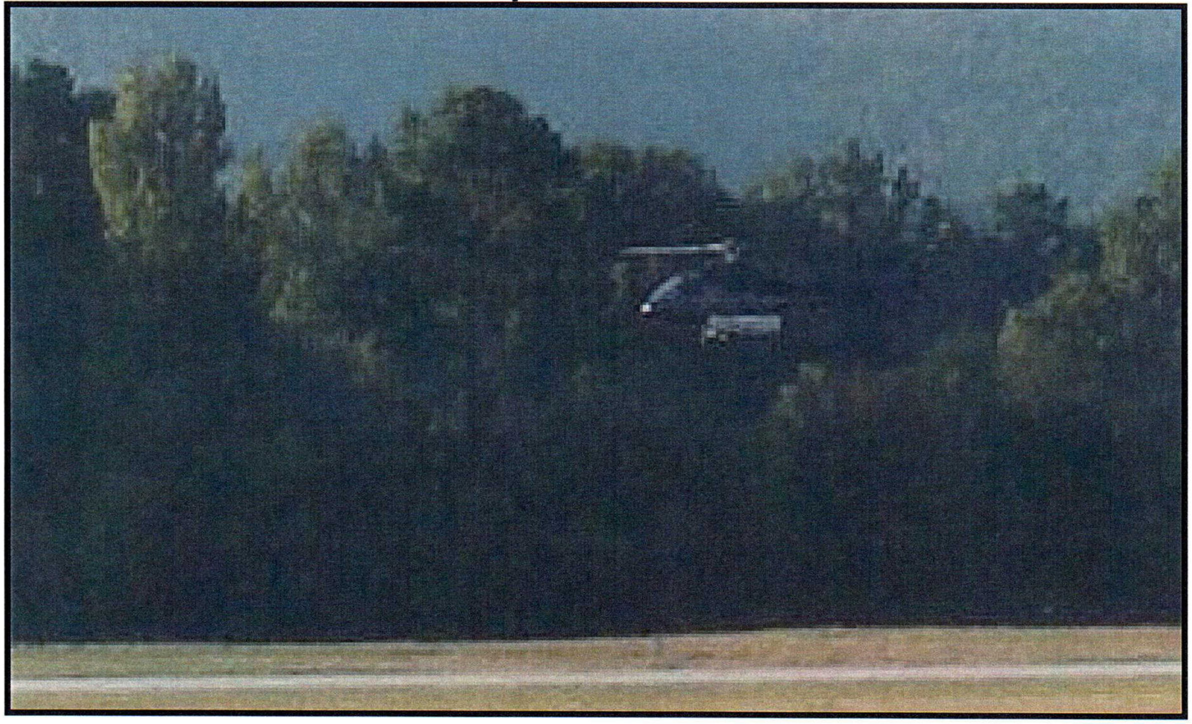
Figure 1.3 Spectrometer Installation in Helicopter

Testing and daily calibration of the equipment was performed at Anniston airport (Figure 1.4). Flight lines were flown in an east-west direction on Pelham Range and north-south on Main Post with a line separation of 33 feet. The helicopter flew at an average airspeed of 45 kts. The intended terrain clearance for the helicopter and gamma-ray spectrometer was 33 feet, however tree cover prevented this from being achieved in most of the area, and steep terrain was a limiting factor in some of the cleared areas. The pilot's judgement and Federal Aviation Administration regulations govern all matters regarding the safe operation of the aircraft including terrain clearance, speed, proximity to obstacles and proximity to persons and occupied buildings.

All flight operations within the Pelham Range Area were coordinated with the Pelham Range Control Office. Some restrictions were encountered due to live fire exercises utilizing the Large Impact Area, which was within the area being surveyed. The flyover was conducted from 0700 to 1700 hours 7 days a week. Flying within the Main Post Area was coordinated with the Transition Force at the Main Post. Flying of the Main Post Area was limited to Fridays and weekends to avoid interference with UXO removal and destruction operations. Anniston and Oxford Police Departments, and the Local Sheriff's office were notified in advance of the helicopter activity.

Final data processing and analysis was completed in Fugro Airborne Surveys' center of excellence for helicopter surveys in Toronto, Ontario. The raw 512 channel data were processed to produce ^{137}Cs and ^{60}Co counts, Total Exposure Rate and Low-energy to High-energy ratio maps. Concentrations for the natural radiation windows; potassium, uranium and thorium were also produced and used in the analysis but maps were not required. Anomalous areas identified on the ratio maps were viewed as the 512 channel spectrum to identify the isotopes producing anomalous radiation.

Figure 1.4 Fugro Airborne Gamma-ray Spectrometer System on Test Line at Anniston Airport



2. SURVEY EQUIPMENT

This section provides a brief description of the instruments used to acquire the survey data and the calibration procedures employed.

Spectrometer

Manufacturer: Exploranium
Model: GR-820
Type: Multichannel, Potassium stabilized
Accuracy: 1 count per second (cps).
Update: 1 integrated sample per second (S).

The GR-820 Airborne Spectrometer was equipped with eight downward looking crystals (2048 cu in). The downward crystals record the radiometric spectrum from 410 kilo electron volts (keV) to 3000 keV over 512 discrete energy windows, as well as a cosmic ray channel which detects photons with energy levels from above 3000 keV. From these 512 channels, the standard Total Count, potassium, uranium and thorium channels are extracted along with the specialized cobalt, cesium and low-energy channels which are used in locating man-made radioactive sources (see Table 2.1).

Table 2.1 Data Recording of Windows

Element	Window (keV)
Potassium	1370 - 1570
Uranium	1660 - 1860
Thorium	2410 - 2810
Total Count	400 - 2810
Cesium-137	600 - 730
Low Energy	400 - 1370
Cobalt-60	1070 - 1410
Cosmic	3000 - >6000

The shock-protected NaI(Tl) crystal package is unheated, and is automatically stabilized with respect to the potassium peak. The GR-820 provides raw or Compton stripped data that has been automatically corrected for gain, base level, analog to digital offset and dead-time.

The system was calibrated before and after each flight using three accurately positioned hand-held sources. Additionally, fixed-site test line flights were carried out at Anniston-Oxford Municipal airport to determine if there were any differences in background due to moisture and to monitor equipment function.

The 512 channel configuration represents an increase over the 256 channel standard configuration for the Exploranium GR820. The increase in channels was thought to improve the resolution for detection of ^{137}Cs and ^{60}Co. The disadvantage of using the 512 channel configuration is that an upward crystal cannot be used to monitor radon due to limitations in the data acquisition system. This can be overcome if regular flights over a suitably large body of water can be arranged to monitor radon fluctuations. Unfortunately a suitable body of water was not available. The effects of radon were noticeable in the U window (^{214}Bi peak at 1764 kev) and in the ^{137}Cs window (peak at 662 kev adjacent to ^{214}Bi peak at 609 keV) as line to line amplitude variations. These along-line stripes were not easily confused with point source anomalies and were removed with background level shifts and microlevelling. This remedy did not adversely affect the final results for the cobalt and cesium point source detection.

Altimeters

Manufacturer:	Honeywell/Sperry
Model:	AA 330
Type:	Short pulse modulation, 4.3 GigaHertz
Sensitivity:	1 foot

Manufacturer:	Optech
Model:	G150
Type:	laser rangefinder
Accuracy:	+/- 4 inches

The radar altimeters measure the vertical distance between the helicopter and the ground. This information is used to correct the raw counts for altitude.

Barometric Pressure and Temperature Sensors

Model:	DIGHEM D1300	
Type:	Motorola MPX4115AP analog pressure sensor	
	AD592AN high-impedance remote temperature sensors	
Sensitivity:	Pressure:	150 milliVolts(mV)/kilo Pascals
	Temperature:	100 mV/°Celcius (C) or 10 mV/°C (selectable)
Sample rate:	10 per second	

The D1300 circuit is used in conjunction with one barometric sensor and up to three temperature sensors. Two sensors (barometer and temperature) are installed in the console in the aircraft to monitor pressure and internal operating temperatures.

Analog Recorder

Manufacturer: RMS Instruments
Type: DGR33 dot-matrix graphics recorder
Resolution: 4x4 dots/millimeter (mm)
Speed: 1.5 mm/S

The analog profiles are recorded on chart paper in the aircraft during the survey. Table 2.2 lists the geophysical data channels and the vertical scale of each profile and Figure 2.1 shows an example of an analog profile.

Table 2.2 The Analog Profiles

Channel Name	Parameter	Scale units/mm
ALTR	Altimeter (radar)	9.8 feet
ALTL	Altimeter (laser)	9.8 feet
GPSZ	GPS height above the ellipsoid	9.8 feet
TC	Total counts	100 cps
C137	Cesium	10 cps
CO60	Cobalt	10 cps
LOWE	400 keV to 1370 keV	10 cps
1KPA	Altimeter (barometric)	30 m
2TDC	Internal (console) temperature	1° C
OATC	External temperature	1° C
BAT+	Aircraft battery monitor	100 Volts

Digital Data Acquisition System

Manufacturer: RMS Instruments
Model: DGR 33
Recorder: Flashcard

The data are stored on a Flashcard and are downloaded to the field workstation PC at the survey base for verification, backup and preparation of in-field products.

Figure 2.1 Analog Profile

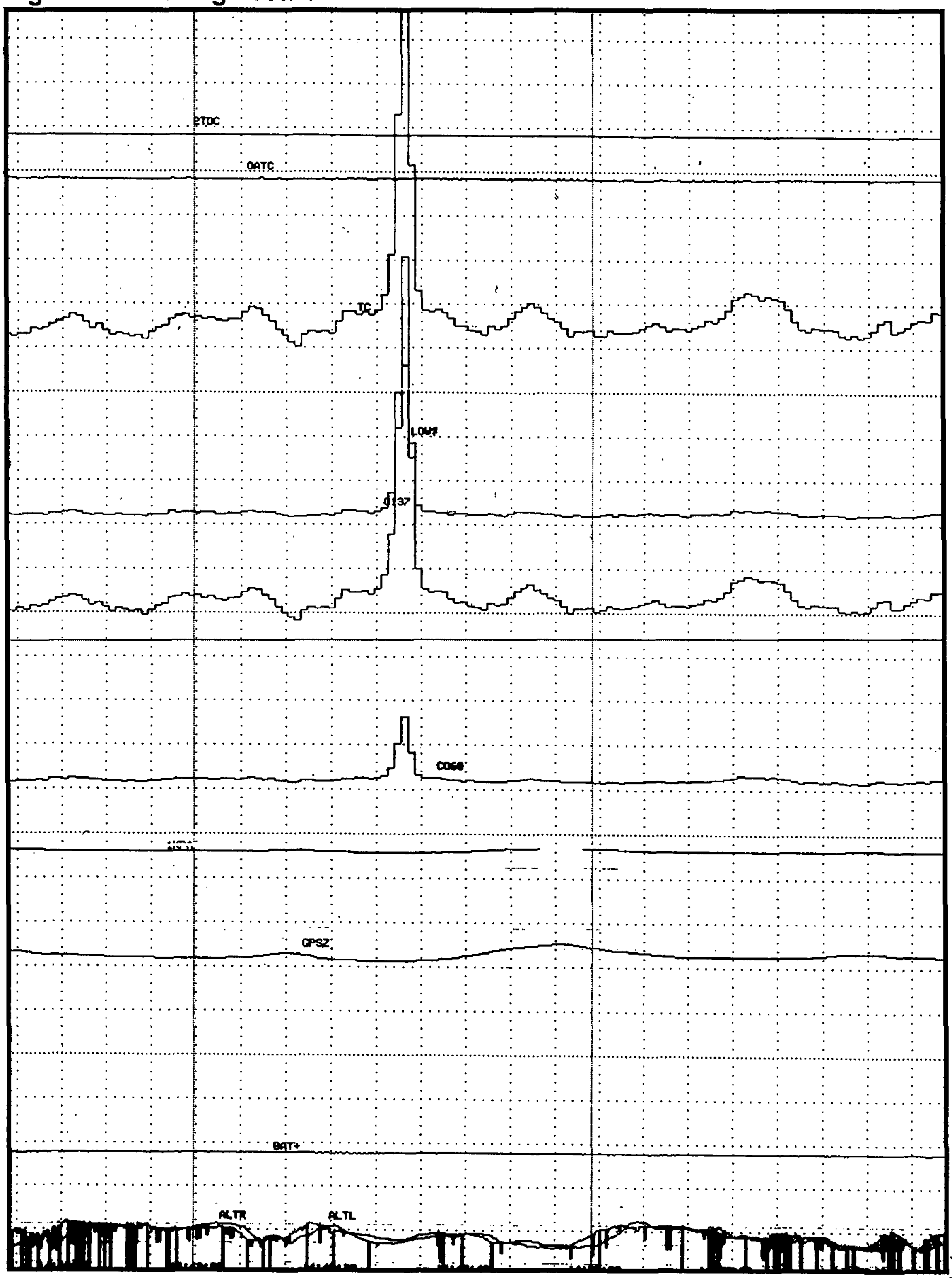


Figure 2.1 Analog Profile

Video Flight Path Recording System

Type:	Panasonic VHS Color Video Camera (NTSC)
Model:	AG 2400/WVCD132

Fiducial numbers are recorded continuously and are displayed on the margin of each image. This procedure ensures accurate correlation of analog and digital data with respect to visible features on the ground.

Navigation (Global Positioning System)

Airborne Receiver

Model:	Ashtech Glonass GG24
Type:	SPS (L1 band), 24-channel, C/A code at 1575.42 MegaHertz, S code at 0.5625 MHz, Real-time differential.
Sensitivity:	-132 decibel meter (dBm), 0.5 second update
Accuracy:	Manufacturer's stated accuracy is better than 32 feet real-time

Base Station

Model:	Marconi Allstar OEM, CMT-1200
Type:	Code and carrier tracking of L1 band, 12-channel, C/A code at 1575.42 MHz
Sensitivity:	-90 dBm, 1.0 second update
Accuracy:	Manufacturer's stated accuracy for differential corrected GPS is 2 metres

The Ashtech GG24 is a line of sight, satellite navigation system that utilizes time-coded signals from at least four of forty-eight available satellites. Both Russian GLONASS and American NAVSTAR satellite constellations are used to calculate the position and to provide real time guidance to the helicopter. The Ashtech system can be combined with a RACAL or similar GPS receiver which further improves the accuracy of the flying and subsequent flight path recovery to better than 5 metres. The differential corrections, which are obtained from a network of virtual reference stations, are transmitted to the helicopter via a spot-beam satellite. This eliminates the need for a local GPS base station. However, the Marconi Allstar OEM (CMT-1200) was used as a backup to provide post-survey differential corrections.

The Marconi Allstar OEM (CMT-1200) is operated as a base station and utilizes time-coded signals from at least four of the twenty-four NAVSTAR satellites. The base station

raw XYZ data are recorded, thereby permitting post-survey processing for theoretical accuracies of better than 5 metres.

The Ashtech receiver is coupled with a PNAV navigation system for real-time guidance.

For this survey, the GPS base station was located at latitude 64 degrees 01.5555 minutes N, longitude 145 degrees 40.7223 minutes W at an elevation of 381 m above mean sea level. The GPS records data relative to the WGS84 ellipsoid, which is the basis of the revised North American Datum (NAD83).

Field Workstation

A PC is used at the survey base to verify data quality and completeness. Flight data are transferred to the PC hard drive to permit the creation of a database using a proprietary software package (typhoon-version 17.01.04). This process allows the field operators to display both the positional (flight path) and geophysical data on a screen or printer.

3. PRODUCTS AND PROCESSING TECHNIQUES

The following maps and products have been provided under the terms of the survey agreement.

Color Maps (2 sets) at 1:6,000 and 1:12,000

- Total Exposure Rate (µR/h)
- ^{60}Co (counts per second)
- ^{137}Cs (counts per second)
- Low-energy to High-energy Ratio
- Anomaly Locations

Additional Products

- Digital XYZ archive and a digital database in Geosoft format (CD-ROM)
- Digital grid archives in Geosoft format (CD-ROM)
  - Total Exposure Rate (µR/h)
  - ^{60}Co (cps)
  - ^{137}Cs (cps)
  - Low-energy to High-energy Ratio
  - Potassium concentrations (%)
  - Equivalent uranium concentrations (parts per million;ppm)
  - Equivalent thorium concentrations (ppm)
- Coordinate Referenced images of the "digital grid archives" (*.tiff) (CD-ROM)
- Digital version of map products (PDF) (CD-ROM)
- Survey report (3 copies)
- Analog chart records
- Flight path video cassettes

Other products can be prepared from the existing dataset, if requested.

Base Maps

Base maps of the survey area have been produced from digital topographic layers provided by IT Corporation. All maps and data are created using the following parameters:

Projection Description:

Datum:	NAD83
Ellipsoid:	GRS 1980
Projection:	US State Plane (feet), Alabama East

Scale Factor: 0.9996
WGS84 to Local Conversion: Molodensky
Datum Shifts: DX: 0 DY: 0 DZ: 0

Radiometrics

All radiometric data reductions performed by Fugro Airborne Surveys rigorously follow the procedures described in the IAEA Technical Report[1]. The coefficients used in each step are listed in Appendix D Radiometrics Control File.

All processing of radiometric data was undertaken at the natural sampling rate of the spectrometer, i.e., one second. The data were not interpolated to match the fundamental 0.1 second interval of the ancillary data.

The following sections describe each step in the process.

NASVD

Fugro Airborne Surveys utilizes a multi-channel technique developed by Hovgaard and Grasty to reduce statistical noise in AGS data. This method (described as *noise adjusted single valve decomposition* or "nasvd"[2]), analyses the 512 channel survey data to identify all statistically significant spectral shapes. These "spectral components" are used to reconstruct new cobalt, cesium, potassium, uranium and thorium window values, which then have significantly less noise than the original raw windows. This is particularly effective for the uranium and cesium[3] windows because of the low count rates, and should also be effective for cobalt. The spectral component method results in a more accurate measure of the ground concentration, which improves considerably the discrimination between background and anomalous ground concentrations.

Pre-filtering

The radar altimeter data were processed with a 49-point median filter to remove spikes.

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[1] Exploranium, I.A.E.A. Report, Airborne Gamma-Ray Spectrometer Surveying, Technical Report No. 323, 1991.

[2] Hovgaard, J. and Grasty, R. L.; "Reducing statistical noise in airborne gamma-ray data through spectral component analysis"; in Proceeding of Exploration 97, 1997; p.753-764

[3] Hovgaard, J. ; "A new processing technique for airborne gamma-ray data (noise adjusted single value decomposition); Am. Nucl. Soc. Symp. on Emergency Preparedness and Response; San Francisco 1997.

Live Time Correction

The spectrometer, an Exploranium GR-820, uses the notion of "live time" to express the relative period of time the instrument was able to register new pulses per sample interval. This is the opposite of the traditional "dead time", which is an expression of the relative period of time the system was unable to register new pulses per sample interval.

The GR-820 measures the live time electronically, and outputs the value in milliseconds. The live time correction is applied to all final windows.

Reduction to Standard Temperature and Pressure

The radar altimeter data were converted to effective height in feet using the acquired temperature and pressure data.

Aircraft and Cosmic Background

Aircraft and cosmic background corrections were applied to all channels. Aircraft and cosmic backgrounds were determined from data obtained in a flight over Lake Ontario during the mobilization. The background over water (BOW) tests isolate the gamma-rays coming from sources on-board the aircraft and cosmic radiation. It is necessary to use a lake or river with a width such that the terrestrial radiation including radon gas from the shore is not significant during the measurement. The other component of gamma radiation measured during this test is the contribution of cosmic radiation, which is unique to the altitude of the test.

The helicopter pilot, and helicopter company owner, did not agree to complete a cosmic calibration flight. The cosmic calibration flight is used to determine the cosmic stripping ratios for each of the windows. The cosmic stripping ratios allow a correction for the variation in cosmic contribution with altitude. The variation of cosmic radiation with altitude in the Fort McClellan survey is within the statistical noise range of the data and does not affect the validity of the results. For example, for thorium, over the 500 foot range of altitudes involved in this project, the maximum correction for the cosmic contribution with altitude amounts to less than .05 ppm.

The pilot's objection is based on safety concerns due to the lack of visual motion reference that occurs in a light helicopter at 5 to 10 thousand feet above ground as required for the standard test. Winds that occur at that ground clearance and the relatively low forward airspeed of helicopters can create a dangerous control situation which is hard to correct because of the lack of visual motion reference.

Radon Background

The GR820 Spectrometer is limited to a combination of 2048 cu in of detector with 512 channels. This prevented the use of an upward looking detector for radon monitoring. In the absence of an upward looking crystal, a suitably large, deep and nearby body of water can be used to do regular background over water tests (BOW). Unfortunately a suitable body of water was not available. It was thought that the increase in resolution available from the 512 channel configuration and the increase in sensitivity with 2048 cu in of crystal over the basic 1024 cu in was more important for point source detection of ^{137}Cs and ^{60}Co than the radon removal.

Radon was evident as banding in the uranium channel and to a lesser extent in other channels. Adjusting base levels to match local backgrounds on a line to line basis minimized this banding. While this will not affect identification and location of point source anomalies, it may cause errors in defining the absolute background and concentration values.

Stripping

Following the radon correction, the ^{137}Cs, ^{60}Co, potassium, uranium and thorium data were corrected for spectral overlap. First the stripping ratios were modified according to altitude. Then an adjustment factor based on the reversed stripping ratio, uranium into thorium, was calculated. The stripping ratio altitude correction constants are expressed in change per metre.

It is apparent from a final examination of the data that there is still a contribution in the ^{60}Co window from the overlapping potassium window, and in the ^{137}Cs window from the overlapping bismuth peak. In any interpretation of the data from this survey leading to recommendations for further investigations this must be taken into account. This will also affect the accuracy of absolute background and ground concentration values for ^{137}Cs and ^{60}Co.

Attenuation Corrections

The total count, ^{137}Cs, ^{60}Co, potassium, uranium and thorium data were corrected for attenuation due to air to a nominal survey altitude. The data were reduced to the intended flying height of 33 feet.

Conversion of Counts to Concentrations

The potassium, uranium and thorium windowed counts are converted to potassium concentration in percent (%), equivalent uranium concentration (eU) in parts per million (ppm) and equivalent thorium concentration (eTh) in ppm using sensitivities derived from test flights of the spectrometer and detector package over the Breckenridge calibration range test strip.

The ground concentrations of the calibration range were determined by taking 50 measurements of 2 minute duration with a calibrated portable spectrometer of the test strip. The system sensitivities are then calculated from the corrected counts over the calibration range

The concentrations of uranium and thorium are termed "equivalent" because the gamma energy measured is that of the bismuth (^{214}Bi) and thallium (^{208}Tl) daughter products respectively, and the assumption is made that the daughter products are in equilibrium with the parent.

Calculation of Total Exposure Rate

The total exposure rate represents the integrated radiation intensity measured through the number of ion pairs formed in a standard mass of air[4]. The total exposure rate expressed as μR/h is derived from the total count comprising the counts for all energies from .4 to 3 MeV. The total count, measured as counts per second corrected to nominal survey altitude, was converted to total exposure rate at 3.3 feet above ground level using a conversion factor derived experimentally for the spectrometer and detector package used.

Calculation of Low-energy to High-energy ratio

The Low-energy to High-energy Ratio parameter is a ratio of the summed counts in the low-energy portion of the spectrum to the summed counts in the high-energy portion of the spectrum. Low-energy is defined as 0.4 to 1.4 MeV and high-energy is 1.4 to 3 MeV. The counts have been corrected for cosmic and aircraft background.

Adjustments

Manual adjustments to base levels on a line by line basis were made to the uranium and cesium counts to minimize along-line levelling differences caused by radon. This adjustment has little effect on the location of point sources, which is the main purpose of the survey, but may locally reduce the reliability of ground concentration values.

Contour and Color Map Displays

The geophysical data are interpolated onto a regular grid using a minimum curvature technique. The resulting grid is suitable for generating contour maps of excellent quality. The grid cell size is 25% of the line interval. For this survey original grids were produced at 8.2 foot cell spacing.

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[4] Construction and use of calibration facilities for radiometric field equipment, Technical Report Series No. 309, IAEA, 1989, p20.

Color maps are produced by interpolating the grid down to the pixel size. The parameter is then incremented with respect to specific amplitude ranges to provide color "contour" maps.

Identification of Man Made Sources

The ^{137}Cs and ^{60}Co in cps, total exposure rate and low-energy to high-energy ratio were the primary parameters used to identify any detectable radiological sources. Grids of the natural isotopes; uranium, potassium and thorium, were produced, delivered and used in the analysis. The natural exposure rate and full 512 channel spectrum were also used in the analysis that is reflected in this report.

Anomalous areas on the total exposure rate and high-energy to low-energy Ratio were viewed as the 512 channel spectrum using the Fugro SPECTPLOT Tool waterfall diagrams and single point spectrum display tools to identify the isotopes producing anomalous radiation. The ^{137}Cs and ^{60}Co parameters were used as a direct indication of man-made isotopes producing anomalous radiation, however the noise and spectral overlap conditions of these parameters required careful analysis and comparison to the natural isotope parameters to confirm anomalies.

Figure 3.1 shows a typical spectrum and the location of the gamma-ray energy from the isotopes of interest. The 0.66 Milli electron Volt (MeV) peak was used to produce the cesium parameter. The 1.17 and 1.33 MeV cobalt peaks were summed to produce the cobalt parameter. There is some overlap of the 0.61 MeV bismuth peak and 1.46 MeV potassium peak with the cesium and cobalt respectively which must be taken into account when analyzing the survey results. The exposure rate and potassium, uranium and thorium parameters were compared to the ratio and man-made radioelement maps to classify anomalous areas.

Figure 3.1 Typical Spectrum

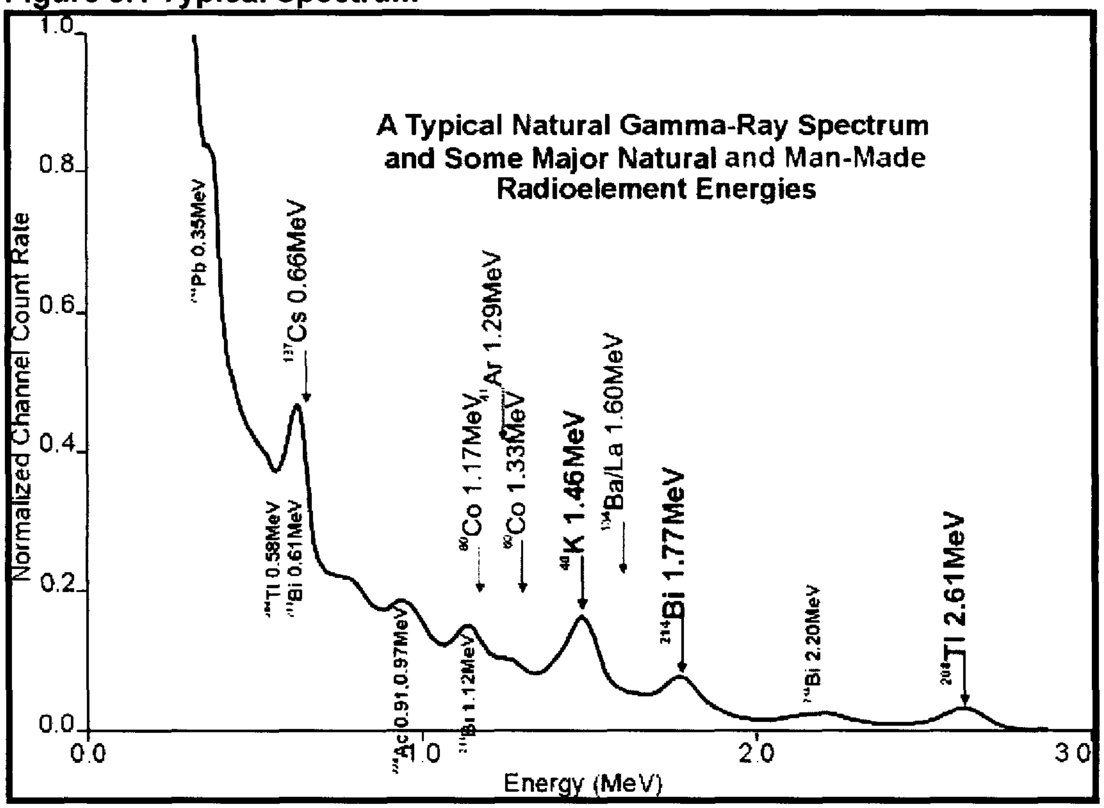
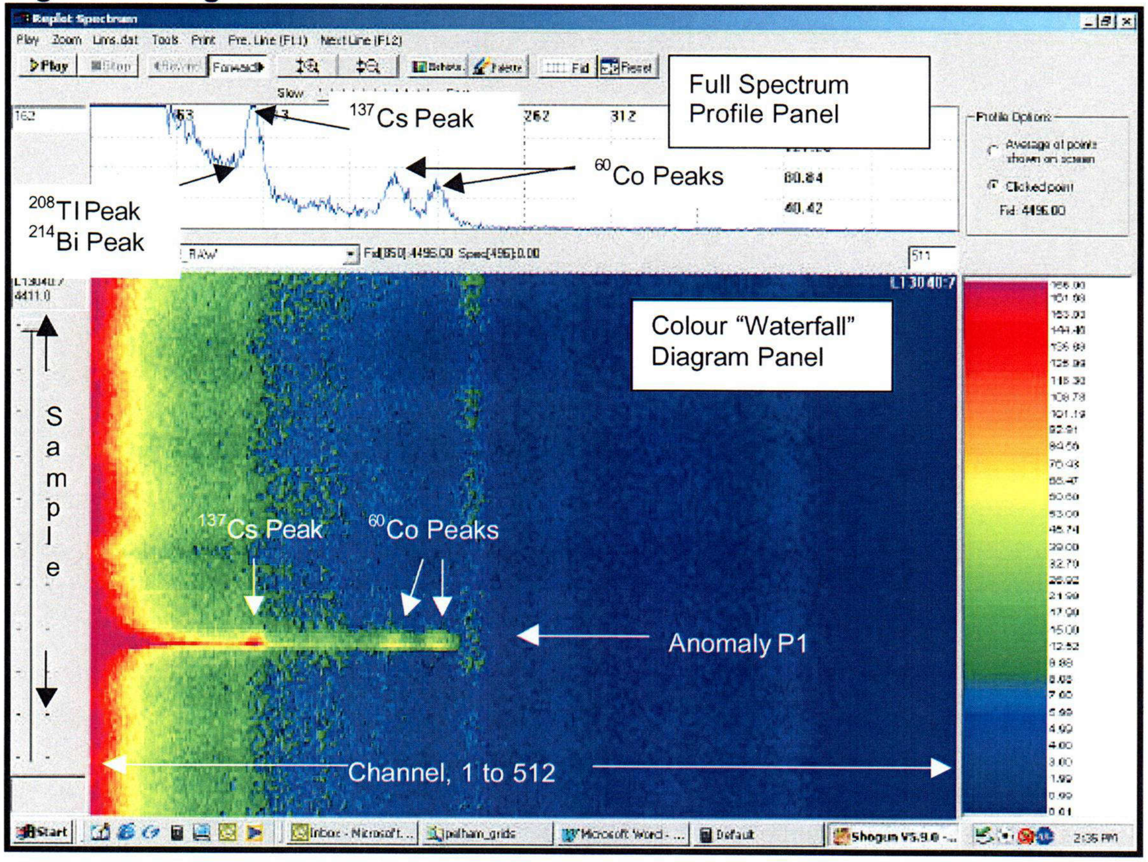


Figure 3.2 is an example of the Fugro SPECTPLOT Tool. Anomaly P1 from Rideout Field is shown. The twin ^{60}Co peaks are clearly evident straddling channel 205, and the ^{137}Cs peak is apparent at about channel 103 in the full spectrum profile panel at the top of the figure. The bottom "waterfall" diagram panel shows counts in colored intensity as a function of channel for each data record. It is obvious from the waterfall diagram alone that ^{137}Cs and ^{60}Co are responsible for the anomaly at this location as the anomalous counts are limited to energies corresponding to and below ^{137}Cs and ^{60}Co.

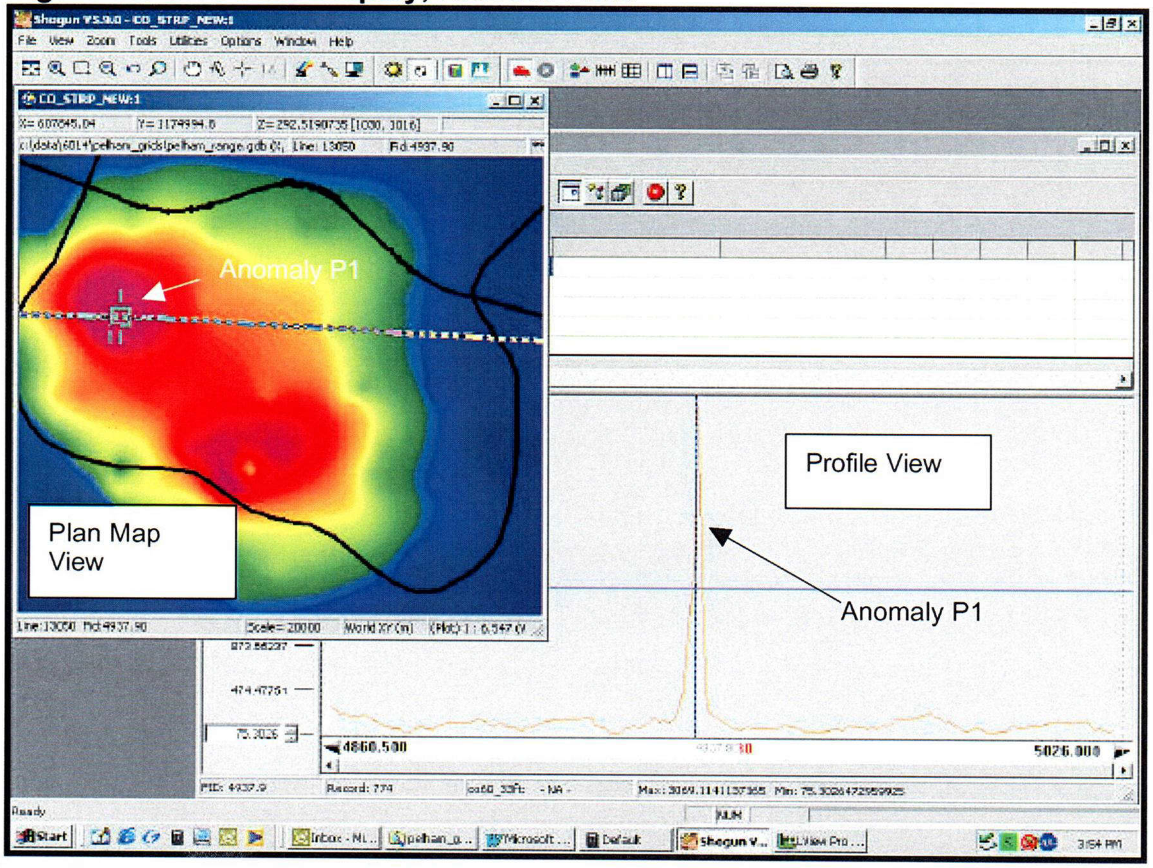
Figure 3.2 Fugro SPECTPLOT Tool



The SHOGUN display links the gridded data to the profile data and is also useful for analyzing and defining the location of the anomaly. The left upper panel shows a plan view of the Rideout field anomaly. The cursor in the bottom right profile panel and crosshairs in the upper left panel are linked.

C02

Figure 3.3 SHOGUN Display, Rideout Field



4. RESULTS

Maps of the ^{137}Cs and ^{60}Co in counts per second (cps), Total Exposure Rate (μR/h) and Low-energy to High-energy Ratio were prepared along with digital data consisting of grids of the natural isotopes (uranium, potassium and thorium) and full 512 channel spectrum data. See Table 4.1 for a list of the maps, brief description and corresponding figure numbers. The following describes the map products delivered as well as the significant findings of the analysis. The locations of suspected man-made sources and statistics on the anomalies are provided in table form in Tables 4.2 and 4.3. Two anomalies including one from a confirmed man-made ^{137}Cs source were identified in the Main Post area. These are labeled M1 and M2. Five anomalies including two from confirmed sources of ^{137}Cs and ^{60}Co labeled P1 to P5 were identified in the Pelham Range area.

Table 4.1 Map Figures

Map	Description	Figure Number	
		Pelham Range	Main Post
Total Exposure Rate (μR/h)	Combined measure of naturally occurring and man-made radioactivity	Figure 4.1	Figure 4.6
Low-energy to High-energy Ratio	Interpretive tool for identifying man-made sources	Figure 4.2	Figure 4.7
^{137}Cs (counts per second)	Corrected counts measured in the ^{137}Cs window	Figure 4.3	Figure 4.8
^{60}Co (counts per second)	Corrected counts measured in the ^{60}Co window	Figure 4.4	Figure 4.9
Anomaly Locations	Symbols indicate target areas recommended for ground follow-up	Figure 4.5	Figure 4.10

The anomalies have been given priority classifications based on how well the anomaly characteristics match the expected characteristics of man-made source anomalies. These priority classifications are indicated in Tables 4.2 and 4.3. Priority 1 type is a definite match. Priority 2 type is a questionable match and Priority 3 have some matching characteristics, but with strong indications that they are due to natural radiation or measurement and data reduction artifacts.

Total Exposure Rate

The total exposure rate includes contributions from naturally occurring radioactive material in the soil and rock and man-made isotopes. The results are presented as maps in Figures 4.1 and 4.6.

Substantial variation in natural exposure rates due to geological and soil conditions in the areas surveyed are not unusual. The exposure rate measured from the air will be understated for man-made sources that are small compared to the ground area that influences each sample. For these reasons, the total exposure rate was cross-checked with the low-energy to high-energy ratio and man-made isotope parameters, which are

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED: FIGURE 4.1 , "RADIOACTIVITY - EXPOSURE RATE (in μ R/h)"

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FIGURE 4.2, "RADIOACTIVITY Low Energy / High Energy Ratio"

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FIGURE 4.10 ,
"SELECTED RADIOACTIVE ANOMALIES"

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Table 4.2 Main Post Anomalies

Anom-aly	Prior-ity	x	y	Alt ft	^{60}Co counts	^{137}Cs counts	^{40}K counts	^{214}Bi (U) counts	^{208}Tl (Th) counts	Tot. Exp υR/h	Low-E: High-E Ratio	Comment
M1	1	662369	1164074	57	13.3	150.82	0.2	1.7	6.9	3.9	5.4	^{137}Cs source (confirmed by ground follow-up)
M2	3	663329	1165310	64	8.7	58.0	0.2	1.3	3.2	2.3	5.1	High Low-E:High-E ratio. Probably an artifact due to low natural exposure rate, selected based on historical land use
Main Post												
Max.				264	33.3	150.82	1.6	3.9	19.1	7.7	5.4	
Mean				89	12.0	41.5	0.3	1.5	7.6	3.7	4.3	
Min.				32	-4.6*	-46.7*	-0.1*	-0.1*	1.7	1.2	3.2	

Table 4.3 Pelham Range Anomalies

Anom-aly	Prior-ity	x	y	Alt ft	^{60}Co counts	^{137}Cs counts	^{40}K counts	^{214}Bi (U) counts	^{208}Tl (Th) counts	Tot. Exp υR/h	Low-E: High E Ratio	Comment
P1	1	607615	1175235	77	2750	3618	1.7	3.0	7.9	45.3	31.5	Source removal in progress at time of flyover
P2	1	607714	1175091	89	2251	5206	0.9	1.4	10.2	43.8	50.3	Source removal in progress at time of flyover
P3	3	607364	1173790	56	-6.8*	25.6	2.1	4.7	14.9	10.2	3.9	Relatively high total exposure rate on road near Rideout field. Man-made isotope counts low. Most probably natural radiation, selected based on historical land use
P4	3	606874	1173161	74	75.2	95.8	1.3	5.0	15.1	10.3	4.6	Relatively high total exposure rate on road near Rideout field. Man-made isotope count for cobalt above average but within noise range , selected based on historical land use
P5	3	609485	1172312	52	-1.32	-10.8*	3.3	2.6	15.8	10.7	3.6	Relatively high total exposure rate on road near Rideout field. Man-made isotope counts low. Most probably natural radiation, selected based on historical land use
Pelham												

Range												
Max.				212	2750	5206	3.4	8.7	19.4	45.3	50.3	
Mean				90	23	47	0.6	1.8	8.0	4.6	4.3	
Min.				30	-58*	-55.7*	-0.1*	-0.5*	0.3	0.4	3.0	

* Negative numbers are meaningless and reflect only the statistical noise in the data.

less influenced by variations in natural radiation, in order to identify locations of man-made radioactive sources.

Main Post

The total exposure rate in the Main Post area measured by the radiological flyover ranges from 1.2 μR/h to 8.15 μR/h, with a mean of 3.7 μR/h[5]. This is consistent with the UNSCEAR world average terrestrial outdoor ground exposure rate of 5.2 μR/h. In general, excluding the ^{137}Cs source identified by the flyover, the patterns produced by variations in the exposure rate most likely reflect natural changes in soil composition and soil thickness or variation in underlying rock formations.

The yard surrounding the Lenlock Community Center and road from Summerall gate yield somewhat higher natural radiation. This may be due to importation of fill from another site with relatively higher natural radiation or removal of soil exposing bedrock. The natural radiation in these locations appears to be potassium-rich based on a comparison of the K, eU and eTh concentration parameters with the total exposure rate.

Topographically elevated areas such as Iron Mountain exhibit generally lower exposure rates. Changes in geology are the most likely reason for this effect as ridge forming rock units such as quartzite may be naturally low in radioactivity. Some areas in the vicinity of Iron Mountain were also clearcut for road construction and the ground has been coated in dampened wood chips as part of the construction process (possibly to control dust?). A layer of damp wood chips would be expected to reduce the apparent exposure rate.

The exposure rate at the location of the ^{137}Cs source identified using other products from the survey at anomaly M1 is 3.89 μR/h (see Table 4.2 and Figure 4.10). Ground surveys and soil analysis indicates a much stronger source at this location because of the smaller sample size of the ground investigations.

Pelham Range

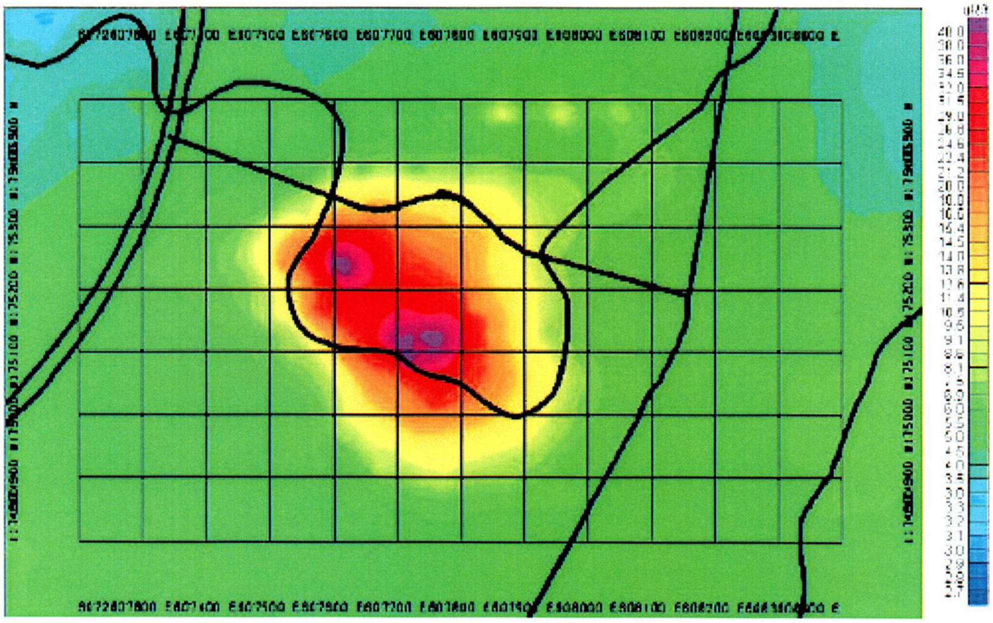
The total exposure rate in the Pelham Range area ranges from 0.3 μR/h to 45.3 μR/h, with a mean of 4.4 μR/h. This average is consistent with the world average terrestrial outdoor ground exposure rate of 5.2 μR/h. The maximum total exposure rate is situated in the vicinity of Rideout field where ^{137}Cs and ^{60}Co sources were under excavation during the flyover. The indicated strength of known sources at this location is much stronger than measured by the flyover. Again, this is due to averaging of the gamma

[5] Note that airborne measurements will vary from ground measurements with similar detectors due to the fact that the airborne measurement averages the contribution of gamma-rays from a much larger area. This will cause airborne measurements to underestimate the exposure rate of compact sources.

radiation within the large area sampled by the airborne detector relative to the size of the actual sources.

Figure 4.11 shows a detailed enlargement of the Rideout Field area from the Total Exposure Rate map (Figure 4.1). Figure 4.1 clearly shows two distinct centers although the peak anomalous area to the southeast may reflect two or three sources within a 60 m radius. These peaks correspond to anomalies in the 137 Cs and 60 Co data and are labeled as P1 and P2. The broad area that measures above normal is due to scattering and geometric effects inherent in airborne measurements. The sources are most likely confined to the two smaller peak regions.

Figure 4.11 Rideout Field Detail*



*Note that the gridding process will show the peaks slightly offset from the location at which the sample was taken. The Tables in this report give more accurate locations than the maps. The grid on the figure represents 100 foot square areas.

Several locations with locally anomalous exposure rates were selected for follow-up (P3, P4, P5 in Table 4.3 and Figure 4.5). Although the measured exposure rates are well within the variation expected due to geological sources, historical land uses suggest that these may warrant further investigation. If any of these should prove to be significant sources of man-made radiation, the rest of the data should be re-evaluated using these as characteristic signatures.

Otherwise, the patterns produced by variations in the natural exposure rate most likely reflect changes in soil composition and soil thickness or variation in underlying rock

formations. Changes in geology are the most likely reason for lower exposure rates on ridges as ridge forming rock units such as quartzite may be naturally low in radioactivity.

Low-Energy to High-Energy Ratio

As the low-energy portion of the spectrum contains the energy from the man-made sources of interest and the high-energy portion of the spectrum is dominated by natural radiation, high numbers in the Low-energy to High-energy ratio parameter are a useful indication of potential locations of man-made radiation.

Because the measured spectrum is a complex combination of altitude effects as well as variations in man-made and natural radiation the ratio is not completely free of background variations that are unrelated to man-made radiation. Cross checks of the ratio parameter with the natural exposure rate, natural and man-made isotope maps and the full spectrum presentations were performed for a complete analysis.

Main Post

The Low-energy to High-energy Ratio for Main Post (Figure 4.7) appears to be almost a complete inversion of the Total Exposure Rate map (Figure 4.6) with low ratio numbers correlating with the higher exposure rate values. This suggests that most of features on the ratio map are due to variations in the natural radiation. The one prominent exception to this is the M1 ^{137}Cs anomaly.

It was determined that the low-energy to high-energy ratio anomaly on Iron Mountain (anomaly M2 in Table 4.2 and Figure 4.10) should be investigated on the ground. Although the total exposure rate and the man-made isotope counts are low in this location historical land uses suggest that this anomaly should be investigated. If this anomaly should prove to be a significant source of man-made radiation, the rest of the data should be re-evaluated using this anomaly as a characteristic signature.

Pelham Range

Similar to the Main Post area, the patterns in the Pelham Range Low-energy to High-energy Ratio map (Figure 4.2) correlate with patterns in the Total Exposure Rate map (Figure 4.1) suggesting that most of the features on the ratio map are due to variations in the natural radiation. The area under excavation for known buried man-made ^{137}Cs and ^{60}Co sources in Rideout field yields a prominent high in the ratio map as expected.

^{137}Cs

The ^{137}Cs maps, Figures 4.3 and 4.8, are expressed as counts per second. The counts in the ^{137}Cs window have been corrected for aircraft and cosmic radiation background

and corrected to the nominal survey height of 33 feet. The ^{137}Cs window has been stripped to remove the influence of scattered gamma-rays from the interaction of higher energy natural isotopes (^{40}K, ^{214}Bi and ^{208}Tl) with the detector. The ^{137}Cs peak overlaps somewhat with the 0.61 MeV ^{214}Bi and the 0.58 MeV ^{208}Tl peaks resulting from natural uranium radiation and radon (^{222}Rn). A comparison of the ^{137}Cs maps with the natural and total exposure rate and natural isotope parameters indicates that some of the background patterns likely reflect changes in natural radioactivity particularly in the U (^{214}Bi) parameter. Variations in the distribution of ^{137}Cs that are present in the soil due to fallout from nuclear testing and soil moisture variations may also cause some of the variations in the background areas.

Main Post

Anomaly M1 (see Table 4.2 and Figure 4.10) reflects elevated ^{137}Cs levels. Table 4.2 gives the location and characteristics of this anomaly. The anomaly is found about 820 feet northeast of the Lenlock Community Center on the side of Iron Mountain just outside the existing perimeter of Ft. McClellan. The vicinity of this anomaly was investigated using a hand-held portable spectrometer. Background radiation was measured at 12.5 μR/h with the suspected location of the source producing 120 μR/h on the ground.

There are several somewhat broader areas with slightly elevated total exposure rates and ^{137}Cs counts through the central and southern portions of Figures 4.6 and 4.8. Based on the wide extent of the anomalous area and a comparison with the uranium (^{214}Bi) parameter it is likely that these anomalies result from spectral peak overlap with ^{214}Bi. Normal variations in the ^{137}Cs background or soil moisture variations are other contributing factors.

Pelham Range

"Rideout Field" in the Pelham Range Area contained two distinct peak locations within a broad area of elevated concentrations of ^{137}Cs (P1 and P2 in Table 4.3 and Figure 4.5). Examination of the spectrum information confirmed the presence of both ^{137}Cs and ^{60}Co. This area was under excavation for removal of radioactive contamination during the flyover. Movement of soil and the sources may have occurred between successive airborne passes over the site. As a result, there may be inconsistencies in the locations and measured strengths of the sources. It is also possible that the discrete sources detected during the flyover may have been located within "rollaway" disposal containers.

^{60}Co

The ^{60}Co maps (Figures 4.4 and 4.9) are expressed as counts per second. The counts in the ^{60}Co window have been corrected for aircraft and cosmic radiation background and corrected to the nominal survey height of 33 feet. The ^{60}Co window has been "stripped" to remove the influence of scattered energy from the higher energy natural isotopes (^{40}K, ^{214}Bi and ^{208}Tl).

Unlike ^{137}Cs and the natural isotopes it is not expected that there would be a measurable ^{60}Co background in the survey area. In background area the ^{60}Co parameter is indicative of a wide range of statistical noise associated with the measurements. The ^{60}Co peaks overlap somewhat with the ^{40}K peak. A comparison of the ^{60}Co maps with the ^{40}K parameter indicates that some of the background patterns likely reflect natural changes in the ^{40}K ground concentrations.

Significant ^{60}Co sources are not indicated anywhere in the Main Post or Pelham Range areas except for two or possibly three anomalous areas in Pelham range (P1, P2 and P4) as discussed in more detail below.

Main Post

Significant ^{60}Co sources are not indicated anywhere in the Main Post area by the survey results.

Pelham Range

"Rideout Field" in the Pelham Range Area contained two distinct peak locations within a broader area of elevated concentrations of ^{60}Co (P1 and P2 in Table 4.3 and Figure 4.5). Examination of the spectrum information confirmed the presence of both ^{137}Cs and ^{60}Co. This area was under excavation for removal of suspected radioactive contamination. Movement of soil and the sources may have occurred between successive airborne passes over the site. As a result, there may be inconsistencies in the locations and measured strengths of the sources. It is also possible that the discrete sources detected during the flyover may have been located within "rollaway" disposal containers. Investigation on the ground or in the air is warranted after removal of the material to verify that none has been missed.

Anomaly P4 was selected because of the relatively high total exposure rate at this location and because of historical land use. There is also a coincident ^{60}Co high at this location. The ^{60}Co counts are not above what should be considered the noise range, and an analysis of the full spectrum indicates natural uranium and potassium appear to be responsible for the total exposure rate high at this location. However further investigation may be warranted. If this should prove to be a significant source of man-made radiation, the rest of the data should be re-evaluated using this anomaly as characteristic signature.

5. CONCLUSIONS AND RECOMMENDATIONS

Two sites at the former U.S. Army installation, Fort McClellan, Calhoun County, Alabama were surveyed using a helicopter-borne gamma-ray spectrometer to detect, locate and identify isotopes of radiological sources. Area one comprised 470 acres of the Main Post and the second area comprised 4,900 acres in the northwest portion of Pelham Range. Maps were produced of ^{137}Cs and ^{60}Co count rates (cps), Total Exposure Rate in micro Roentgens per hour (µR/h) and Low-energy to High-energy Ratio. Digital grids were produced and delivered for the naturally occurring radioelement parameters, potassium, uranium and thorium. In addition the natural exposure rate and 512 channel spectrum were used in the analysis of the results.

Tables 4.2 and 4.3 list the significant anomalies identified by the survey. The Tables give the characteristics and location of the anomalies. Three anomalies; M1, P1 and P2, have been confirmed as man-made radioactive isotope sources. These were considered "priority 1" targets as the survey results clearly indicated the presence of man-made sources. The locations of these anomalies with symbols denoting the priority and parameters affected are shown on Figures 4.5 and 4.10.

No priority 2 and four priority 3 anomalies have been identified. Based on the analysis of the survey results these are not thought to be significant sources of man-made radiation at this time but ground follow-up is warranted to determine the source of the radiation. The location of the anomalies should be investigated using a hand held spectrometer to determine the exact position and obtain a more exact measurement of the activity and isotopes of the sources.

Many other areas that are either local total exposure rate highs or local man-made isotope highs are apparent on the maps accompanying this report. These are attributed to local variations in natural radiation and statistical errors associated with the data collection and are not considered significant at this time. However the maps should be re-evaluated, more targets identified and investigated if any of the Priority 3 anomalies prove to be man-made radioactive sources based on the follow-up. Historical land uses should be taken into account in the selection. The follow-up results will lead to the establishment of type signatures that can be used for comparison with the data produced from this flyover to determine further courses of action based on the airborne data.

The raw 512 channel spectra have been delivered to The IT Group along with the NASVD corrected 512 channel data and the processed windowed data. Inclusion of the raw data allows for further processing or analysis at a later date should there be interest in determining the presence of other isotopes in the survey areas or if new techniques for analysis become available.

Respectfully submitted,

FUGRO AIRBORNE SURVEYS CORP.

Doug McConnell, P.Eng.
Senior Geophysicist

APPENDIX A

LIST OF PERSONNEL

The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a radiological airborne survey carried out for IT Corporation at Ft. McClellan, Alabama.

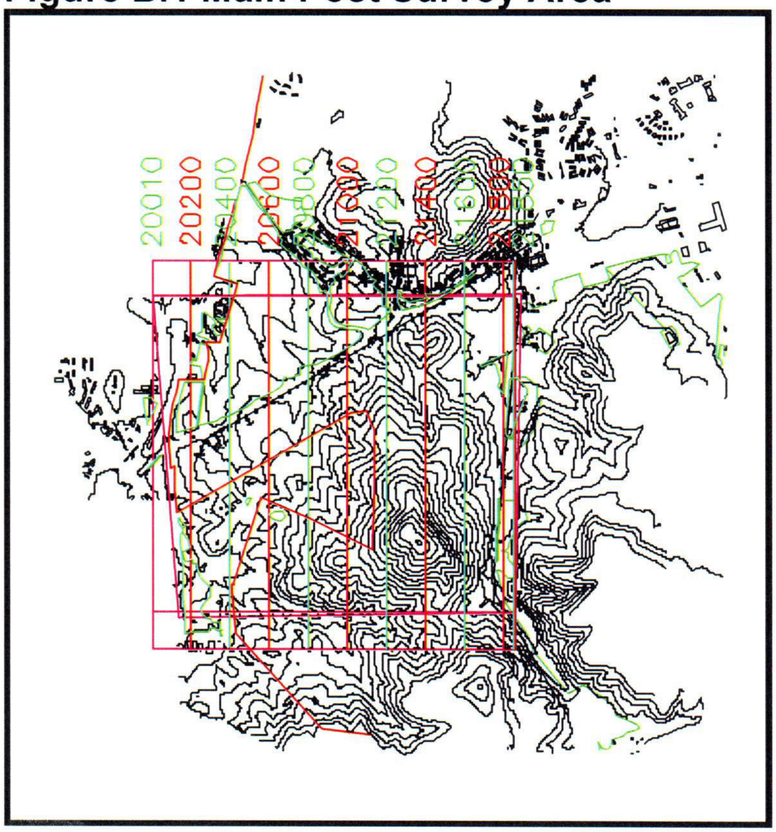
Dave Miles	Manager, Helicopter Operations
Emily Farquhar	Manager, Data Processing and Interpretation
Greg Hodges	Chief Geophysicist
Doug McConnell	Project Manager
Patrick Dickenson	Senior Geophysical Operator
Dereck Wagg	Field Geophysicist
Dave Tomassini	Pilot (Four Seasons Aviation Inc.)
Dak Darbha	Geophysicist
Elizabeth Bowslaugh	Geophysicist
Lyn Vanderstarren	Drafting Supervisor
Susan Pothiah	Word Processing Operator
Albina Tonello	Secretary/Expeditor

All personnel are employees of Fugro Airborne Surveys, except for the pilot who is an employee of Four Seasons Aviation Inc.

APPENDIX B

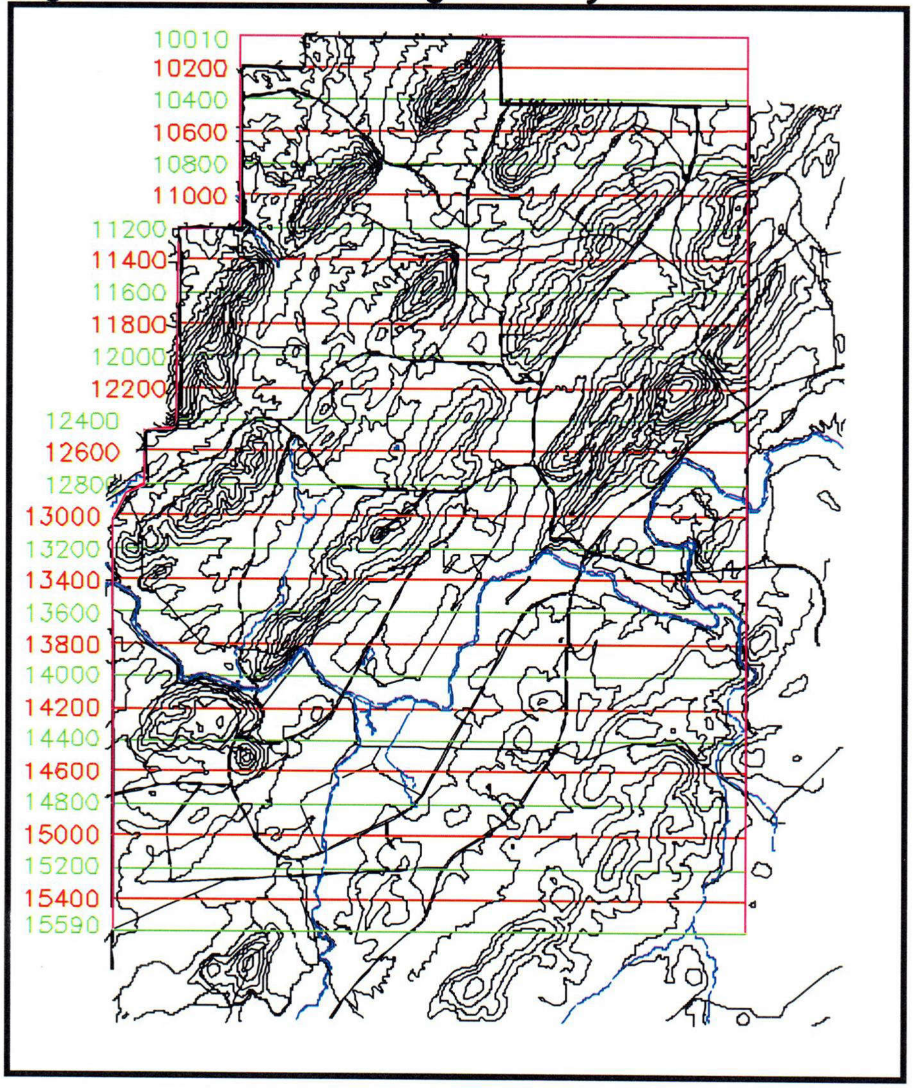
SURVEY AREA MAPS

Figure B.1 Main Post Survey Area



C05

Figure B.2 Pelham Range Survey Area



APPENDIX C

BACKGROUND INFORMATION

Natural Radiation

Radioelement concentrations are measures of the abundance of radioactive elements in the rock and soil. The original abundance of the radioelements in any rock can be altered by the subsequent processes of metamorphism and weathering.

Gamma radiation in the range, which is measured in the thorium, potassium, uranium and total count windows, is strongly attenuated by rock, overburden and water. Almost all of the total radiation measured from rock and overburden originates in the upper 0.5 metres. Moisture in soil and bodies of water will mask the radioactivity from underlying rock. Weathered rock materials that have been displaced by glacial, water or wind action will not reflect the general composition of the underlying bedrock. Where residual soils exist, they may reflect the composition of underlying rock except where equilibrium does not exist between the original radioelement and the products in its decay series.

Radioelement counts (expressed as counts per second) are the rates of detection of the gamma radiation from specific decaying particles corresponding to products in each radioelement decay series. The radiation source for uranium is bismuth (^{214}Bi), for thorium it is thallium (^{208}Tl) and for potassium it is potassium (^{40}K).

The uranium and thorium radioelement concentrations are dependent on a state of equilibrium between the parent and daughter products in the decay series. Some daughter products in the uranium decay are long lived and could be removed by processes such as leaching. One product in the series, radon (^{222}Rn) with a half-life of 3.82 days, is a gas which can easily escape. Both of these factors can affect the degree to which the calculated uranium concentrations reflect the actual composition of the source rock. Because the daughter products of thorium are relatively short lived, there is more likelihood that the thorium decay series is in equilibrium. ^{220}Rn, which is part of the thorium decay series, has a half-life of only 51 seconds.

Lithological discrimination can be based on the measured relative concentrations and total, combined, radioactivity of the radioelements. Feldspar and mica contain potassium. Zircon, sphene and apatite are accessory minerals in igneous rocks which are sources of uranium and thorium. Monazite, thorianite, thorite, uraninite and uranothorite are also sources of uranium and thorium, which are found in granites and pegmatites.

In general, the abundance of uranium, thorium and potassium in igneous rock increases with acidity. Pegmatites commonly have elevated concentrations of uranium relative to thorium. Sedimentary rocks derived from igneous rocks may have characteristic signatures which are influenced by their parent rocks, but these will have been altered by subsequent weathering and alteration. Quartzites, orignating as quartz sandstone and

quartz-rich sands, are likely to be low in radioactivity compared to shales and granitic rocks. The radioactivity of soils such as clay will depend on the originating rocks. Uranium and potassium are soluble and can be transported and concentrated by groundwater.

Metamorphism and alteration will cause variations in the abundance of certain radioelements relative to each other. For example, alterative processes may cause uranium enrichment to the extent that a rock will be of economic interest. Uranium anomalies are more likely to be significant if they consist of an increase in the uranium relative to thorium and potassium, rather than a sympathetic increase in all three radioelements.

Faults can exhibit radioactive highs due to increased permeability, which allows radon migration, or as lows due to structural control of drainage and fluvial sediments which attenuate gamma radiation from the underlying rocks. Faults can also be recognized by sharp contrasts in radiometric lithologies due to large strike-slip or dip-slip displacements. Changes in relative radioelement concentrations due to alteration will also define faults.

Certain rock types can be identified by their plan shapes if they also produce a radiometric contrast with surrounding rock. For example, granite intrusions will appear as sub-circular bodies, and may display concentric zonations. They will tend to lack a prominent strike direction. Offsets of narrow, continuous, stratigraphic units with contrasting radiometric signatures can identify faulting, and folding of stratigraphic trends will also be apparent.

APPENDIX D

RADIOMETRIC PROCESSING CONTROL FILE

APPENDIX D

RADIOMETRIC PROCESSING CONTROL FILE

```
DBGR820    APPLY RADIOMETRIC CORRECTIONS                        DBGR820_BKV1.CR
--------------------------------------------------------------------------------
A10     ,      --- ignored (40X) ---       =A8, F10, or I10
--------------------------------------------------------------------------------
         type of corrections:(all=1,dt=2,dt+BG+comp=3,DT+BG=4)
                 (1 =survey,2=cosmic test,3=alt test,4=HOVER LINES)
IPTYPE                              =1
-------------6014- USE -NASVDED- DATA ---------------------------------------
         INPUT DATABASE PARAMETER NAMES:
FID        ,     FIDUCIAL                      DBASE NAME =FID
ALT        ,     ALTIMETER             DBASE NAME =ALTFT
LIVE       ,     LIVE TIME                     DBASE NAME =LIVTIM
TEMP       ,     TEMPERATURE (OPT.)            DBASE NAME =TDC3
BAR PRESS  ,     BARO PRESSURE (OPT.)          DBASE NAME =barop
RAW_TC     ,     RAW TOTAL COUNT               DBASE NAME =TCR_NEW
RAW_K      ,     RAW POTASSIUM                 DBASE NAME =KR_NEW
RAW_U      ,     RAW URANIUM                   DBASE NAME =UR_NEW
RAW_TH     ,     RAW THORIUM                   DBASE NAME =THR_NEW
RAW_UP_U   ,     RAW URANIUM UP                DBASE NAME =URANUP
COSMIC     ,     RAW COSMIC TOTAL CTS          DBASE NAME =COSMIC
----------------------NOTE: NO UPWARD XL. FOR 6014-AND NO COSMIC TEST----------
         OUTPUT DATABASE PARAMETER NAMES:
COR_TC     ,     COR TOTAL COUNT               DBASE NAME =TC_COR
COR_K      ,     COR POTASSIUM                 DBASE NAME =K_COR
COR_U      ,     COR URANIUM                   DBASE NAME =U_COR
COR_TH     ,     COR THORIUM                   DBASE NAME =TH_COR
COR_UPU    ,     COR URANUP                    DBASE NAME =UPU
CONC_K     ,     K CONCENTRATION (OPT.)        DBASE NAME =eK
CONC_U     ,     U CONCENTRATION (OPT.)        DBASE NAME =eU
CONC_TH    ,     TH CONCENTRATION (OPT.)       DBASE NAME =eTh
EXPOSURE   ,EXPOSURE RATE (OPT.)               DBASE NAME =
EXPORADR   ,        EXP-?R/HR(0) OR NADR-NG/HR(1)       =0
--------------------------------------------------------------------
TRAP_NEG   , OUTPUT NEGATIVES AS ZERO(YES=1,NO=0) =0
RAWORHG    , INPUT DATA RAW(0) OR NASVD(1)       =1
------------------A/C BG FROM BGOW TEST OVER LAKE ONTARIO--------------------
         HANNING FILTER LENGTH FOR EACH DATABASE PARAMETER (0=NO FILTER):
FILT_ALT   ,     ALTIMETER                     FILTER LENGTH =5
FILT_TMP   ,     TEMPERATURE                   FILTER LENGTH =5
FILT_PRESS,      PRESSURE                      FILTER LENGTH =5
FILT_TC    ,     RAW TOTAL COUNT               FILTER LENGTH =0
FILT_K     ,     RAW POTASSIUM                 FILTER LENGTH =0
FILT_U     ,     RAW URANIUM                   FILTER LENGTH =0
```

FILT_TH ,	RAW THORIUM	FILTER LENGTH =0
FILT_UPU ,	RAW URANIUM UP	FILTER LENGTH =11
FILT_COS ,	RAW COSMIC TOTAL CTS	FILTER LENGTH =21

--6014-NOTE: NO UPWARD XL.(HENCE NO RDN) AND NO COSMIC TEST (HENCE NO CSR)----

RADIOMETRIC COEFFICIENTS:

ABCK_TC ,	AIRCRAFT BACKGROUND - TOTAL CTS	=352.62
ABCK_K ,	AIRCRAFT BACKGROUND - POTASSIUM	=23.0
ABCK_U ,	AIRCRAFT BACKGROUND - URANIUM	=18.56
ABCK_TH ,	AIRCRAFT BACKGROUND - THORIUM	=7.76
ABCK_UPU ,	AIRCRAFT BACKGROUND - URANIUM UP	=0.0
CSR_TC ,	COSMIC STRIPPING RATIO - TOTAL CTS	=0.0
CSR_K ,	COSMIC STRIPPING RATIO - POTASSIUM	=0.0
CSR_U ,	COSMIC STRIPPING RATIO - URANIUM	=0.0
CSR_TH ,	COSMIC STRIPPING RATIO - THORIUM	=0.0
CSR_UPU ,	COSMIC STRIPPING RATIO - URANIUM UP	=0.0
RDN_ATC ,	RADON - UR IN TC COEFFICIENT	=0
RDN_BTC ,	RADON - UR IN TC CONSTANT	=0
RDN_AK ,	RADON - UR IN K COEFFICIENT	=0
RDN_BK ,	RADON - UR IN K CONSTANT	=0
RDN_ATH ,	RADON - UR IN TH COEFFICIENT	=0
RDN_BTH ,	RADON - UR IN TH CONSTANT	=0
RDN_AUPU ,	RADON - UR IN UPU COEFFICIENT	=0
RDN_BUPU ,	RADON - UR IN UPU CONSTANT	=0
RDN_A1 ,	RADON - U IN UPU	=0.0
RDN_A2 ,	RADON - TH IN UPU	=0.0
ALPHA ,	COMPTON TH > U	=0.245
BETA ,	COMPTON TH > K	=0.401
GAMMA ,	COMPTON U > K	=0.782
BACKA ,	GRASTY BACKSCATTER U > TH (0.05)	=0.064
BACKB ,	GRASTY BACKSCATTER K > TH (0.0)	=0.006
BACKG ,	GRASTY BACKSCATTER K > U (0.0)	=0.005
ATN_TC ,	HEIGHT ATTENUATION OF TC	=0.002390
ATN_K ,	HEIGHT ATTENUATION OF K	=0.003116
ATN_U ,	HEIGHT ATTENUATION OF U	=0.001938
ATN_TH ,	HEIGHT ATTENUATION OF TH	=0.002581
SENS_K ,	CPS PER PERCENT POTASSIUM ON GROUND	=133.9
SENS_U ,	CPS PER PPM URANIUM ON GROUND	=13.633
SENS_TH ,	CPS PER PPM THORIUM ON GROUND	=7.169

-----------------SENS FROM 2029 GSC--

GENERAL PARAMETERS:

S_FREQ ,	RADIOMETRIC SAMPLES PER SECOND	=1
ALT_OFF ,	HEIGHT OF SENSOR ABOVE ALTIMETER (ft)=0	
ALT_DTM ,	SURVEY HEIGHT DATUM (ft)	=33
ALT_MAX ,	MAXIMUM ALTITUDE (1000ft)	=300

APPENDIX E

ARCHIVE DESCRIPTION

APPENDIX E

ARCHIVE DESCRIPTION

This CD-ROM contains final data archives of an airborne survey conducted by Fugro Airborne Surveys on behalf of IT Corporation of Ft. McClellan, Alaska during October 2001.

Fugro Airborne Surveys Job # 6014.

The archives contain 3 directories.

1. Line data:
   Line data in montaj (geosoft) Database (*.gdb)

2. Grids: Grids in Geosoft format for the following parameters (*.grd):
   1. Cobalt cps.
   2. Cesium cps.
   3. Low-energy to high-energy ratio.
   4. Total exposure rate
   5. Potassium concentrations.
   6. Equivalent uranium concentrations.
   7. Equivalent thorium concentrations.

3 Report in MS-Word, Version 97-sr2.

4 Plot files of Maps Produced in PostScript format (*.PDF)
   1. Cobalt cps.
   2. Cesium cps.
   3. Low-energy to high-energy ratio.
   4. Total exposure rate

<u>Projection Description</u>:

Datum:	NAD83
Ellipsoid:	GRS 1980
Projection:	US State Plane (feet), Alabama East
Scale Factor:	0.9996
WGS84 to Local Conversion:	Molodensky
Datum Shifts:	DX: 0 DY: 0 DZ: 0

APPENDIX F

LIST OF ACRONYMS

Abreviation	Meaning
^{0}C	Degrees Celsius
AGS	Airborne gamma-ray survey
BOW	Background over water
Ci	Curie, unit of radioactivity equal to 3.7 $X10^{10}$ disintegrations per second
cm	Centimetre
cps	Counts per second, gamma-ray interactions with detector
cu in	Cubic inch
dBm	decibel metre
Deg.	Degrees of latitude or longitude
eTh	Equivalent thorium corresponding to measured gamma-rays from ^{208}thalium daughter product
eU	Equivalent uranium corresponding to measured gamma-rays from ^{214}bismuth daughter product
FID	Fiducial, one second counter, set to zero at start of each flight
ft	Feet
GHz	Giga hertz
GPS	Global positioning system
h	Hour
K	Potassium
keV	Kilo electron volts
kPa	Kilopascal
kts, knot	Nautical mile(s) per hour
l	Litre
M	meter
MeV	Mega electron volts
MHz	Megahertz
Min.	Minutes of latitude or longitude
mm	Millimetre
mR/h, µR/h	Milli roentgens per hour, micro roentgens per hour, unit of exposure per hour.
mrem	Millirem, dose equivalent units
mV	Millivolts
NAD27	North American Datum, 1927
Nal	Sodium iodide
Nal(Tl)	Sodium iodide, thallium activated
NORM	Naturally occurring radioactive material. Any nuclide that is radioactive in its natural physical state and is not manufactured, includes raw and waste products from mining and other industrial uses
NTSC	National Television Standards Committee
mCi, pCi,	Millicuries, picocuries, picocuries per gram

pCi/g	
ppm	Parts per million
UTM	Universal Transverse Mercator system of northing and easting
V	Volts
WGS84	US Department of Defense, World Geodetic System 1984