BUREAU OF RURAL SCIENCES

Operations and Processing Report

Honeysuckle Creek
Billabong Creek
Airborne Geophysical Surveys

May 2001 – July 2001

FLOWN AND PROCESSED BY KEVRON GEOPHYSICS FOR AND ON BEHALF OF THE BUREAU OF RURAL SCIENCES

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1. SURVEY AREA AND PARAMETERS

1.1 SURVEY AREA

The Honeysuckle Creek Geophysical Survey is located southeast of Shepparton, VIC, and covers portions of the following map sheets.

1:250,000 Map Reference	Sheet No.
Bendigo	SJ 55-01
Wangaratta	SJ 55-02

GDA94 co-ordinates for the Honeysuckle Creek survey area

	Longitude E	Latitude S
1	145.881000°	-36.551000°
2	145.881000°	-36.654000°
3	145.762000°	-36.676000°
4	145.721000°	-36.618000°
5	145.590000°	-36.742000°
6	145.566000°	-36.739000°
7	145.546000°	-36.753000°
8	145.388000°	-36.614000°
9	145.388000°	-36.423000°
10	145.741000°	-36.423000°
11	145.741000°	-36.499000°
12	145.770000°	-36.499000°°

	AREA A – Honeysuckle Creek
Number of Flight Lines	447
Number of Tie Lines	45
Totals	492
Flight Line Kms	12582.1
Tie Line Kms	1257.2
Totals	13839.3

The Billabong Creek Geophysical Survey is located north of Albury, NSW and covers portions of the following map sheets.

1:250,000 Map Reference	Sheet No.
Jerilderie	SI 55-14
Wagga Wagga	SI 55-15

GDA94 co-ordinates for the Billabong Creek survey area

	Longitude E	Latitude S
1	147.081000°	-35.529000°
2	147.081000°	-35.971000°
3	146.479000°	-35.971000°
4	146.479000°	-35.529000°

	AREA B – Billabong Creek
Number of Flight Lines	498
Number of Tie Lines	56
Totals	554
Flight Line Kms	28,091
Tie Line Kms	2,868
Totals	30,959

Location diagrams for the Honeysuckle Creek and Billabong Creek Survey areas are provided in ***APPENDIX 1***.

1.2 SURVEY PARAMETERS

Coverage specifications for the Honeysuckle Creek survey area	
Line spacing	100 metres
Tie line spacing	1000 metres
Line direction	east-west
Tie line direction	north-south
Terrain clearance	60 metres
Project number	908

Coverage specifications for the Billabong Creek survey area	
Line spacing	100 metres
Tie line spacing	1000 metres
Line direction	east-west
Tie line direction	north-south
Terrain clearance	60 metres
Project number	907

Time base and approximate sampling interval (in still air):

- Magnetics 0.1 second (7 metres approx.)
- Radiometrics 1.0 second (70 metres approx.)
- GPS system 1.0 second (70 metres approx.)
- Radar altimeter 0.1 second (7 metres approx)
- Barometric altimeter 0.1 second (7 metres approx)

2. LOGISTICS

2.1 OPERATIONS BASE AND SURVEY DATES

HONEYSUCKLE CREEK

Base Airfield: Shepparton (YSHT) VIC
36° 25.7' S 145° 23.6' E
Elevation 374 ft asl

Crew Accommodation: c/- Peppermill Motor Inn
Wyndham Street
SHEPPARTON VIC

BILLABONG CREEK

Base Airfield: Albury (YMAY) NSW
36° 04.2' S 146° 57.2' E
Elevation 539 ft asl

Crew Accommodation: Meramie Motor Inn
595 Kiewa St
ALBURY NSW

Survey Dates and Production Summary

Refer to ***APPENDIX 5*** for detailed production summary.

HONEYSUCKLE CREEK – SHEPPARTON	
Mobilisation	30th April 2001
Production flying commenced	2nd May 2001
Production flying completed	20th May 2001 22nd June 2001(Reflies)
Demobilisation	20th May 2001
Total days on job	27
Total number of flights	24
Total production days	21
Total days lost due to weather	.5
Total days lost due to aircraft maintenance	9.0
Total days lost due to other causes	.5
Total kilometres flown	13,845
Average acquisition rate - km per flight	577
km per production day	659

BILLABONG CREEK – ALBURY NSW	
Mobilisation	23rd May 2001
Production flying commenced	24th May 2001
Production flying completed	11th July 2001
Demobilisation	12th July 2001
Total days on job	51
Total number of flights	55
Total production days	40.5
Total days lost due to weather	9
Total days lost due to aircraft maintenance	7.5
Total days lost due to other causes	3.0
Total kilometres flown	34,178.2
Average acquisition rate - km per flight	621.42
km per production day	854.45

2.2 SURVEY AIRCRAFT SPECIFICATIONS AND FIELD CREW

Aircraft
Twin engine Rockwell
AeroCommander 500S "Shrike"
Registration VH KAV

Field Crew	Pilots	Operators
	I. Hussein	R. Rackham (Crew Leader)
	G. Wornes	M. Gray
	M. Cote	K. Cahill
	R. Jamieson	

Aircraft Specifications	
1. Aircraft	Aerocommander Shrike
2. Make	Rockwell
3. Model	500s
4. Type	Twin Piston Engine
5. VH-Registration/Year /Hours	KAC/1974/23691, KAV/1973/9460, WAM/1974/18337, EXS/1970/24798.
6. Cabin Dimensions, Excl Cockpit	Refer Pilot Operating Handbook
7. Cruising Range	955nm
8. Survey Power Settings Endurance	7 hrs30 min (450min) @21" 2200rpm
	6 hrs20min (380min) @ 22" 2300rpm
9. Engines / Make & Model	Lycoming IO540 EIB5
10. Engine Ratings	285 hp
11. Propeller Make	Hartzell
12. Propeller Diameter	80.0 inches (6.7 feet)
13. Propeller Gearing	N/A
14. Propeller Blades (Qty)	3
15. Ramp Weight (Inc Acqn Sys & Crystal)	3335 kg (with wingtip sensors)
16. MTOW (in Survey Configuration)	3335 kg
17. Landing Weight	3335 kg
18. Fuel Capacity (USG)	193 Useable
19. Fuel Capacity (Ltr)	730
20. Fuel Capacity (kg)	526
21. Max ROC 2 Engines	1400 fpm
22. Time to climb to 10000 feet	20 min
23. Time to climb to Service Ceiling	20 min
24. ROC – Maximum Weight	500 fpm
25. Max ROC 1 Engine @ SL ISA	75 fpm
26. Max ROC 1 Engine @ 5000'ISA @ 500lbs below MGW.	Maintain Height Only
27. Velocity of Minimum Control in the air	69 Knots

3. SURVEY EQUIPMENT, OPERATION AND QUALITY CONTROL

3.1 MAJOR EQUIPMENT SUMMARY

Aircraft Magnetometer	Geometrics G-822A Caesium vapour
Magnetic Compensator	RMS Instruments Automatic Aeromagnetic Digital Compensator (AADC)
Base station magnetometer	Geometrics G856 proton precession
Gamma-ray spectrometer	Exploranium GR820, 256 channels
Gamma-ray detector	NaI(T1) crystals; 50 L down
Altimeter	Sperry AA-210 radio altimeter
Barometer	Rosemount 1241m
Thermometer	Rosemount Model 2200 temperature sensor
Navigation system	Fugro Omnistar Virtual Base Station mode with G12 Ashtech GPS receiver.
Flight Track Recording	VHS video tracking camera with wide-angle lens
Data acquisition system	RMS Instruments DAS-8 digital acquisition system

3.2 MAGNETOMETER AND COMPENSATOR

A Geometrics G-822A optically pumped caesium vapour magnetometer was used for the survey with the sensor mounted in a tail stinger on the aircraft. The magnetometer sensor was coupled to a RMS Instruments Automatic Aeromagnetic Digital Compensator (AADC) to produce real time compensation for the effects of the aircraft's motion, changes in attitude and heading. The AADC interference coefficients were calculated from compensation flights carried out before the survey commenced and after aircraft maintenance. The AADC output data, with a resolution and sensitivity of 0.001 nT at a sampling rate of ten (10) times per second, were recorded digitally and in analogue form.

In addition to the tail "stinger" mounted sensor, wing-tip sensors were also installed to acquire transverse and horizontal gradient data.

The noise envelope for compensated magnetometer readings was less than 0.1 nT (refer to Section 4.1).

3.3 BASE STATION MAGNETOMETER

A Geometrics Caesium Vapour Magnetometer Base Station (model G823B) sampling at 1 second intervals, was used to measure diurnal variation of the magnetic field. A Geometrics G856 proton precession magnetometer base station was also established as a storm monitor and backup for the caesium vapour base station. Both base stations were established in an area of low gradient at Shepparton Airport for the Honeysuckle Creek Area and Albury Airport for the Billabong Creek Area. The base stations were operated continuously throughout the survey flying period.

The base station data were closely examined after each days production flying to determine if any data had been acquired during periods of out-of-specification diurnal variation.

Refer to APPENDIX 7 for Base Station Magnetometer plots.

3.4 SPECTROMETER

An Exploranium GR-820, 256-channel gamma ray spectrometer with automatic crystal gain control was used to record 256 channels of data. Total downward crystal array volume was 50 litres. System sample time and live time were also recorded. The digital data and four channels of analogue data were recorded once per second.

The pre-set spectral window limits were:

	Spectrometer Channel Number		**Equivalent Energy Levels (keV)**	
Window	**Lower**	**Upper**	**Lower**	**Upper**
Total Count	34	237	410	3 005
K-40	116	132	1 370	1 562
Bi-141	140	156	1 660	1 858
Tl-208	204	237	2 410	2 804
Cosmic	255	255	3 000	∞ kev

Note that the GR820 channels were reset so that the 2.615 MeV Tl-208 peak falls in channel 221 and not in the factory-set channel 206.

3.5 ALTIMETERS

A Sperry AA-210 Radio Altimeter system was used to measure ground clearance. The radio altimeter indicator provides an absolute altitude display from 0 - 750 metres (0 - 2,500 feet) with a sensitivity of 4 mV/ft.

A Rosemount 1241m barometer, with an output sensitivity of 0.666 mV/ft, was used to measure barometric altitude of the aircraft.

The radar altimeter system was checked prior to commencement of production flying. This involved flying the aircraft at 30 metre height intervals, up to a height of 300 metres over the base of operations airstrip using the aircraft's barometric altimeter as the height reference. Radar altimeter and GPS height data were recorded for each flight interval flown. A comparison of these data with the aircraft's barometric altimeter verified that the system was operating satisfactorily.

3.6 NAVIGATION AND FLIGHT PATH RECOVERY

Aircraft navigation was controlled by real-time differential GPS using an Ashtech G12 GPS receiver in the aircraft with pseudo range corrections obtained through the commercial FUGRO VBS system transmitting via the OPTUS B satellite. The horizontal position of the aircraft was fixed and recorded once per second. The on-board pilot guidance steering signal was updated once every half second.

The pseudo range information was recorded every 1 seconds at both the aircraft receiver and also at a base station receiver situated at the crew operations base in Shepparton Airport (YSHT) & Albury Airport (YMAY). The position of both GPS base stations were calculated by averaging data acquired over a 24 hour period using the Ashtech "Ranger" PPAVG software. Refer to ***APPENDIX 3 for Base Station Location Diagram.***

The differentially corrected flight path data were inspected after each flight for any deviations of flight path from specifications and for any gaps caused by momentary loss of satellites. Flight path quality was confirmed at Kevron's processing centre by maps, plotted from the recorded real time data, highlighting any portions of lines, which exceeded the specified horizontal and altitude tolerances.

To verify the repeatability of the GPS navigation system, real time DGPS data were recorded with the morning and afternoon radiometric calibrations with the survey aircarft parked in the same position. The results indicated that the GPS system was functioning correctly with all static positions repeatable within two metres.

3.7 FLIGHT TRACK RECORDING SYSTEM

The flight path of the aircraft was recorded with a National CCD colour video camera and a VHS video recorder. Line and fiducial numbers were recorded on the video image.

3.8 DATA ACQUISITION

A RMS Instruments DAS-8 Data Acquisition System was used to record all data in digital format on hard disk. Survey data were downloaded post flight into a field PC where backup copies were copied to CD and dispatched to Perth for processing. Data verification was undertaken in the field using a combination of Kevron proprietary software and CHRISDBF, a commercial database software package.

3.9 GENERAL QUALITY CONTROL

A running log of each flight was maintained recording details of all lines flown. Transcribed flight logs are included in ***APPENDIX 4.*** Equipment tests and calibrations are described in Section 4 and tabulations of the calibration and test flight data are in ***APPENDIX 6.***

Field data were sent to Kevron's processing centre in Perth where they were further inspected for data quality and conformance to specifications before commencing processing.

3.10 SAFETY MANAGEMENT

All aircraft operations, including pilot flying hours and aircraft maintenance, complied with the requirements of the Federal Civil Aviation Safety Authority (CASA) and the CASA-approved procedures set out in Kevron's Aircraft Operations Manual.

A revision of Kevron's Occupational Health, Safety and Environment was undertaken in January 2001 and a comprehensive Safety Management System was implemented in February 2001. The Safety Management System includes Risk Evaluation Processes and Procedures and Occupational Health Safety & Environment Policies for the entire Kevron Group of Companies.

Copies of Kevron's Occupational Health, Safety and Environment Polices are provided in ***APPENDIX 9.***

All aircraft operations, including pilot flying hours and aircraft maintenance, complied with the requirements of the Federal Civil Aviation Safety Authority (CASA) and the CASA-approved procedures set out in Kevron's Aircraft Operations Manual.

An integral part of the Safety Management System provides for the installation of a Flight Following System that transmits a position via satellite at pre determined intervals. The Fugro EagleStar Flight Following System is fitted to all Kevron aircraft and position information was transmitted every 4 minutes to Fugro's Network Control Centre in Perth. This information can be monitored by accessing the FUGRO web page where the updated flight path is displayed. In the event that positional information from the aircraft is lost for a period exceeding 12 minutes or three consecutive transmissions, an alarm is raised and a SMS text message sent to nominated contacts and the Emergency Response plan implemented.

4. CALIBRATIONS

4.1 MAGNETICS

Compensation coefficients for the AADC were established by flying a "compensation box" test (a series of pitch, roll and yaw manoeuvres in each of the four cardinal headings) before survey production commenced.

Area A – Honeysuckle Creek – Shepparton

Location: 10 NM North of Shepparton
Latitude 36° 06.3041' S Longitude 145° 23.2913' E

	SDU	SDC	IR	VN
Tot Field #1	0.368.2	0.0274	13.4	26.6
Tot Field #2	0.7158	0.08836	8.1	59.0
Tot Field #3	1.195	0.04844	24.7	33.5
Gradient 1	7.964	0.2031	39.2	57.3
Gradient 2	8.751	0.2433	36.0	51.6
Gradient 3	10.20	0.1738	58.7	51.6

SDU, SDC= Respectively, the standard deviation of uncompensated and compensated data;
IR (Improvement Ratio) = SDU/SDC;
VN = Vector Norm, measure of degree of difficulty in calculating coefficients.

Area B – Billabong Creek – Albury NSW

Location: 40 NM North West of Albury
Latitude 36° 00.5026' S Longitude 146° 16.6151' E

	SDU	SDC	IR	VN
Tot Field #1	0.2969	.02616	11.4	27.8
Tot Field #2	0.6556	.05479	12.0	43.4
Tot Field #3	1.109	.05127	21.6	31.2
Gradient 1	7.687	.1603	47.2	55.2
Gradient 2	9.603	.3295	29.1	61.2
Gradient 3	10.971	.2521	43.5	55.2

SDU, SDC= Respectively, the standard deviation of uncompensated and compensated data; IR (Improvement Ratio) = SDU/SDC;
VN = Vector Norm, measure of degree of difficulty in calculating coefficients.

The AADC solution statistics for the compensation test is presented in the table above. A check "compensation box" flight made immediately after the test indicated a maximum noise envelop of 0.1 nT. Refer to ***APPENDIX*** 6 for compensated and uncompensated profiles.

The parallax error was established by flying the radiometric test line in opposite directions and using the peak of a prominent magnetic feature as a reference.

The following Parallax corrections were applied:

Magnetics	5 fids	(approx 35 metres)
Radiometrics	9 fids	(approx 63 metres)
DTM	no parallax applied	

A heading error check was flown on 3rd May 2001 to determined heading errors on the 4 cardinal headings. Traverse line 10580 and Tiel Line 9008 from the Honeysuckle Creek survey area were used as the reference lines. The paralax corrected intersection values were exctracted and compared for all 4 headings. The results of the Heading check are presented in Appendix 6.

4.2 RADIOMETRICS

4.2.1. Aircraft and Cosmic Background Corrections

Aircraft and Cosmic spectra were determined from high altitude calibration flights using the procedure described by R.L. Grasty and B.R.S Minty (Record 1995/60) A Guide to the Technical Specifications for Airborne Gamma-Ray Surveys.

4.2.2 Pre and Post Flight Checks

In order to verify the system sensitivity remained constant throughout the survey, thorium source test and background measurements were carried out before and after every day of flying. A source was placed in a rack mounted above each detector so that all detectors were adequately illuminated. A statistical summary of the checks is presented in ***APPENDIX 10***

4.2.3 Test Line

A test line approximately 8 kilometres long was chosen at each Base of Operations. The start and end co-ordinates are as follows; (WGS84)

SHEPPARTON	**Latitude S**	**Longitude E**
Start	-36° 33’ 00.0000” S	145° 16’ 25.0000” E
End	-36° 25’ 59.0112” S	145° 16’ 45.1618” E

ALBURY	**Latitude S**	**Longitude E**
Start	-36° 06’ 26.6417” S	146° 35’ 30.2097” E
End	-36° 00’ 21.2307” S	146° 36’ 34.8511” E

Refer to ***APPENDIX*** 1 for Test Line Location Diagrams

4.2.4 Compton Stripping Coefficients

The following Compton stripping coefficients, derived from calibrations over test pads in Perth were used in subsequent processing:

Alpha	0.278075
Beta	0.415943
Gamma	0.842565
a	0.0994

4.2.5 Spectrometer Count-rate Sensitivities

Broad source sensitivities for each of the radio-element windows were obtained from a flight line flown at a height of 60 m over the Carnamah Test Range and a corresponding line on the ground surveyed with a calibrated hand-held spectrometer supplied by Tesla Geoscience. The Carnamah Test Range is located approximately 10 kilometres east of Carnamah, 200 kilometres north of Perth, on the Carnamah-Belvoir Road. The Test Range follows the power line south for eight kilometres crossing undulating wheat crops and rocky scrub covered hills.

The aircraft acquisition system was not changed between the date of the calibration flight and the survey dates. The following Sensitivity values were obtained:

SK	225.8433
SBi	11.4295
STh	11.8320
STot	49.0693

5. DATA PROCESSING

5.1 DATA VERIFICATION AND EDITING

Rigorous data verification was undertaken in the field using a combination of ChrisDBF software commercially available data verification Data Base software package) and Kevron proprietary software. Acquired data were routinely backed up onto CD-ROM at the completion of data verification.

Any data found to be out of tolerance was flagged as a reflight and reflown.

The field data were sent regularly to Kevron's processing centre in Perth for further verification and editing with in-house software installed on Sun Sparc 20 workstations.

The data were loaded into a database and a statistical report generated for each variable on a line by line basis. The data were then edited for scrubbed or duplicate lines and checked for spikes, steps or high noise levels. Lines with any out-of-specification data were flagged for reflight.

5.2 FLIGHT PATH RECOVERY

The differentially corrected GPS data were converted from WGS84 to GDA94 Universal Transverse Mercator coordinates.

Both the Honeysuckle Creek and Billabong Creek survey areas lie within grid UTM Zone 55 with a central meridian of 147° East, with an x-bias of 500 kilometres and a y-bias of 10,000 kilometres.

Flight path maps were generated to verify the off-line tolerances and to make sure all necessary data had been loaded into the geophysical database.

5.3 MAGNETIC PROCESSING

After correcting the magnetic data for diurnal variations, the International Geomagnetic Reference Field (IGRF) was subtracted and the data were tie line levelled. These processes are described more fully below.

5.3.1 Diurnal Correction

The diurnal data were edited to keep only those readings taken during flight time. The data were visually checked on the computer screen for spikes, noise and any apparent cultural magnetic events.

After editing, the data were low pass filtered using a twenty-term, spatial domain filter, which removed periods of less than thirty seconds. The data were again checked visually for integrity after the filtering process.

The filtered data were synchronised with the airborne data, interpolated and subtracted

from the airborne data, one sample at a time. After subtraction, the mean diurnal value was added back to the airborne data for each line to produce diurnally corrected data.

5.3.2 Subtraction of the IGRF

The International Geomagnetic Reference Field (IGRF) was removed from the diurnally-corrected data by fitting a second order polynomial surface to thirteen coefficients computed from the IGRF model and then subtracting the IGRF values on a sample by sample basis.

The IGRF 2000 model updated to 2001.4 (Honeysuckle Creek) and 2001.5 (Billabong Creek) was used with the following values:

Area	Inclination	Declination	Total Field
Honeysuckle	-67.858299 (deg)	11.697905 (deg)	59535.91 (nT)
Billabong Creek	-67.011963 (deg)	11.889520 (deg)	58923.71 (nT)

A mean value for the IGRF Total Field was added to the final magnetic data.

5.3.3 Tie Line Levelling

The diurnally corrected and IGRF-removed data were processed using a Kevron proprietary-levelling program.

The program compares the magnetic differences at intersections of the flight lines and tie lines and calculates individual magnetic field biases for each flight line based on the tie line intersection. The miss-ties are minimised in a least-squares sense for all intersections. The biases are manually evaluated and selectively applied. Further reduction of the miss-ties can be removed by fitting a polynomial to produce levelled magnetic data.

The levelled data were then gridded to a grid cell size of one fifth of the minimum line spacing (20m x 20m mesh for 100m flight lines) using a minimum curvature algorithm based on Briggs (1974). The gridded data were displayed on an image processor to check data integrity and data levelling. Further levelling adjustments were made and checked until all line dependencies were removed.

5.3.4 Gradient Processing

The transverse gradient output by the AADC, left wing tip minus right wingtip, filtered and compensated, was divided by the sensor separation (16.49 m). The resulting data along with the horizontal derivative of the tail sensor data was used to compute the X and Y gradient.

The X and Y gradients were then corrected for heading errors and levelled. No tie line levelling or microlevelling was performed on the X and Y gradient data. The final gradients were used to assist the gridding process to estimate the unfilled grid node values.

5.4 RADIOMETRIC PROCESSING

5.4.1 System Deadtime and Energy Calibrations

Following correction for system deadtime, the 256 channel spectrometer data were energy calibrated using the following procedure:

For each line, the individual 256 channel data from each sample point were stacked to produce a single spectrum. The peak positions of the standard potassium and thorium windows were found by performing a gaussian fit to the spectral data for the energy range of each window after first removing the Compton continuum slope. If the measured peak positions were shifted by more than one channels for the thorium peak or 0.5 channels for the potassium peak, an energy recalibration was performed to obtain the correct spectral channel positions for the lower and upper bounds of each of the required windows. Using these corrected channel limits, new window counts were then extracted from the 256 channel data for each 1 second data sample on the line

5.4.2 Noise Adjusted Singular Decomposition (NASVD)

The raw gamma-ray spectra were smoothed using the Noise Adjusted Singular Value Decomposition (NASVD – Hovgaard and Grasty, 1997) spectral smoothing technique. This technique is a spectral component analysis procedure for the removal of noise from gamma-ray spectra. The observed spectra were transformed into orthogonal spectral components in which lower order components represent the signal and higher order components represent noise. Noise was removed from the observed spectra by rejecting the noise components and reconstructing the spectra using the first 7 (seven) eigenvectors.

Data has been tie-levelled and micro-levelled to remove minor residual errors.

5.4.3 Aircraft and Cosmic Background Removal

Aircraft and cosmic background were removed from the data using the normalised 256 channel cosmic spectrum for the aircraft, and the aircraft 256 channel background spectrum.

5.4.4 Airborne radon removal

Data were corrected for airborne radon using Minty (1996 – Alt Method B) two component spectral ratio method.

Calibration constants for Method B derived directly from observed radon and ground spectra at a height of 60m STP. C_1, *and* C_2, are the ratios between the 0.609 MeV peak count rate and the conventional U window count rate for a radon spectrum and a composite K, U and Th ground spectrum respectively.

Calibration Constants for Method B	
C1	1.944
C2	0.859

5.4.5 Effective Altitude Calculations and Compton Scattering Corrections

At this point, the conventional radiometric windows are extracted from the 256 channel data and all further gamma-ray corrections are performed using three-window radiometric data processing.

Following reduction of the altitude data to effective altitude at standard temperature and pressure as described in Grasty and Minty (1995), Compton scattering stripping was carried out on the background corrected count rates in the potassium, uranium and thorium channel data using the coefficients.

5.4.6 Height attenuation corrections

A height attenuation factor was applied to reduce the data for each channel to a nominal datum of 60 m above ground level. The program used, limits corrections to data at terrain clearances between 30m and 250m. Data recorded at terrain clearances outside these limits are corrected assuming they are at these limits.

The attenuation factors used are listed below and were determined from tests carried out over the Carnamah Test Range.

Height Attenuation Coefficients	
Total_Count	-0.0072
Potassium	-0.0095
Uranium	-0.0084
Thorium	-0.0075

Due to the nature of the topography of the survey area ie. trees and fences etc. the radio altimeter channel was altered. The altered altimeter was created by subtracting the GPS height from the levelled DTM. The resulting channel was then inverted and any features greater than 20 metres over .2 seconds was nulled. The nulled sections of the channel were then interpolated. This channel was used in the height corrections during the radiometric processing.

5.4.7 Conversion To Ground Element Concentrations

The air-absorbed dose rate at ground level from natural sources of radiation was calculated from the total count rate following the procedure as described in Grasty and Minty (1995) using the equation

$$\mathbf{D = N_{TC} / F}$$ (Equation 4.18, page 42)

where D = air absorbed dose rate in nanograys per hour;
N_{TC} = fully corrected total count rate; and
F = experimentally determined conversion factor.

The conversion factor, F, was determined using data flown over a line on the Carnamah Test Range

The average ground concentrations were calculated using the procedure described in section 5.4.6 above.

The average air-absorbed dose rate in nGh-1 for these lines given by

$$A = 13.1 * K + 5.43 * U + 2.69 * Th$$ (Equation 4.19, page 42)

where A = average air - absorbed dose rate; and
K = %K, U = ppm eU and Th = ppm eTh.

5.4.8 Levelling

The corrected and reduced radiometric data were tie line levelled and micro-levelled using the procedure described above for the magnetic data.

5.5 DIGITAL ELEVATION MODEL

A digital elevation model (DEM) was computed by subtracting the terrain clearance measured by the radar altimeter from the GPS measured aircraft altitude to obtain a nominal ground elevation. The nominal ground elevation data were tie line levelled and micro-levelled using the same technique described for the levelling of the magnetic data.

Allowance was made for the constant 3.9 m elevation difference between the radar altimeter and the GPS antenna. A set of geoid-ellipsoid separation N values were obtained from AUSLIG, gridded and values interpolated for each point along the survey lines. The AUSGEOID N values were subtracted to produce heights relative to AHD.

5.6 DELIVERABLE PRODUCTS

- Supply of airborne magnetic located and gridded data (including horizontal gradient data) on CD ROM as per the Technical Specifications.
- Supply of airborne gamma-ray spectrometric located and gridded data on CD ROM as per the Technical Specifications.
- Supply of digital elevation model located and gridded data on CD ROM as per the Technical Specifications.
- Supply of Raw Data to the Technical Specifications including;
  - a) navigation data;
  - b) raw 256 channel gamma-ray spectrum for each observation point;
  - c) gamma-ray spectrometic calibration and background data;
  - d) diurnal data
- Supply of Preliminary Gridded data to the Technical Specifications.
- Supply of an Operations and Processing Report to the Technical Specifications.

6. REFERENCES

- Briggs, I.C., 1974. Machine Contouring Using Minimum Curvature. Geophysics, v.39: p. 39 - 48.
- R.L. Grasty and B.R.S Minty, 1995: A Guide To The Technical Specifications For a Airborne Gamma-Ray Survey. AGSO Record 1995/60.
- Hovgaard, J. and Grasty, R.L, (1997). Reducing noise in airborne gamma-ray data through spectral component analysis. Exploration 97, Ontario Geological Survey.
- Minty, B.R.S., 1996. The analysis of multichannel airborne gamma-ray spectra. PhD Thesis, Australian National University.