Thomson Aviation

Geophysical Survey

Spirit Hills, NT (GA#1274)
Delamere, NT (GA#1274)
Geophysical Survey
Processing Report

January 2016

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1. Datum Specification

The output survey coordinates are based on the Geocentric Datum of Australia 1994 (GDA94), zone 52.

It has the following parameters:

Projection name:	Map Grid of Australia
Datum:	Geocentric Datum of Australia (GDA94)
Reference Frame:	ITRF92 (International Terrestrial Reference 1992)
Epoch:	1994.0
Ellipsoid:	GRS80
Semi-major axis:	6,378,137.0 metres
Inverse flattening:	298.257222101
False Northing:	10,000,000 m N
False Easting:	500,000 m E
Scale Factor:	0.9996

2. Magnetic processing

2.1 Processing Flow

The diurnal base station data was checked for spikes and steps, and suitably filtered prior to the removal of diurnal variations from the aircraft magnetic data.

The diurnal data was filtered with a 3 point wide Naudy filter to identify and remove noise below 0.05nT.

The filtered diurnal are then applied to the survey data by synchronising the diurnal data time with the aircraft survey time. The average diurnal base station value was added to the survey data.

The aircraft data was subject to field QC during the acquisition phase, and then additional QC during the final processing.

Parallax correction of 0.135 seconds was applied to the magnetic data.

A fourth difference filter was run on the raw magnetic survey data in order to identify any remaining spikes in the data, which were manually edited from the data.

The X and Y positioning of the data was then checked for spikes before applying the IGRF correction. Any spikes in the positions were manually edited.

The IGRF 2015 (Geosoft) correction was calculated at each data point taking into account the height above sea level using the GPS altitude. This regional magnetic gradient was subtracted from the survey data points. Average of IGRF was added back to the data.

The data was then tie-line levelled and micro-levelled.

2.2 Compensation

The data was compensated post flight using a 16 term model based on the work done by C.D. Hardwick.

Magnetic compensation sequences were flown before acquisition commenced and after routine maintenance was performed, as required. The resulting coefficients were used for post flight magnetic compensation.

2.3 Magnetic Model

IGRF was removed using the GPS altitude.

The magnetic model for the centre of the area is detailed below:

Model	IGRF 2015
Declination	3.231 degrees
Inclination	-43.885 degrees
Field strength	47870.642nT
Grid zone	52

Table 1. IGRF details

2.4 Diurnal Base Value

The average diurnal base value was 47266.378nT.

2.5 Tie Line levelling Method

Tie line levelling was applied to the data by least squares minimisation, using a polynomial fit of order 0, of the differences in magnetic values at the crossover points of the survey traverse and tie line data.

The least squares tie line levelling process employs a two pass Gauss-Seidel iterative scheme. The essential steps in this process are:

In the first pass the tie lines were first adjusted to minimise, in the least squares sense, the crossover values with the traverse line values being held constant.

The second pass held the levelled tied line values constant, and minimised in the least squares sense, the crossover values with traverses.

The DC correction values to be applied to the traverse lines and tie lines were then applied to the data.

2.6 Polynomial levelling Method

In order to remove any residual long wavelength variations in the tie line levelled data along the traverse lines, least squares polynomial levelling was applied. A polynomial order of 0 was used for both traverses and ties.

Polynomial levelling was used in the magnetic levelling process.

2.7 Micro-levelling Method

Micro-levelling was applied to the Polynomial levelled data to remove any residual levelling artifacts using Intrepid Data Processing software. The software uses a two step process involving de-corrugation and micro-levelling.
De-corrugation is first applied to the Polynomial levelled gridded data, which detects residual features parallel to the acquisition line direction and produces a grid of the corrections required to remove the levelling artifacts.
Micro-levelling is then applied, which extrapolates the correction values from the de-corrugation grid to an appropriate value for each point in the traverse lines. It then applies the corrections to the point data to remove the residual levelling artifacts.

This micro-levelling process is based on a paper by Minty, 1991.

2.8 Gridding Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs, 1974. The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel.

A tension factor of 0 was used to interpolate the magnetic data.

The mesh size for data interpolation was 20% of the line spacing.

3. Radiometric Processing

3.1 Processing Flow

The processing steps radiometric data were as follows:

1. A parallax correction of 0.3 sec was applied to the data.
2. Checked radar altimeter, pressure and temperature data for spikes. No filter was applied.
3. NASVD spectral smoothing done
   - Examine the output to determine the number of components required.
   - Select 8 components for spectral reconstruction.
4. Standard 256 channel radiometric corrections done:
   - Dead-time correction performed on 256 channel data.
   - Check if energy recalibration required
   - Remove 256 channel aircraft and cosmic backgrounds from the data
   - Remove background radon from window data using Minty's method (1996)
   - Perform STP height corrected spectral stripping
   - Perform STP height correction of window data to specified survey height (80m).
5. Micro-levelling

Spectral smoothing was applied using the NASVD process, and spectral reconstruction was employed using 8 spectral components.

Micro-levelling was applied.

3.2 Principal Component Spectral Vectors

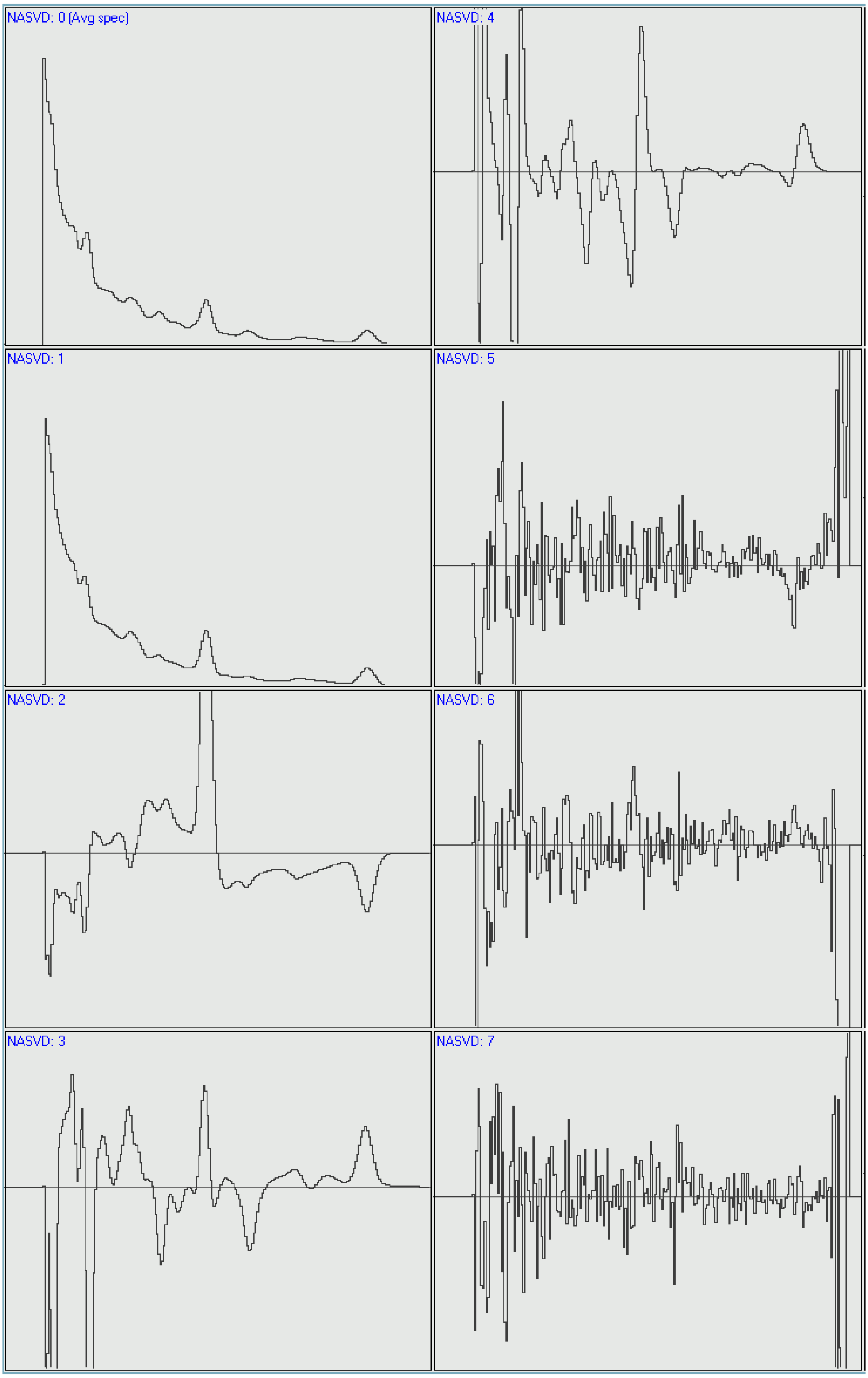

Figure 1. Principal components. Aircraft: SUX

3.3 Window Energy Limits

The energy bounds for the windows were

Window Name	Energy Range (Mev)
Potassium	1.374 – 1.566
Thorium	2.416 – 2.799
Uranium	1.662 – 1.854
Total Count	0.414 – 2.799

Table 2. Energy range

3.4 Spectral Stripping Ratios

Aircraft	Detector #	Alpha	Beta	Gamma	a	b	g
SUX	5427	0.272	0.400	0.767	0.047	0.001	0.000
	5428	0.283	0.415	0.786	0.043	0.004	0.001
	Average	0.278	0.408	0.777	0.045	0.003	0.001

Table 3. Stripping ratios

The reverse stripping ratios were adopted from theoretical physical constants. Note that the reverse stripping ratios 'b' and 'g' are not used in the processing.

3.5 Aircraft, Cosmic Backgrounds and Height Attenuation coefficients

The Aircraft and Cosmic Background values are for the windows only. During processing the equivalent 256 channel aircraft and cosmic backgrounds are removed.

The Height attenuation coefficients were determined from communication with Mr Jens Hovgaard. These values are based on his testing and IAEA values.
These ratios are determined by the natural laws of radiometric attenuation, so one set of ratios was used for the survey.

Aircraft	Background	Total Count	Potassium	Uranium	Thorium
SUX	Aircraft	28.611	13.163	0.0	0.0
	Cosmic	1.124	.064	0.054	0.064
	Height Attn	-0.007434	-0.009432	-0.008428	-0.007510

Table 4. Background and height attenuation coefficients

3.6 Conversion to Ground Concentrations

	Total Count Cps to Dose rate	Potassium Cps to Percent	Uranium Cps to PPM	Thorium Cps to PPM
Conversion Factor	30.332	86.212	14.914	5.030

Table 5. Ground concentration convention coefficients

Above coefficients were derived from a flight over the test range in WA performed on March, 2015.

3.7 Micro-levelling Method

Micro-levelling was applied to the processed data to remove any residual artifacts using Intrepid Data Processing software. The software uses a two step process involving decorrugation and micro-levelling.
Decorrugation is first applied to the Polynomial levelled gridded data, which detects residual features parallel to the acquisition line direction and produces a grid of the corrections required to remove the levelling artifacts.
Micro-levelling is then applied, which extrapolates the correction values from the de-corrugation grid to an appropriate value for each point in the traverse lines. It then applies the corrections to the point data to remove the residual levelling artifacts.

This micro-levelling process is based on a paper by Minty, 1991.

3.8 Gridding Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs, 1974.

The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel, 1990.

A tension factor of 0 was used to interpolate the data

The mesh size for data interpolation was 20% of the line spacing.

4. Elevation Processing

4.1 Processing Flow

The processing steps for digital elevation data were as follows:

1. Parallax check. No parallax correction is required for the GPS data.
2. Calculation of raw digital elevation data by subtracting the radar altimeter from the GPS altitude. Height difference between GPS antenna and radar altimeter (1.60m) were also included.
3. Tie line levelling
4. Micro-levelling
5. Aircraft elevation
6. Adjusting to AHD

4.2 Tie Line levelling Method

Tie line levelling was applied to the data by least squares minimization, using a polynomial fit of order 0, of the differences in data values at the crossover points of the survey traverse and tie line data.
The least squares tie line levelling process employs a two pass Gauss-Seidel iterative scheme. The essential steps in this process are:
In the first pass the tie lines were first adjusted to minimize, in the least squares sense, the crossover values with the traverse line values being held constant.
The second pass held the levelled tied line values constant, and minimized in the least squares sense, the crossover values with traverses.

The DC correction values to be applied to the traverse lines and tie lines were then applied to the elevation data.

4.3 Polynomial levelling Method

In order to remove any residual long wavelength variations in the tie line levelled data along the traverse lines, least squares polynomial levelling was applied. A polynomial order of 3 was used for both traverses and ties.

Polynomial levelling was used in the elevation levelling process.

4.4 Micro-levelling Method

Micro-levelling was applied to the Polynomial levelled data to remove any residual levelling artifacts using Intrepid Data Processing software. The software uses a two step process involving decorrugation and micro-levelling.
Decorrugation is first applied to the Polynomial levelled gridded data, which detects residual features parallel to the acquisition line direction and produces a grid of the corrections required to remove the levelling artifacts.
Micro-levelling is then applied, which extrapolates the correction values from the de-corrugation grid to an appropriate value for each point in the traverse lines. It then applies the corrections to the point data to remove the residual levelling artifacts.

This micro-levelling process is based on a paper by Minty, 1991.

4.5 Aircraft elevation

Aircraft elevation (ElevAC) channel was calculated by subtracting radar altimeter channel from processed elevation channel before adjusting to AHD.

4.6 Adjusting to AHD

N value correction to AHD was acquired from AusGeoid09 grid version 1.01. Data interpolation was done using GeoidInterpolation software version 1.03 (Inter-government Committee on Surveying & Mapping, 2011) based on Long, Lat coordinates. N value was then subtracted from the levelled elevation data.

4.7 Gridding Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs, 1974.

The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel, 1990.

A tension factor of 0 was used to interpolate the data

The mesh size for data interpolation was 20% of the line spacing.

5. Deliverable Items

The deliverable items included all digital data. The located data conformed to ASEG-GDF II format and the gridded data was suppled in ERMapper format. The description of the located data is below:

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Located data supplied in ASEG GDF2 format

File name	Definition
RAW_MAG	Raw magnetic data
RAW_ELEV	Raw elevation data
RAW_RAD	Raw 256 channel and window radiometric data
FINAL_MAG	Final magnetic data
FINAL_ELEV	Final elevation data
FINAL_RAD	Final Radiometric Data

Gridded data supplied in ER Mapper format

File name	Definition	Units
MagLev	Final magnetic gridded data	nT
MagLev_1VD	Final 1st Vertical derivative	nT/m
MagLev_2VD	Final 2nd Vertical derivative	nT/m
MagLev_RTP	Final RTP magnetic gridded data	nT
MagLev_RTP_1VD	Final 1st Vertical derivative of RTP	nT/m
MagLev_RTP_2VD	Final 2nd Vertical derivative of RTP	nT/m
ElevAHD	Final elevation (AHD) gridded data	m
NASVDTotDose	Final smooth radiometric dose rate gridded data	nGy/hr
NASVDKperc	Final smooth radiometric potassium gridded data	percent
NASVDThppm	Final smooth radiometric thorium gridded data	ppm
NASVDUppm	Final smooth radiometric uranium gridded data	ppm
NonNASVDTotDose	Final radiometric dose rate gridded data	nGy/hr
NonNASVDKperc	Final radiometric potassium gridded data	percent
NonNASVDThppm	Final radiometric thorium gridded data	ppm
NonNASVDUppm	Final radiometric uranium gridded data	ppm

6. References

Briggs I. C., 1974: Machine contouring using minimum curvature. *Geophysics*. Vol. 39, No. 1. February 1974. pp. 39-48.

Geoscience Australia, 2010. 1 Second SRTM Derived DSM and DEM User Guide, 2010. (Distributed by Geoscience Australia with the 1 second DEM products.)

Minty, B.R.S., 1991. Simple Micro-Levelling for Aeromagnetic Data,., Exploration Geophysics (1991), **22**, 591-592.

Smith, W. H. F, and P. Wessel, 1990, Gridding with continuous curvature splines in tension, Geophysics 55, 293-305

7. Appendix B: ASEG-GDF II description files

7.1 Common header

```
CLIENT DETAILS
---------------
Company Flown for:  Geoscience Australia
Company Flown by :  Thomson Aviation Pty. Ltd.
Company Processed:  Thomson Aviation Pty. Ltd.
Company Job      :  Thomson 15027
GA Project       :  1274 NT



AIRBORNE SURVEY EQUIPMENT:
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Aircraft                          : Cessna 210
Magnetometer                      : Kroum
Magnetometer Resolution           : 0.001 nT
Magnetometer Compensation         : Post Flight
Magnetometer Sample Interval      : 20 Hz, Approx 3.75 meters
Data Acquisition                  : GeOZ Model 2013
Spectrometer                      : Radiation Solutions RS 500
Crystal Size                      : 33 lt downward array
Spectrometer Sample Interval      : 0.5 Seconds (approx 37 meters)
GPS Navigation System             : Novatel 951R GPS Receiver


AIRBORNE SURVEY SPECIFICATIONS
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Area: Delamere/Spirit Hills, WA

Flight Line Direction             :    000 - 180 degrees
Flight Line Separation            :          400 metres
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Tie Line Direction              :    090 - 270 degrees
Tie Line Separation             :         4000 metres
Terrain Clearance               :           80 metres (MTC)
Survey flown                    :       2015.7 – 2015.8
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DATUM and PROJECTION
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```
Datum                                    :  Geodetic Datum of
                                Australia 94.  GDA94
Projection                          :  Map Grid of Australia.
                                MGA
Zone                                :  Zone 52
```

7.2 Additional details

- Raw elevation data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
GPSTime	F9.2	-9999.99	S	GPS time after midnight in seconds
GPSHt	F7.2	-99.99	m	GPS Height

- Raw radiometric data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
RawTC	I6	-99	cps	Raw Total count
RawK	I5	-99	cps	Raw Potassium
RawU	I5	-99	cps	Raw Uranium
RawTh	I5	-99	cps	Raw Thorium
Cosm	I5	-99	cps	Cosmic
Samp	F4.1	-0.9	sec	Sampling time
LowE	F4.1	-0.9	MeV	Low Energy bound of Spectrum
HighE	F4.1	-0.9	MeV	High Energy bound of Spectrum
Live	F6.3	-0.999	sec	Live time
Spectrum	256I5	-999	cps	Spectrum (256 channels)

- Raw magnetic data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
FluxX	F10.2	-99999.99	nT	Fluxgate X
FluxY	F10.2	-99999.99	nT	Fluxgate Y
FluxZ	F10.2	-99999.99	nT	Fluxgate Z
MagRaw	F11.4	-9999.9999	nT	Raw magnetics
MagLev	F11.4	-9999.9999	nT	Compensated magnetics
Diurnal	F9.2	-9999.99	nT	Diurnal
IGRF	F9.2	-9999.99	nT	IGRF

- Final elevation data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
ElevAHD	F7.2	-99.99	m	Elevation (AHD)
ElevAC	F7.2	-99.99	m	Aircraft Elevation
Nvalue	F6.2	-9.999	m	N value to AHD

- Final radiometric data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
NASVDTotDose	F7.2	-99.99	nGy/h	Total Dose. NASVD smoothed
NASVDK	F7.3	-9.999	%	Potassium. NASVD smoothed
NASVDU	F7.3	-9.999	ppm	Uranium. NASVD smoothed
NASVDTh	F7.3	-9.999	ppm	Thorium. NASVD smoothed
NonNASVDTotDose	F7.2	-99.99	nGy/h	Total Dose. Not smoothed
NonNASVDK	F7.3	-9.999	%	Potassium. Not smoothed
NonNASVDU	F7.3	-9.999	ppm	Uranium. Not smoothed
NonNASVDTh	F7.3	-9.999	ppm	Thorium. Not smoothed

- Final magnetic data

Field name	Format	Dummy	Unit	Comment
FLTLINE	F10.1	NA	-	Line number. Generated by Geosoft.
Project	I5	-99	-	Project number
Flt	I4	-9	-	Flight number
Line	I7	-9999	-	Line number
Fid	I8	-99999	-	Fid
Date	I9	-999999	YYYYMMDD	Date
Bearing	I4	-9	dega	Bearing
Long	F11.6	-99.999999	dega	Long
Lat	F11.6	-99.999999	dega	Lat
EAST	F10.2	-99999.99	m	Easting,DATUM: GDA94,PROJECTION:MGA52
NORTH	F11.2	-999999.99	m	Northing,DATUM: GDA94,PROJECTION:MGA52
RadAlt	F7.2	-99.99	m	RadAlt
Press	F8.2	-999.99	mbar	Press
Temp	F6.2	-9.99	deg C	Temp
MagTie	F11.4	-9999.9999	nT	Tie line levelled magnetics
MagLev	F11.4	-9999.9999	nT	Final levelled magnetics