KIRKLAND LAKE – LARDER LAKE AREA

Discover Abitibi Initiative



Discover Abitibi
A project of innovation, cooperation and revitalization

Découvrons l' Abitibi
Un projet d' innovation, de coopération et de renouvellement

Ontario Airborne Geophysical Surveys
High Resolution MIDAS Magnetic Gradient Survey
Geophysical Data Set 1053

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CREDITS

This survey is part of the Discover Abitibi Initiative **(DAI)**, a regional cluster economic development project based on geoscientific investigations of the western Abitibi greenstone belt. FedNor-Industry Canada, Northern Ontario Heritage Fund Corporation and private sector investors have provided funding for the initiative. Project management was performed by the Timmins Economic Development Corporation.

List of accountabilities and responsibilities:

- **Timmins Economic Development Corporation** (TEDC) – overall project management
- Robert Calhoun, Project Manager, Discover Abitibi Initiative – contract management, project management
- Karl Kwan, Senior geophysicist for Paterson, Grant & Watson Limited (PGW), – responsible for field and office quality assurance (QA) and quality control (QC)
- Thomas Watkins, publication services, Ministry of Northern Development and Mines (MNDM) – preparation of base maps and map surrounds
- Fugro Airborne Surveys, Mississauga, Ontario - data acquisition and data compilation

DISCLAIMER

To enable the rapid dissemination of information, this digital data has not received a technical edit. Every possible effort has been made to ensure the accuracy of the information provided; however, the Ministry of Northern Development and Mines does not assume any liability or responsibility for errors that may occur. Users may wish to verify critical information.

CITATION

Information from this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Ontario Geological Survey 2004. Ontario airborne geophysical surveys, magnetic data, Kirkland Lake – Larder Lake Area; Ontario Geological Survey, Geophysical Data Set 1053.

1.0 INTRODUCTION

On October 10th, Fugro Airborne Surveys Corp. (FAS) was awarded the Kirkland Lake – Larder Lake Survey by the Timmins Economic Development Corporation (TEDC). The contract required FAS to carry out 12,779 line-kilometres of high-resolution helicopter horizontal magnetic gradient survey on two contiguous blocks located in the Kirkland Lake area of Northern Ontario, Canada.

The western block (Block 1) was flown with traverse lines oriented at 140 degrees azimuth with a spacing of 75 metres. The eastern block (Block 2), was flown with traverse lines oriented North-South and with a spacing of 75 metres. There was an area of overlap between the two blocks. Control lines for both blocks were oriented East-West with a spacing of 3000 metres. Control lines were also flown along the survey boundary when the boundary was not parallel to the traverse line direction. The survey was flown with a nominal terrain clearance of the higher of 50 metres or 15 metres above the tallest obstacle. The area flown is shown in Figure 1.

The field base of operation for the Kirkland Lake - Larder Lake survey was located in the town of Kirkland Lake. After pre-survey flight tests in Timmins, Ontario, and surveying of the Porcupine Destor-Pipestone area and the Lake Abitibi area, the first production flight was flown out of Kirkland Lake on March 3rd, 2004 with helicopter C-GIGS. Surveying commenced with a second system in helicopter C-FFUJ on March 7th, 2004. The last flight over the Kirkland – Larder Lake area ended on March 19th, 2004 for C-GIGS. The blocks were completed by C-FFUJ on April 7th, 2004. A total of 12,779 line kilometres was needed to cover the outlined survey blocks. An initial flight line bearing of 0 degrees azimuth was selected by the DAI technical authority for both blocks but this was later changed to 140 degrees azimuth for the western block. A total of 1,315 survey lines and 27 control lines were planned and flown using two helicopters, each installed with the Fugro MIDAS Helicopter Mounted Horizontal Gradient system.

This report describes the survey procedures and data verification, which were carried out in the field, and the data processing, which followed in the office.

2.0 SURVEY LOCATION AND SPECIFICATIONS

The block is located roughly centred on Kirkland Lake, Ontario, extending southwest to Powell Township and east to the Ontario-Quebec border. Figure 1 shows the survey location with respect to the local township boundaries.

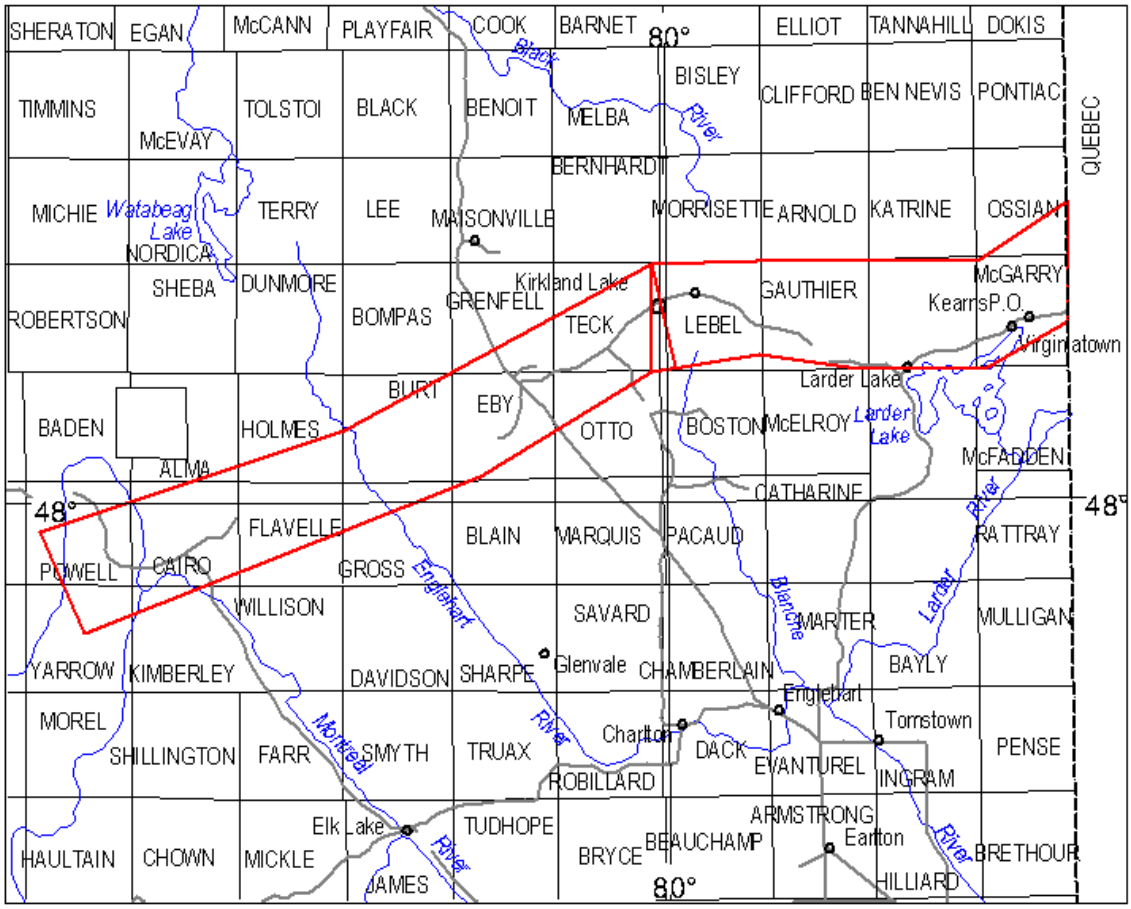


Figure 1: Kirkland Lake – Larder Lake Survey Area

The airborne survey and noise specifications for the Kirkland Lake – Larder Lake survey are as follows:

a) traverse line spacing and direction
   - flight line spacing is 75 m
   - West Block : flight line direction is 140 degrees azimuth ; East Block : flight line direction is North - South
   - maximum allowable deviation from nominal flight path is +/- 25 m over a distance of 500 metres

b) control line spacing and direction
   - at a regular 3000 m interval, flight line direction East-West
   - along each survey boundary (if boundary not parallel to the flight line direction)
   - maximum allowable deviation from nominal flight path is +/- 100 m over a distance of 1000 metres

c) terrain clearance
   - nominal terrain clearance is 50 m
   - altitude tolerance limited to ±10 metres , except in areas of severe topography

d) aircraft speed
   - nominal helicopter speed is 40 m/sec
   - aircraft speed tolerance limited to ±5.0 m/sec, except in areas of severe topography

e) magnetic diurnal variation
   - could not exceed a maximum deviation of 10 nT from a 2-minute chord.

f) magnetometer noise envelope
   - in-flight noise envelope could not exceed 0.2 nT
   - Figure of Merit to be no greater than 2.5 nT for the two side mounted magnetometers

3.0 AIRCRAFT, EQUIPMENT AND PERSONNEL

3.1 Aircraft and Geophysical On-Board Equipment for each Aircraft:

Aircraft:	2 Bell 206 Jet Rangers
Operator:	National Helicopters
Registrations:	C-GIGS, C-FFUJ
Survey Speed:	80 knots / 90 mph / 40m/sec.
Magnetometers:	Fugro MP7 processor with 2 Scintrex CS-2 single cell cesium

	vapour, side-boom mounted installation, sensitivity of 0.01 nT, sampling rate = 0.1 sec., ambient range 20,000 to 100,000 nT. The general noise envelope was kept below 0.2 nT. Nominal sensor height of 50 metres above ground. Sensor separation 13.4 metres.
Magnetic compensation system:	Fugro FASDAS compensator with a resolution of 1 picotesla and an accuracy of 0.035 nT
Digital Acquisition:	FUGRO AIRBORNE SURVEYS FASDAS with data storage on an IBM MicroDrive
Radar Altimeter:	Sperry RT220, accuracy 5%, sensitivity 0.3 m, range 0 to 2,500 feet, analog device
Laser Altimeter:	Optech G-330 with first-last pulse capability, sensitivity +/- 5 cm from 10° to 30° C, +/- 10 cm from -20° to 50° C
Barometric Pressure:	Motorola MPX4115AP analog pressure sensor, sensitivity 150 mV/kPa
Camera:	Sony DXC-101 video camera with a Panasonic AG720 colour video recorder, super VHS
Electronic Navigation:	Novatel 3951R GPS receiver, 1 sec recording interval, with a resolution of 0.00001 degree and an accuracy of ±10m. Real time differential correction was provided by Omnistar. PNAV 2100 interface
GPS receiver for post processing	Ashtech Zsurveyor with L1/L2 capability, 12 channel, 0.5 sec recording interval. With post processing, can provide accuracy of greater than 5 metres.

* The dual frequency GPS receiver is located on the starboard boom and the real time corrected navigation GPS receiver is located on the port boom.

3.2 Base Station Equipment

Fugro CF1 Base Station consisting of the following:

Magnetometer:	Scintrex CS-2 single cell cesium vapour, mounted in a magnetically quiet area, measuring the total intensity of the earth's magnetic field in units of 0.01 nT at intervals of 1.0 second, within a noise envelope of 0.40 nT
GPS Receiver:	Ashtech Zsurveyor with L1/L2 capability , measuring all GPS channels, for up to 12 satellites

Computer	CF1 has its own LCD screen for display. All data recorded at 1-second intervals on compact flash card.

3.3 Field Office Equipment

Computers:	Toshiba Laptop, model 2300, P3 with 40 gigabyte hard drive
Printer:	HP 450C
DVD writer Drive:	DVD +R format.
Hard Drive:	20 GB removable Peerless drive

3.4 Field Personnel

The following personnel were on-site during the acquisition program.

Igor Sram	Crew Chief - Geophysicist
Jeff Fullerton	Helicopter pilot
Gord Stone	Helicopter pilot
Al Singh	Helicopter engineer
Tim Slater	Helicopter engineer
Iaroslav Gorokhovski	Geophysical Operator
Francois Nguyen	Geophysical Operator

The above personnel were responsible for the operation and data handling from the aircraft. All personnel were employees and contractors of Fugro Airborne Surveys, except for the helicopter pilots and engineers who were contracted by National Helicopters. There was a pilot and operator assigned to each of the helicopters used for survey flying.

4.0 DATA ACQUISITION

The town of Kirkland Lake, Ontario was selected as the base of operations to start the project. The survey was carried out from March 3rd , 2004 to April 7th, 2004. The area is covered by a total of 12,779 line kilometres of flying using two helicopters. The second helicopter was deployed to the survey area after a short period of scheduled maintenance in Timmins Ontario. The survey area consisted of two contiguous and overlapping blocks, defined by a flight line bearing of 140° azimuth to the west and 0° azimuth to the east. These directions were selected to run perpendicular to the average trend of local geologic structures of interest. A total of 1,315 individual survey lines with a separation of 75 metres, were planned and flown. An additional 27 control lines were flown at a flight

azimuth of 90° with a separation of 3000 metres and along the survey block boundaries where these were not parallel to the traverse line direction.

4.1 General statistics

Survey dates	March 3rd, 2004 to April 7th, 2004
Total km	12,779 km
Total flying hours	187.5 hours for 2 machines
Production hours	185.8 hours for 2 machines
Number of production days	28 days for 2 machines
Number of production flights	68 flights for 2 machines
Bad weather days	23.5 days for 2 machines
Testing	4.0 hours for 2 machines
Equipment breakdown	0.5 days for 2 machines
Aircraft breakdown/maintenance	6.0 days for 2 machines
Pilot Rest Day	1.5 days for 2 crews
Average production per flight	189 km for both machines
Average production per hour	68.2 km for both machines
Average production per day	213 km for both machines

The following tests and calibrations were performed prior to the commencement of or during the survey flying:

- Magnetometer lag check
- Altimeter calibration
- Magnetometer heading (cloverleaf) check
- Magnetometer FOM check

These tests were flown out of Timmins and at the bases of operations as part of the start-up procedures and ongoing survey tests.

Details of these tests and their results are given in Appendix A.

After each flight, all analogue records were examined as a preliminary assessment of the noise level of the recorded data. Altimeter deviations from the prescribed flying altitudes were also closely examined as well as the magnetic diurnal activity, as recorded on the base station.

All digital data were verified for validity and continuity. The data from the aircraft and base station were transferred to the PC's hard disk. Basic statistics were generated for each parameter recorded. These included the minimum, maximum and mean values, the standard deviation and any null values located. Editing of all recorded parameters for spikes or datum shifts was done, followed by final data verification via an interactive graphics screen with on-screen editing and interpolation routines.

The quality of the GPS navigation was controlled on a daily basis by recovering the flight path of the aircraft. The differential correction procedure employed Waypoint Grafnav/Grafnet software, which uses the raw ranges from the base station to create improved models of clock error, atmospheric error,

and satellite orbit. These models are used to improve the conversion of aircraft raw ranges to aircraft position. For the dual frequency GPS units that were employed on this survey, the accuracy of the final X,Y was considered to be +/- 5 metres.

Checking all data for adherence to specifications was carried out in the field by the Fugro Airborne Surveys field geophysicists.

5.0 DATA COMPILATION AND PROCESSING

5.1 Personnel

The following personnel were involved in the compilation of data and creation of the final products:

Emily Farquhar	Manager, Data Processing
Russell Imrie	Senior Data Processor
Karl Kwan	Senior Geophysicist (Paterson, Grant & Watson Limited) and DAI Technical Manager who was involved with GSC-type magnetic levelling

5.2 Base maps

Base maps of the survey area were supplied by the Ontario Ministry of Northern Development and Mines

Projection description

Datum:	NAD83
Projection:	Universal Transverse Mercator (UTM Zone 17N)
Central Meridian:	81° West
False Northing:	0 m
False Easting:	500,000 m
Scale factor:	0.9996

*The geophysical data were collected using the UTM NAD83 datum (WGS84 ellipsoid), then reprojected to the NAD27 (Canada (Manitoba; Ontario) local datum) and NAD83 (Canada local datum) datums, in both UTM and geographic (i.e. latitude/longitude) coordinate systems.

5.3 Processing of Base Station data

The recorded magnetic diurnal base station data was reformatted and loaded into the OASIS database. After initial verification of the integrity of the data from statistical analysis, the appropriate portion of the data is selected to correspond to the exact start and end time of the flight. The data were then checked and corrected for spikes using a fourth difference editing routine. Following this, interactive editing of the data is done, where necessary, via a graphic editing tool, to remove events caused by

man-made disturbances. A small running average filter equivalent to less than 8 sec was applied to remove high-frequency noise if necessary. The final processing step consists of extracting the long wavelength component of the diurnal signal through low pass filtering, to be subtracted from the airborne magnetic data as a pre-leveling step.

5.4 Processing of the Positioning Data (GPS)

The raw GPS data from both dual frequency mobile (aircraft) and base station GPS units were recovered. Using Waypoint Grafnav/Grafnet software, differential corrections were applied to the raw aircraft fixes using the range data recorded by the base station. Solutions were calculated in both the forward and reverse directions in order to improve the quality of the final position. The resulting differentially corrected latitudes and longitudes were then converted from the WGS-84 spheroid to the local map projection and datum (NAD83) and to UTM metres. These final positions were re-merged with the geophysical data based on the GPS time synchronization. A point-to-point speed calculation was then done from the final X, Y coordinates and reviewed as part of the quality control. The flight data was then cut back to the proper survey line limits and a preliminary plot of the flight path was done and compared to the planned flight path to verify the navigation

Base station location used for processing of GPS data was determined to be:
Kirkland Lake Municipal Airport 48° 44' 26.4290" N, 79° 59' 16.5915" W, 317.78 m

5.5 Processing of the Altimeter data

The altimeter data, which includes the radar altimeter, the laser altimeter and the GPS elevation values, after differential corrections, were checked and corrected for spikes using a fourth difference editing routine. Laser altimeter values of '0' were defaulted and a filtered laser altimeter channel was created from the last return laser data, which should best represent the reflection from the ground surface. Following this, a digital terrain trace was computed by subtracting the laser altimeter values from the differentially corrected GPS elevation values. All resulting parameters were then checked, in profile form, for integrity and consistency, using a graphic viewing editor.

Following this the final levelling process was undertaken. This consisted of applying a micro-levelling technique described below to remove residual errors from the digital terrain grid.

5.6 Processing of Magnetic data

The data was reformatted and loaded into an Oasis Montaj^{TM} database. After initial verification of the data by statistical analysis, the data was then checked and corrected for any spikes using a fourth difference editing routine and inspection on the screen using a graphic profile display. Interactive editing, if necessary, is done at this stage. The spike corrected magnetic values from each magnetometer were then adjusted for system lag as determined by the lag test. Following this, the long wavelength component of the diurnal was subtracted from the data from both sensors as a pre-leveling step. A preliminary grid of the values was then created and verified for obvious problems, such as

errors in positioning or bad diurnal and also to ensure that data quality was improved by diurnal removal.

The lagged, diurnally corrected magnetic data for the two sensors were averaged to create a dataset centred on the flight path. The International Geomagnetic Reference Field (IGRF) was then calculated from the 2000 model year, for this survey, extrapolated according to the dates associated with each survey flight and calculated at the survey elevation as measured by the differentially corrected GPS altitude for every measurement point. This reference field was removed from the diurnally corrected, lagged, centre averaged magnetic values.

Following this, the final leveling process was undertaken. This consisted of calculating the positions of the control points (intersections of lines and tie lines), calculating the magnetic differences at the control points and applying a series of leveling corrections to reduce the misclosures to near zero. A new grid of the values was then created and checked for residual errors. Any gross errors detected were corrected and the leveling process repeated. Residual errors were extracted from the gridded data using a proprietary microlevelling technique. The microlevel corrections were low-pass filtered to ensure that only non-geologic residual level errors were removed. The correction was also amplitude limited to +/- 5.0 nT although the typical correction value was less than 1.0 nanotesla.

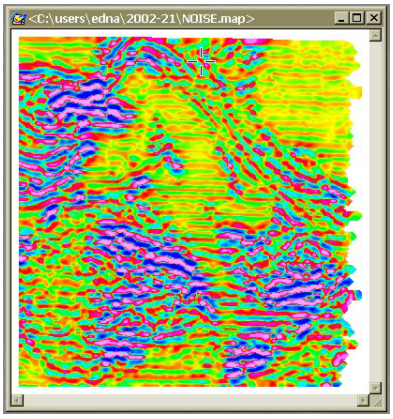
The microlevelling technique used for this survey is very similar to that developed by PGW, the key strength of which is the separation of noise from geological signal and the correction of the profiles rather than being just a grid based operator. The PGW microlevelling technique resulted from a new application of filters used in the process of draping profile data onto a regional magnetic datum (Reford et al., 1990). It is similar to that published by Minty (1991).
Microlevelling is applied in two steps. The decorrugation steps are as follows:

- Grid the flightline data to a specified cell size using the minimum curvature gridding algorithm.
- Apply a decorrugation filter in the frequency-domain, using a sixth-order high pass Butterworth filter of specified cut-off wavelength (tuned to the flightline separation), together with a directional cosine filter, so that a grid of flightline-oriented noise is generated.
- Extract the noise from the grid to a new profile channel.

At this stage, the noise grid may be examined to ensure that the flightline noise has been isolated, and to determine what parameters will be required to separate the true residual flightline noise from the high-frequency geological signal incorporated in the filtering described above.

The steps for the microlevelling procedure are as follows:

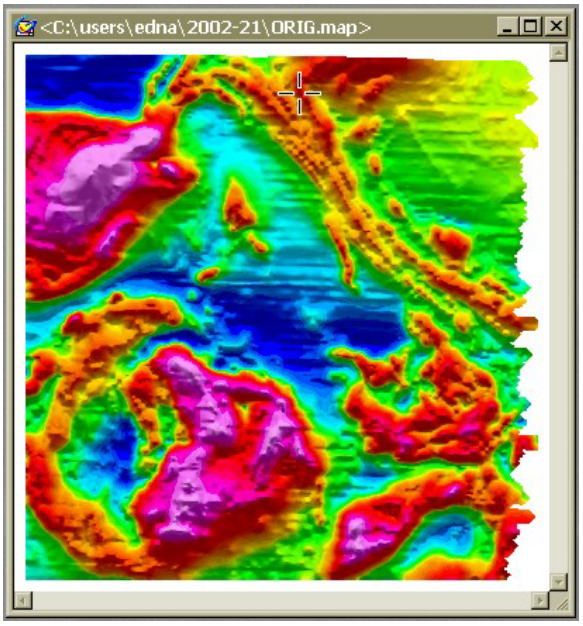
- Apply an amplitude limit to clip or zero high amplitude values in the noise channel, if desired.
- Apply a low pass non-linear filter (Naudy and Dreyer, 1968), so that only the longer wavelength flightline noise remains, forming the microlevel correction.
- Subtract the microlevel correction from the original data, resulting in the final, microlevelled profile channel.



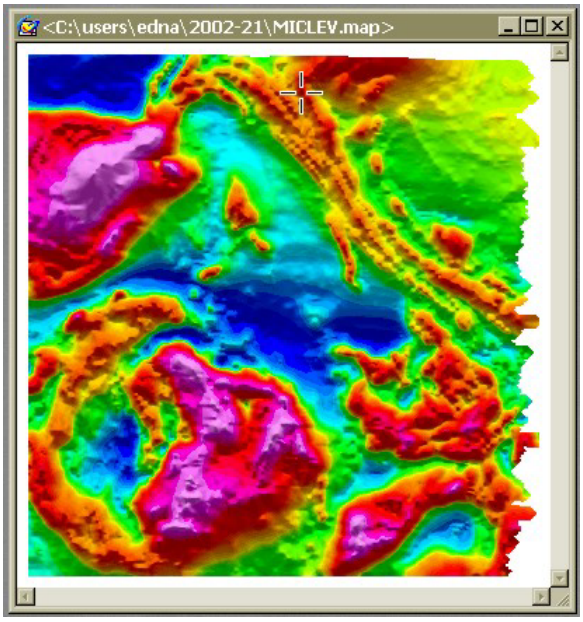
Decorrugation noise grid

In the example shown, the data are windowed from an airborne magnetic and electromagnetic survey flown in the Matachewan area of Ontario, over typical Archean granite-greenstone terrain (Ontario Geological Survey, 1997). Standard corrections (e.g. diurnal, IGRF, conventional tieline levelling) were applied to the magnetic data. However, a considerable component of residual flightline noise remains, due for example to inadequate diurnal monitoring or tieline levelling difficulties.

The resultant microlevelled channel can then be gridded for comparison with the original data. In addition, it is useful to examine the intermediate noise channels in profile and grid form, to verify that the desired separation of residual flightline noise and geological signal has occurred.



Total magnetic field, before microlevelling.



Total magnetic field grid, after microlevelling.

Microlevelling can be applied selectively to deal with noise that varies in amplitude and/or wavelength across a survey area. It can also be applied to swaths of flightlines, where more regional level shifts are a problem due to inadequate levelling to the control lines. This can be particularly useful on older surveys where tieline data may no longer be available.

Microlevelling will not solve all problems of flightline noise. For example, positioning errors (e.g. poor lag correction) may result in some level shift that microlevelling will reduce. However, shorter wavelength anomalies will still remain mis-aligned. Line-to-line variations in survey height result in anomaly amplitude variations. Again, microlevelling will reduce long wavelength level shifts, but cannot compensate for localized amplitude changes.

Decorrugation Parameters

Decorrugation requires a database of geophysical data, oriented along roughly parallel survey lines. Surveys with more than one line orientation should be separated into blocks of consistent line direction. The profile channel to be microlevelled should have had all standard corrections, and

conventional tieline levelling, already applied. Only traverse lines should be selected for microlevelling (i.e. no tie-lines).

Flight Line Spacing
The nominal flightline spacing is required to design the filter parameters. If a survey contains blocks flown at different line spacings, better results will likely be obtained if these blocks are microlevelled separately. If one is attempting to remove wider level shifts, across swaths of lines, then the average width of the swath should be specified instead.

Flight Line Direction
The nominal flightline direction is required so that the directional filtering incorporated in the decorrugation process has the correct orientation. Survey blocks flown with different line directions should be microlevelled separately.

Grid Cell Size for Gridding
The cell size chosen should be small enough so that the residual flightline noise represented in the grid of original data is well defined on a survey line basis. Thus, a grid cell size of ¼ the line spacing or smaller is recommended. However, a cell size that is too small (i.e., less than 1/10 the line spacing) will not improve the microlevelling results, and will increase the processing time required.

Decorrugation cut-off wavelength
This parameter defines the cut-off wavelength of the sixth-order, high-pass Butterworth filter, which is combined with a directional cosine filter (power of 0.5) oriented perpendicular to the flightline direction, to extract the residual flightline noise component from the grid of the original data. A wavelength of four times the line spacing has typically proven to produce the best results. Setting this wavelength too small will not give the filter enough width to isolate the effect of each flightline. Setting it too large will extract more geological signal than necessary.

Microlevelling Parameters

Once decorrugation has been applied, it is recommended that the decorrugation grid be reviewed and compared to the original data. This is best done by shaded relief imaging. The purpose is to:

- Ensure that the parameters chosen when decorrugation was applied have properly isolated the residual flightline noise.
- Measure the amplitudes (e.g. determine the peak-to-trough amplitude variations between the survey lines) and wavelengths (in the flightline direction) of the residual flightline noise, from the decorrugation grid.

Amplitude limit value
The amplitude limit defines the value estimated by the user as the maximum amplitude of the residual flight line noise in a survey. If the absolute value of the decorrugation noise channel exceeds the specified amplitude for a given record, then it will be clipped to that value, or zeroed, depending on the mode chosen. This is one of the techniques employed to separate residual flightline noise from geological signal. It is assumed than any responses of higher amplitude reflect geology.

The user should also consider the sources of noise for the particular survey that is being microlevelled. When considering aeromagnetic data, the noise amplitudes produced by some sources (e.g. diurnal

variation) are not affected by the geological signal of an area, whereas the noise amplitudes from others (e.g. height variations) are affected by the geology, particularly where the magnetic gradients are strong.

If the user does not want to apply an amplitude limit, then a large value, exceeding the dynamic range of the decorrugation noise channel, should be specified. This dynamic range can be determined from the channel statistics.

Amplitude Limit Mode

There are two choices for the amplitude limit mode:

Zero mode – This will set any value in the decorrugation noise channel, whose absolute value exceeds the specified amplitude limit value, to zero prior to application of the non-linear filter. This is suited to areas where the responses exhibit steep gradients (e.g. magnetic survey over near-surface igneous and metamorphic rocks). It has the effect of dividing a simple, high amplitude response into three parts: two flanks centred on a zeroed section, allowing a shorter non-linear filter wavelength to be applied, if appropriate. It also reduces the possibility of this filter distorting a response whose wavelength is close to the filter wavelength.

Clip Mode – This will set any value in the decorrugation noise channel, whose absolute value exceeds the specified amplitude limit value, to the amplitude limit value (with appropriate sign) prior to application of the non-linear filter. This is suited to areas where the magnetic responses exhibit shallow gradients (e.g. magnetic survey over sedimentary terrain). It is also applied where the wavelengths of the residual flightline noise in the line direction are clearly much greater than those of the geological signal in the decorrugation noise grid.

Naudy Filter Length



The Naudy non-linear low pass filter (Naudy and Dreyer, 1968) is used due to its superior qualities for either accepting or rejecting responses beyond the specified filter length. A linear filter, in contrast, would smear an undesirable, short wavelength response into the filtered data, rather than completely remove it. It is applied to the amplitude-limited noise channel, to remove any remaining geological signal The filter length is set to half the length of the shortest linear noise segments visible in the decorrugation noise grid. In most situations, the lengths of these noise segments will still be considerably larger than the wavelengths of geological signal. The exception occurs where there is strong signal due to geology (e.g. magnetic dykes) that strikes subparallel to the line direction. In such cases, it is wise to choose a fairly long filter length for the first pass of microlevelling, and then shorten the filter length for any subsequent microlevelling applied only to survey lines (or parts thereof) where problems remain.

Naudy Filter Tolerance

This parameter sets the amplitude below which the filter will not alter the data. For microlevelling, it is recommended that this value be set quite small (e.g. 0.001 nT for magnetic data) as otherwise, the filtered noise channel may contain low amplitude, high frequency chatter that will then be introduced into the microlevelled channel when the correction is applied.

The microlevelling parameters applied to magnetic and DEM data for the Kirkland Lake – Larder Lake survey are as follows:

	Amplitude limit	mode	filter length
Total Magnetic Field	4.0 nT	zero	500 m
DEM	5.0 m	zero	500 m

Quality Control

Once the microlevelling process has been applied, it is instructive to study five parameters, both in profile and gridded form: original unmicrolevelled data, decorrugated noise, amplitude-limited noise, non-linear filtered noise (i.e. microlevel correction) and microlevelled data. This will allow the user to determine if separation of residual flightline noise from geological signal is satisfactory, and whether any levelling problems remain.

Shaded relief imaging of the total magnetic field and its residual component and/or $1^{st}/2^{nd}$ vertical derivatives will verify that the residual line noise has been minimised, and that new line noise has not been introduced. A grid of the microlevel correction will confirm that significant geological signal has not been removed.

5.7 Measured Horizontal Magnetic Gradient

The diurnally corrected total magnetic field data for the two magnetic sensors was used to calculate the transverse measured magnetic gradient, normalized for sensor separation. The transverse gradient was calculated with respect to the flight line direction. As a first pass correction, the median value was removed from the gradient on a line-by-line basis.

5.8 GSC Levelling of Magnetic Data

In 1989, as part of the requirements for a contract with the Ontario Geological Survey (OGS) to compile and level all existing GSC aeromagnetic data in Ontario, PGW developed a robust method to level the magnetic data of various base levels to a common datum provided by the Geological Survey of Canada (GSC) as 812.8 m grids. The essential theoretical aspects of the levelling methodology were fully discussed in Gupta et al. (1989), and Reford et al. (1990). The method was later applied to the remainder of the GSC data across Canada and the high-resolution AMEM surveys flown by the OGS (Ontario Geological Survey, 1996).

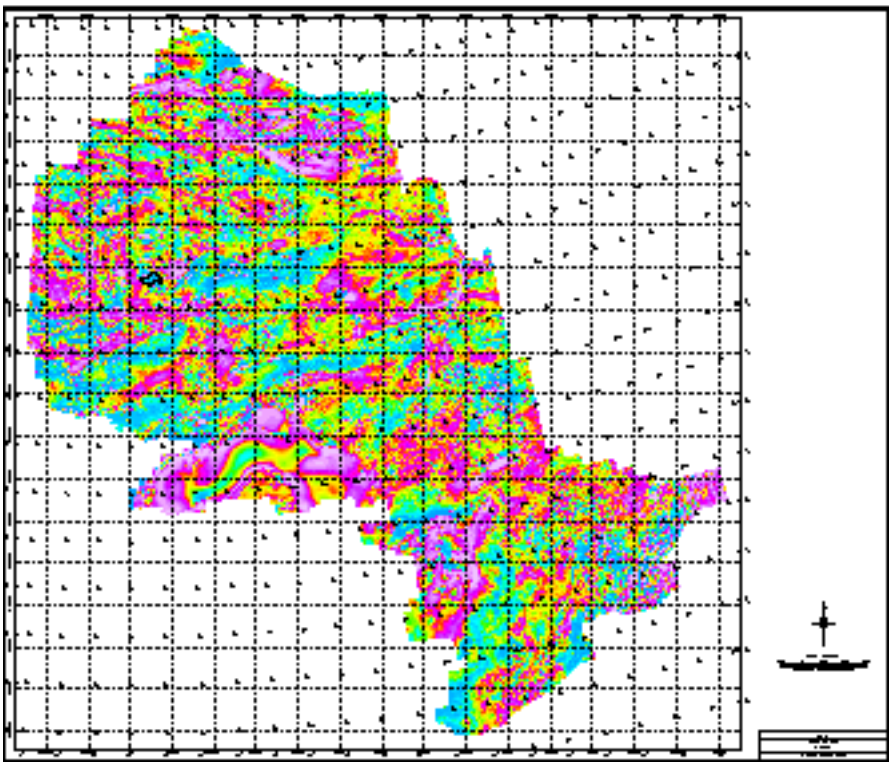
Terminology:

Master grid – refers to the 200 metre Ontario magnetic grid compiled and levelled to the 812.8 metre magnetic datum from the Geological Survey of Canada.

GSC levelling – the process of levelling profile data to a master grid, first applied to GSC data.

Intra-survey levelling or microlevelling – refer to the removal of residual line noise described earlier in this chapter; the wavelengths of the noise removed are usually shorter than tie line spacing.

Inter-survey levelling or levelling – refer to the level adjustments applied to a block of data; the adjustments are the long wavelength (in the order of tens of kilometres) differences with respect to a common datum, in this case, the 200 metre Ontario master grid, which was derived from all pre-1989 GSC magnetic data and adjusted, in turn, by the 812.8 metre GSC Canada wide grid.



Ontario Master Aeromagnetic Grid (Ontario Geological Survey, 1999). The outline for the sample dataset to be levelled (Vickers) is shown.

The GSC Levelling Methodology

Several data processing procedures are assumed to be applied to the survey data prior to levelling, such as microlevelling, IGRF calculation and removal. The final levelled data is gridded at 1/5 of the line spacing. If a survey was flown as several distinct blocks with different flight directions, then each block is treated as an independent survey. The GSC leveling was undertaken by Karl Kwan at Paterson, Grant & Watson Limited for the Kirkland Lake – Larder Lake data. The process included the following:

1. Create an upward continuation of the survey grid to 305m

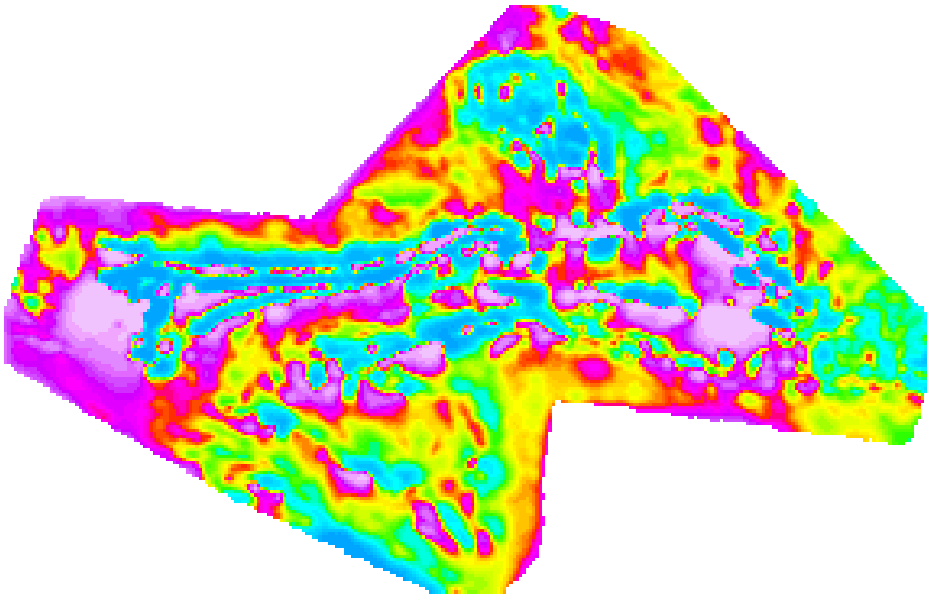
Almost all recent surveys (1990 and later) to be compiled were flown at a nominal terrain clearance of 100 metres or less. The first step in the levelling method was to upward continue the survey grid to 305 metres, the nominal terrain clearance of the Ontario master grid. The grid cell size for the survey grids was set at 100 metres. Since the wavelengths of level corrections will be greater than 10 to 15 kilometres, working with 100 metre or even 200 metre grids at this stage will not affect the integrity of

the levelling method. Only at the very end, when the level corrections are imported into the databases, will the level correction grids be regridded to 1/5 of line spacing.

The unlevelled 100-metre grid was extended by at least 2 grid cells beyond the actual survey boundary, so that, in the subsequent processing, all data points are covered.

2. Create a difference grid between the survey grid and the Ontario master grid

The difference between the upward continued survey grid and the Ontario master grid, regridded at 100 metres, was computed. The short wavelengths represent the higher resolution of the survey grid. The long wavelengths represent the level difference between the two grids.



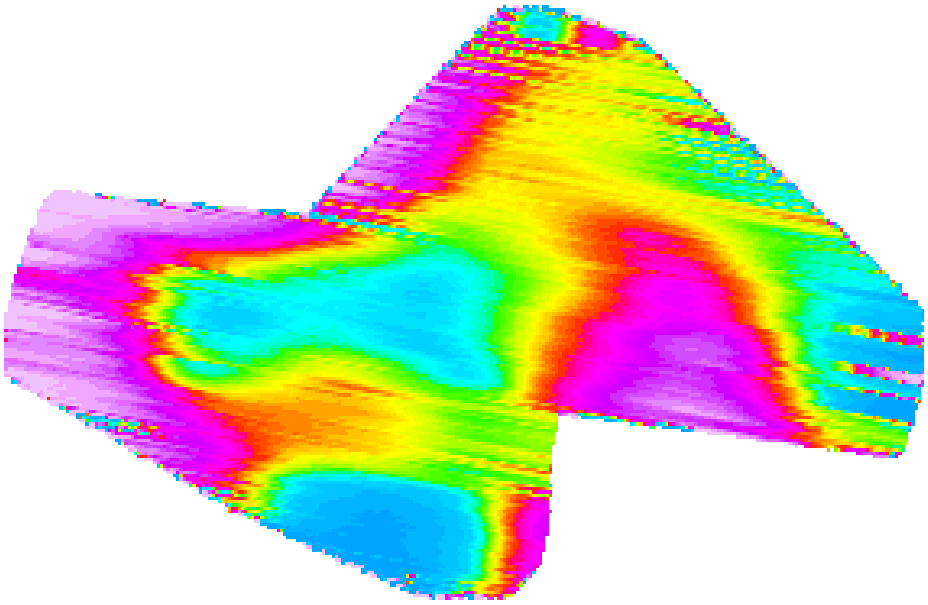
Example of difference grid (difference between survey grid and master grid), Vickers survey.

3. Rotate difference grid so that flight line direction is parallel to grid column or row, if necessary.

4. Apply a first pass of a non-linear filter (Naudy and Dreyer, 1968) of wavelength on the order of 15 to 20 kilometres along the flight line direction. Reapply the same non-linear filter across the flight line direction.

5. Apply a second pass of a non-linear filter of wavelength on the order of 2000 to 5000 metres along the flight line direction. Reapply the same non-linear filter across the flight line direction.

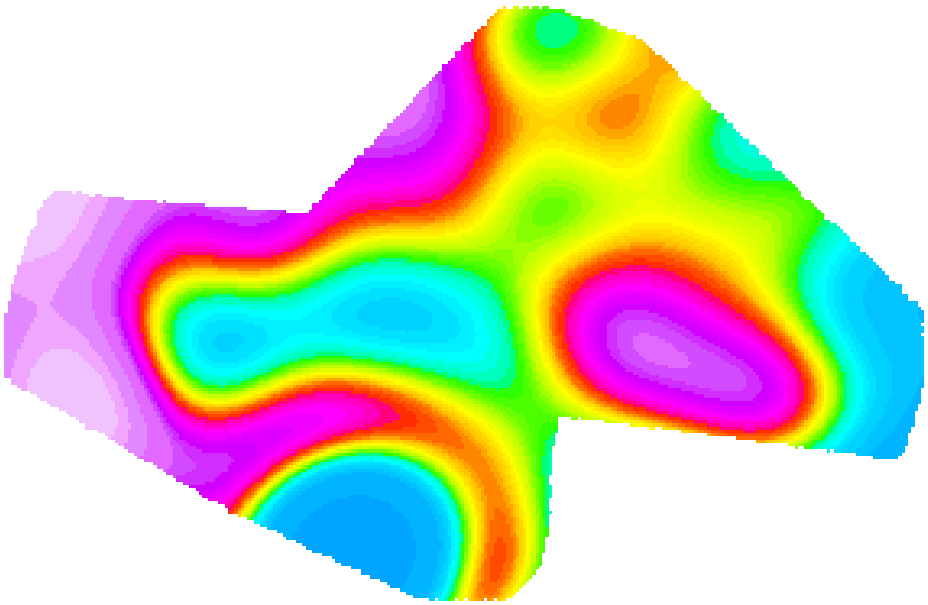
6. Rotate the filtered grid back to its original (true) orientation.



Example of difference grid after application on non-linear filtering, Vickers Survey.

7. Apply a low pass filter to the non-linear filtered grid

Streaks may remain in the non-linear filtered grid, mostly caused by edge effects. They are removed by a frequency-domain, low pass filter with the wavelengths in the order of 25 kilometres.



Example of level correction grid, Vickers Survey.

8. Regrid to 1/5 line spacing and import level corrections into database.

9. Subtract the level correction channel from the unlevelled channel to obtain the level corrected channel.

10. Make final grid using minimum curvature gridding algorithm with grid cell size at 1/5 of line spacing.

The GSC leveling was undertaken by PGW and the following leveling parameters were used in the Kirkland Lake – Larder Lake survey area

Distance to upward continue: 255 metres
First pass non-linear filter length: 15,000 metres
Second pass non-linear filter length: 5,000 metres
Low pass filter cut-off wavelength: 30,000 metres

5.9 Total Magnetic Field and Second Vertical Derivative Grids

This GSC leveled residual magnetic field was gridded using both the minimum curvature algorithm (Briggs, 1974) and the bidirectional transverse horizontal gradient enhanced algorithm, which is part of the Geosoft Oasis^{TM} software package. No trending was applied to the resulting grid. Continuity of magnetic features should be improved from the minimum curvature results through the use of the transverse gradient. The grid cell size for both grids was 15 metres or 1/5 of the flight line spacing.

Minimum curvature gridding provides the smoothest possible grid surface that also honours the profile line data. However, sometimes this can cause narrow linear anomalies cutting across flight lines to appear as a series of isolated spots.

The second vertical derivative of the total magnetic field was computed to enhance small and weak near-surface anomalies and as an aid to delineate the contacts of the lithologies having contrasting susceptibilities. The location of contacts or boundaries is usually traced by the zero contour of the second vertical derivative map.

The grids of the GSC levelled magnetic field values were used as input to create the second vertical derivative. The second vertical derivative values are computed using a fast Fourier transform, combining the transfer functions of the second vertical derivative and an eighth-order Butterworth low-pass filter (90 metre cut-off wavelength). The low pass is aimed at attenuating unwanted high frequencies enhanced by the second derivative operator without aliasing the geologic signal.

5.10 Keating Correlation Coefficients

Possible kimberlite targets are identified from the residual magnetic intensity data, based on the identification of roughly circular anomalies. This procedure is automated by using a known pattern recognition technique (Keating, 1995), which consists of computing, over a moving window, a first-order regression between a vertical cylinder model anomaly and the gridded magnetic data. Only the results where the absolute value of the correlation coefficient is above a threshold of 75% were retained. On the magnetic maps, the results are depicted as circular symbols, scaled to reflect the correlation value. The most favourable targets are those that exhibit a cluster of high amplitude solutions. Correlation coefficients with a negative value correspond to reversely magnetised sources. It is important

to be aware that other magnetic sources may correlate well with the vertical cylinder model, whereas some kimberlite pipes of irregular geometry may not.

The cylinder model parameters are as follows:

Cylinder diameter:	200 m
Cylinder length:	infinite
Overburden thickness:	8 m (average)
Magnetic inclination:	74.18° N
Magnetic declination:	12.00° W
Model window size:	36 x 36 cells (540 x 540 metres)

6.0 FINAL PRODUCTS

Map products at 1:20,000 and 1:50,000 (10 paper copies)

- GSC leveled total magnetic field colour plus contours, including Keating (1995) kimberlite pipe correlation coefficient and MNDM supplied planimetric base and map surround.
- Colour shadow of the second vertical magnetic gradient map, including Keating (1995) kimberlite pipe correlation coefficient and MNDM supplied planimetric base and map surround.

1:20,000 scale maps were presented with flight path. The map layout was optimized at both 1:20,000 and 1:50,000 scale by **DAI** and **MNDM** to make the best use of E-size sheets.

Digital Archives (10 CDROM copies)

- Profile archives on CD-ROM in GEOSOFT ASCII format and Oasis Montaj binary database .GDB format
- Keating Coefficient Anomaly database in ASCII CSV format and Oasis Montaj binary database .GDB format
- Digital grid files of DTM, Total Field Magnetics levelled to Ontario Master Magnetic Datum and 2nd Vertical Derivative of Magnetics in ASCII uncompressed GXF and GEOSOFT binary grid FLOAT format.
- GeoTIFF files of Total Field Magnetics plus planimetric base and colour-shaded 2nd Vertical Derivative of Magnetics plus planimetric base in NAD83 datum
- Vector files of flight path, Keating coefficients and magnetic contours at 1:20000 in NAD83 datum in AutoCAD DXF format
- Final digital plot files for the 1:20,000 and 1:50,000 scale maps in three formats:
  - HP5500 plot files
  - Oasis Montaj packed MAP files
  - GeoTIFF files at 300 dpi
- Final report in Word 97 and Adobe PDF format

7.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) were undertaken by the survey contractor (Fugro Airborne Surveys), by PGW (as DAI Technical Manager), and by TEDC. Stringent QA/QC is emphasised throughout the project so that the optimal geological signal is measured, archived and presented.

7.1 Survey Contractor

Important checks are required during the data acquisition stage to ensure that the data quality is kept within the survey specifications. The following lists in detail the standard data quality checks that were performed during the course of the survey.

Daily quality control

Navigation data

- The differentially corrected GPS flight track is recovered and matched against the theoretical flight path to ensure that any deviations are within the specifications (i.e. deviations not greater than +/- 25 metres from the nominal line spacing over a 500 m distance).

- All altimeter data (radar, laser, barometric and GPS elevation) is checked for consistency and deviations in terrain clearance were monitored closely. The survey is flown in a smooth drape fashion maintaining a nominal terrain clearance of 50 metres, whenever possible. Altitude corrections are done in a smoothly controlled manner, rather than forcing the return to nominal, to avoid excessive motion of the towed-bird which would impact on the quality of the data. A digital elevation trace, calculated from the radar altimeter and the GPS elevation values, is also generated to further control the quality of the altimeter data.

- The synchronicity of the GPS time and the acquired time of the geophysical data is checked by matching the recorded time fields.

- A final check on the navigation data is computing the point-to-point speed from the corrected UTM X and Y values. The computed values should be free of erratic behaviour showing a nominal ground speed of 40 m/s.

Magnetometer data

- The diurnal variation is examined for any deviations that exceed the specified 10 nT peak-to-peak over a 2-minute chord. Data was re-flown when this condition is exceeded, with any re-flown line segment crossing a minimum of two control lines. A further quality control done on the diurnal variation is to examine the data for any man-made disturbances. When noted, these artefacts are graphically removed by a polynomial interpolation so that

they are not introduced into the final data when the diurnal values are subtracted from the recorded airborne data.

- The integrity of the airborne magnetometer data is checked through statistical analysis and graphically viewed in profile form to ensure that there are no gaps and that the noise specifications are met.

- A fourth difference editing routine is applied to the raw data to locate and correct any small steps and/or spikes in the data.

- Any effects of filtering applied to the data are examined by displaying in profile form the final processed results against the original raw data, via a graphic screen. This is done to ensure that any noise filtering applied has not compromised the resolution of the geological signal.

- On-going gridding and imaging of the data is also done to control the overall quality of the magnetic data.

Near-final field products

Near-final products of the profile and gridded navigation, altimeter and magnetic products were made available to **DAI** Technical Manager during visits to the survey site, for review and approval, prior to demobilization.

Quality control in the office

Review of field processing of magnetic data.

The general results of the field processing are reviewed in the profile database by producing a multi-channel stacked display of the data (raw and processed) for every line, using a graphic viewing tool. The magnetic and altimeter data are checked for spikes and residual noise.

Review of leveling of magnetics.

All final levelling of the magnetic data was undertaken in the office following creation of the averaged central total magnetic field value and IGRF removal. Final microlevelling was also applied to the profile data during the office processing.

Creation of second vertical derivative

The second vertical derivative is created from the final gridded values of the total field magnetic data and checked for any residual errors using imaging and shadowing techniques.

Archive files containing the raw and processed profile data and the final gridded parameters were provided to the DAI Technical Manager for review and approval prior to proceeding with creation of final product.

Creation of 1:20,000 and 1:50,000 maps

After approval of the interim data, the 1:20,000 and 1:50,000 maps are created and verified for registration, labelling, dropping weights, general surround information, etc. The hard copy and corresponding digital files were provided to the DAI Technical Manager and Tom Watkins of Information & Marketing Services Section, MNDM for review and approval.

7.2 DAI Technical Manager

The DAI Technical Manager conducted on-site inspections during data acquisition, focusing initially on the data acquisition procedures, base station monitoring and instrument calibration. As data were collected, they were reviewed for adherence to the survey specifications and completeness. Any problems encountered during data acquisition were discussed and resolved.

The QA/QC checks included the following:

Navigation Data

- appropriate location of the GPS base station
- flight line and control line separations are maintained, and deviations along lines are minimized
- verify synchronicity of GPS navigation and flight video
- all boundary control lines are properly located
- terrain clearance specifications are maintained
- aircraft speed remained within the satisfactory range
- area flown covers the entire specified survey area
- differentially-corrected GPS data does not suffer from satellite-induced shifts or dropouts
- GPS height and radar/laser altimeter data are able to produce an image-quality DEM
- GPS and geophysical data acquisition systems are properly synchronized
- GPS data are adequately sampled.

Magnetic Data

- appropriate location of the magnetic base station, and adequate sampling of the diurnal variations
- heading error and lag tests are satisfactory
- magnetometer noise levels are within specifications
- magnetic diurnal variations remain within specifications
- magnetometer drift is minimal once diurnal and IGRF corrections are applied
- spikes and/or drop-outs are minimal to non-existent in the raw data
- filtering of the profile data is minimal to non-existent
- in-field leveling produces image-quality grids of total magnetic field and higher-order products (e.g. second vertical derivative).

Karl Kwan, the **DAI** Technical Manager, reviewed interim and final digital and map products throughout the data compilation phase, to ensure that noise was minimized and that the products adhered to the **TEDC** contract specifications. Considerable effort was devoted to specifying the data formats, and verifying that the data adhered to these formats.

7.3 MNDM

MNDM prepared all base map and map surround information required for the digital and hard copy maps. This ensured consistency and completeness for all of the **TEDC** geophysical map products.

MNDM worked with the DAI Technical Manager to ensure that the digital files adhered to the specified ASCII and binary file formats, that the file names and channel names were consistent, and that all required data were delivered on schedule. The map products were carefully reviewed in digital and hard copy form to ensure legibility and completeness.

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APPENDIX A TESTING AND CALIBRATION

C-GIGS

MAGNETOMETER CLOVERLEAF HEADING TEST

A Heading Test was performed, before production started, in the Timmins area. A calibration site, selected to offer a good visual reference and a low magnetic gradient, was used to verify the heading errors of the magnetometer (basic cloverleaf test)

HEADING TEST:

Project #:
03729 03083

Client: TEDC

Pilot: Louis Boudreau

Operator: Troy Will

Geophysicist: Amir Soltanzadeh

Date: 03-Nov-03

Location: Timmins, Ontario

Aircraft: C-GIGS Bell 206 Jet Ranger

Configuration: MIDAS

Pass 1:

LINE #	HEADING	FIDUCIAL HEADING POINT (sec)	GPS ALTITUDE (m)	x (m)	y (m)	TFC1LD (nT)	TFC2LD	HEADING CORRECTED TFC1	HEADING CORRECTED TFC2
19	270°	40165.0	1507.2	500340.5	5381806.1	57389.03	57397.62	57389.06	57397.48
20	90°	42726.0	1415.0	500340.0	531805.8	57389.70	57397.80	57389.70	57398.01
24	180°	54912.0	1458.4	500337.9	5381806.0	57389.06	57397.67	57389.49	57397.81
25	0°	57429.0	1435.2	500345.9	5381807.2	57389.89	57397.95	57389.44	57397.74

Pass 2:

LINE #	HEADING	FIDUCIAL HEADING POINT (sec)	GPS ALTITUDE (m)	x (m)	y (m)	TFC1LD (nT)	TFC2LD (nT)	HEADING CORRECTED TFC1	HEADING CORRECTED TFC2
23	270°	50913.0	1438.6	50035.9	5381792.2	57389.81	57398.17	57389.84	57398.03
22	90°	48567.0	1446.6	500332.0	5381795.2	57389.19	57397.28	57389.19	57397.49
26	180°	60193.0	1459.8	500323.3	5381794.1	57388.97	57397.55	57389.40	57397.69
27	0°	62921.0	1420.4	500344.4	5381794.5	57389.91	57397.98	57389.46	57397.77

RESULT
:

Direction	Average TFC1LD (nT)	Average of all directions (nT)	Heading correction values (nT)	Average N-S difference (nT)	Average E-W difference (nT)	Mean orthogonal difference (nT)
270°	57389.42		0.03	-0.03		
90°	57389.45	57389.45	0.00			-0.86
180°	57389.02		0.43		-0.89	
0°	57389.90		-0.45			

Direction	Average TFC2LD (nT)	Average of all directions (nT)	Heading correction values (nT)	Average N-S difference (nT)	Average E-W difference (nT)	Mean orthogonal difference (nT)
270°	57397.90		-0.14	0.36		
90°	57397.54	57397.75	0.21			-0.71
180°	57397.61		0.14		-0.35	
0°	57397.97		-0.21			

Mean magnetometer base value
= 57411.2 nT

TFC1LD	Port sensor, lagged and diurnally corrected	lag= 0.4 sec
TFC2LD	Stbd Sensor, lagged and diurnally corrected	

MAGNETOMETER FOM (Figure Of Merit) Test

The compensation flight was flown at 0(north), 90(east), 180(south), 270(west) directions at high altitude (>7,000 ft) at Iroquois Falls, Ontario, on February 28, 2004. The regional magnetic gradient was smooth, and acceptable. The maneuvers, pitch, roll, and yaw, are between 5-10 degrees. The Figures of Merits, 0.95 nT and 1.15 nT for the two mag sensors respectively, are much less than the industry-accepted standard of 2 nT. The Figures of Merit were the peak-to-peak values of the compensated magnetic data, after application of a high-pass filter (60 fiducials wavelength).

Project #:	3083	**Date**:	2/28/2004
Client:	TEDC	**Location**:	Iroquois Falls, Ontario
Pilot:	Jeff Fullerton	**Aircraft**:	C-GIGS
Operator:	Francois Nguyen	**Configuration**:	MIDAS
Compiled By:	Darcy McGill	**Database:**	GIGS_FOM_feb28.gdb

TFU1:	Uncompensated Port Sensor	**TFC1**	Compensated Port Sensor
TFU2:	Uncompensated Starboard Sensor	**TFC2**	Compensated Starboard Sensor

VALUES DETERMINED USING 6 SECONDS (60 FIDUCIALS) HIGH PASS FILTER
VALUES DETERMINED USING MEAN PEAK TO PEAK OF EACH MANEUVER

NORTH	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L10	25356-25522	1.226	0.115	0.173	0.081
ROLL		25607-25765	0.496	0.095	0.750	0.101
YAW		25850-26005	0.205	0.080	0.357	0.083
TOTAL			1.927	0.290	1.280	0.265

EAST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L20	24034-24202	0.903	0.083	0.464	0.058
ROLL		24275-24456	1.578	0.072	1.888	0.064
YAW		24554-24709	0.513	0.077	0.446	0.029
TOTAL			2.994	0.232	2.798	0.151

SOUTH	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L30	22803-22937	0.705	0.056	0.223	0.145
ROLL		23049-23183	0.366	0.079	0.547	0.177
YAW		23307-23475	0.326	0.040	0.259	0.092
TOTAL			1.397	0.175	1.029	0.414

WEST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L40	21634-21784	1.100	0.089	0.163	0.099
ROLL		21900-22029	0.456	0.066	0.320	0.097
YAW		22172-22296	0.532	0.094	0.142	0.122
TOTAL			2.088	0.249	0.625	0.318

TOTAL	TFU1	TFC1	TFU2	TFC2
VALUES	**8.406**	**0.946**	**5.732**	**1.148**

MAGNETOMETER LAG CHECK

The system lag for the magnetometer and system was verified by flying several passes, in opposite directions, over a recognizable feature on the ground giving a sharp magnetic response. Results of this test were made available to DAI Technical Manager for the first field inspection.

LINE #	HEADING (°)	Radar Altimeter (Feet)	FIDUCIAL (sec)	X (m)	Y (m)	SPEED (m/sec)	MAGNETIC FIELD (nT)
10		151.00	77461	504771	5385090	26	58828.700
20		149.60	7785.0	504789	5385099	29	58783.000
30		146.80	78308	504764	5385090	26	58864.000

40		153.50	78720.0	504785	5385095	31	58314.300

MEAN SPEED = $(V_1 + V_2) / 2$
DISTANCE = $\{(X_2 - X_1)^2 + (Y_2 - Y_1)^2\}^{1/2}$
LAG = (DISTANCE / 2) / MEAN SPEED

RESULTS:

MEAN SPEED = 27.50 m/sec
DISTANCE = 20.12 m
LAG = **0.37 sec** **for L10 and 20**

MEAN SPEED = 28.50 m/sec
DISTANCE = 21.59 m
LAG = **0.38 sec** **for l30 and 40**

Starboard Sensor

LINE #	HEADING (°)	Radar Altimeter (Feet)	FIDUCIAL (sec)	X (m)	Y (m)	SPEED (m/sec)	MAGNETIC FIELD (nT)
10		150.60	77460	504771.6	5385093.2	26	58758.2
20		150.20	77884.0	504789.4	5385093.3	29	58332.9
30		146.20	78307	504764.8	5385093.4	26	58769.2
40		153.50	78720.0	504785.8	5385095.4	31	58790.1

MEAN SPEED = $(V_1 + V_2) / 2$
DISTANCE = $\{(X_2 - X_1)^2 + (Y_2 - Y_1)^2\}^{1/2}$
LAG = (DISTANCE / 2) / MEAN SPEED

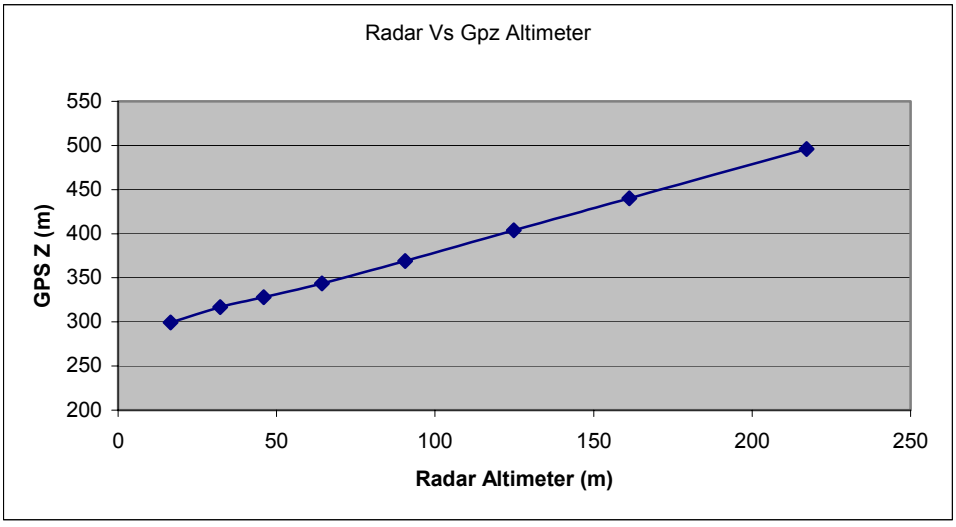
RESULTS:
MEAN SPEED = 27.50 m/sec
DISTANCE = 17.80 m
LAG = 0.32 sec for L20 and L30
MEAN SPEED = 28.50 m/sec
DISTANCE = 21.10 m
LAG =0.37 sec for L60 and L70

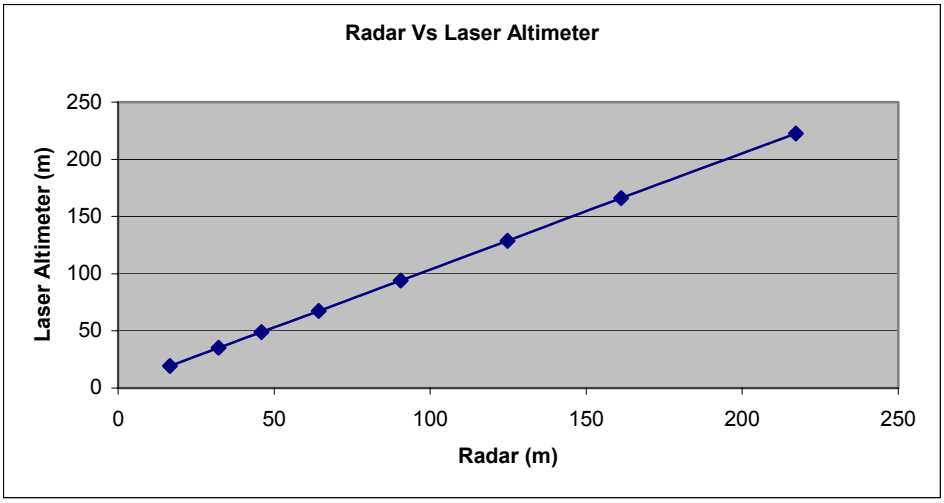
ALTIMETER CALIBRATION

Radar and barometer calibrations

Radar and barometer calibrations were conducted at Timmins airport at 50 foot intervals from 50 to 600 feet. Results of radar altimeter in m vs. differentially corrected GPS altitude (see attached plot) indicate good linear correction. Radar and laser altimeters correlate well also. Results of this test were made available to DAI Technical Manager for the first field inspection and are given below:

Altitude (feet)	Radar (ft)	Radar (m)	laser	GPS (Z)	GPs (base removed)	Baro (m)
50	54.4	16.58112	19.2	300	39.5	323.5
100	105.7	32.21736	35.3	317	56.7	347.3
150	150.7	45.93336	49.1	328	67.9	330.0
200	211.1	64.34328	67.6	344	83.7	343.9
300	297.2	90.58656	94.2	369	109.1	369.3
400	409.3	124.75464	128.7	404	143.7	389.2
500	529	161.2392	166	440	180.1	418.8
600	712.5	217.17	222.6	496	235.8	452.7





a) Static GPS test

Two static tests were performed to check the quality of the GPS Post Processing system. These tests were preformed on Nov 7th and 12th. The following figures (Nov 12 results) visually demonstrate the improvement inaccuracy between raw and post processed GPS.

System:

Airborne:	Ashtech Z-surveyor with L1/L2 capability
Location:	Starboard boom, 2.6 meters from centre of helicopter.
Base:	Ashtech Z-surveyor with L1/L2 capability
Location:	Vi-Mar Hotel, Matheson Ont. 48° 32” 03.19592 North 80° 30” 15.99891 West

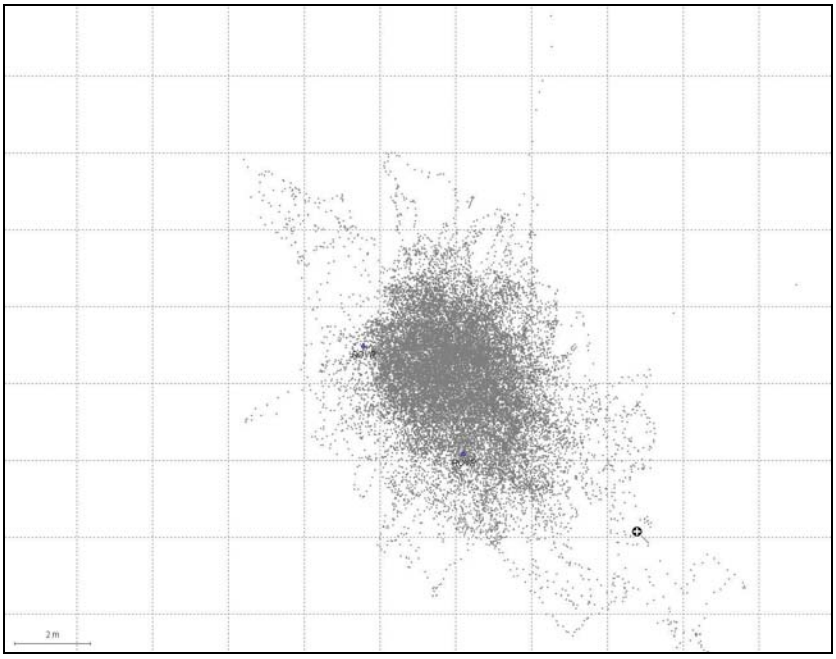


Figure 1: Raw Gps Scatter Plot, Nov 12. 1 square 2 m

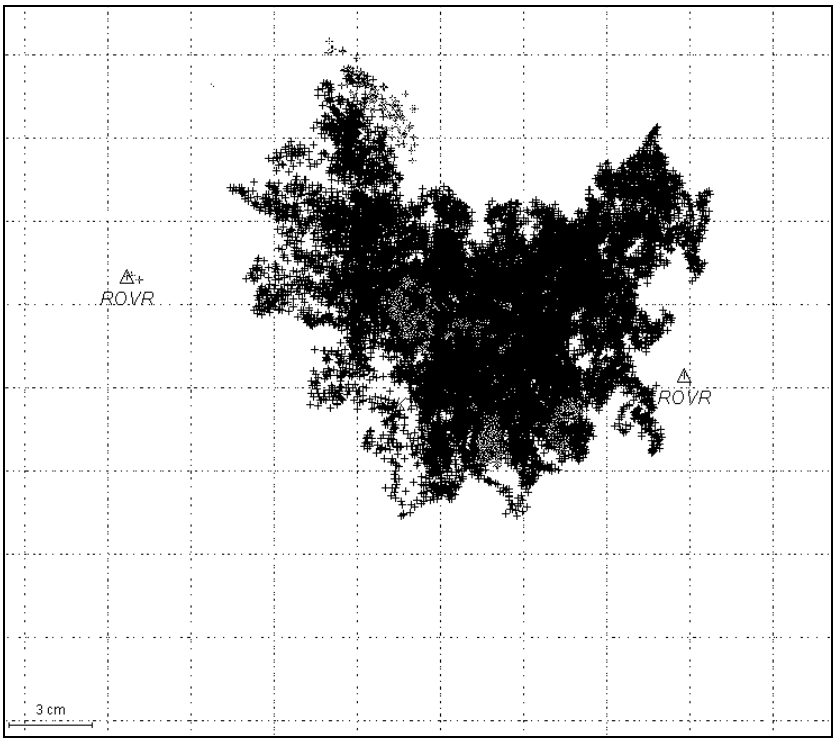


Figure 2: Post Processing Airborne GPS, Nov 12. 1 square= 3 cm

C-FFUJ

FOM (Figure Of Merits) and Heading Tests

The compensation flight was flown at 0(north), 90(east), 180(south), 270(west) directions at high altitude (>7,000 ft) at Kirkland Lake, Ontario, on March 7, 2004. The regional magnetic gradient was smooth, and acceptable. The maneuvers, pitch, roll, and yaw, are between 5-10 degrees. The Figures of Merits, 1.15 nT and .78 nT for the two mag sensors respectively, are much less than the industry-accepted standard of 2 nT. The Figures of Merit were the peak-to-peak values of the compensated magnetic data, after application of a high-pass filter (60 fiducials wavelength).

Project #:	3083	**Date**:	3/7/2004
Client:	TEDC	**Location**:	Kirkland Lake, Ontario
Pilot:	Gord Stone	**Aircraft**:	C-FFUJ
Operator:	Francois Nguyen	**Configuration**:	MIDAS
Compiled By:	Igor Sram	**Database:**	FFUJ_FOM_mar07.gdb

TFU1:	Uncompensated Port Sensor	**TFC1**	Compensated Port Sensor
TFU2:	Uncompensated Starboard Sensor	**TFC2**	Compensated Starboard Sensor

VALUES DETERMINED USING 6 SECONDS (60 FIDUCIALS) HIGH PASS FILTER
VALUES DETERMINED USING MEAN PEAK TO PEAK OF EACH MANEUVER

EAST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L10	19200-19310	0.793	0.105	0.486	0.073
ROLL		19450-19580	2.702	0.166	1.274	0.080
YAW		19710-19820	0.774	0.121	0.417	0.070
TOTAL			4.269	0.392	2.177	0.223

NORTH-WEST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L20	20450-20570	0.467	0.072	0.141	0.057
ROLL		20760-20880	1.776	0.154	0.306	0.107
YAW		21000-21150	0.798	0.060	0.081	0.040
TOTAL			3.041	0.286	0.528	0.204

WEST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L30	21790-21900	0.170	0.068	0.165	0.039
ROLL		22050-22160	1.331	0.077	0.612	0.105
YAW		22300-22450	0.317	0.023	0.129	0.050
TOTAL			1.818	0.168	0.905	0.194

SOUTH-EAST	LINE NUMBER	FID RANGE	TFU1	TFC1	TFU2	TFC2
PITCH	L40	23110-23220	0.533	0.087	0.266	0.052
ROLL		23360-23470	2.084	0.130	0.781	0.066
YAW		23640-23760	0.503	0.084	0.302	0.040

TOTAL		3.120	0.301	1.349	0.158

TOTAL VALUES	**TFU1**	**TFC1**	**TFU2**	**TFC2**
	12.248	**1.147**	**4.960**	**0.779**

ALTIMETER CALIBRATION

Radar and barometer calibrations

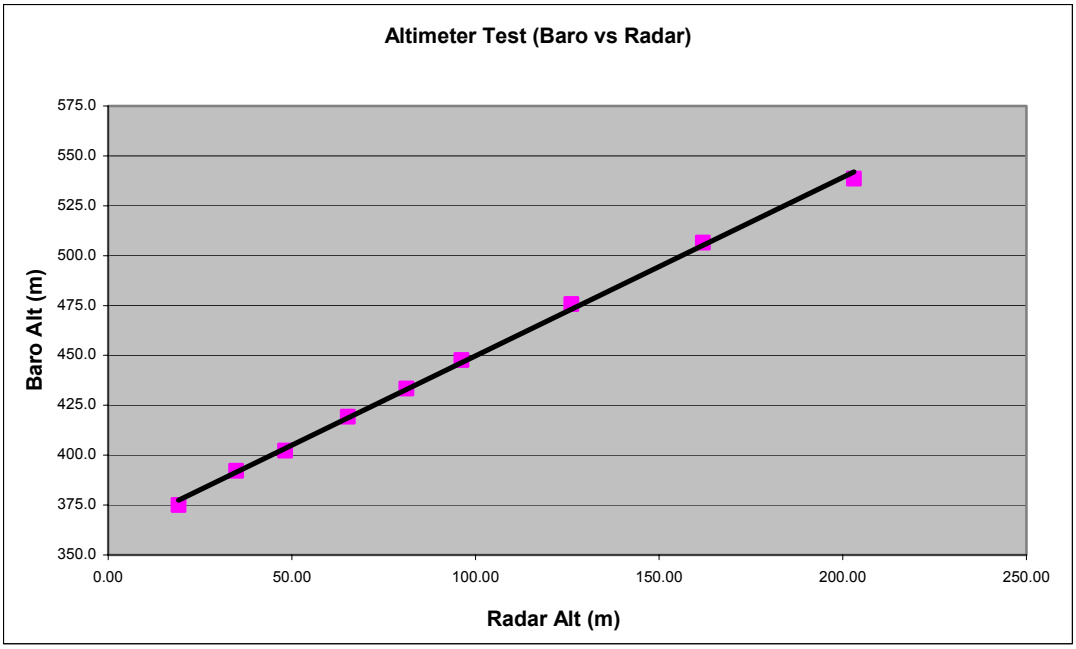
Radar and barometer calibrations were conducted at Iroquois Falls at 50 feet intervals from 50 to 600 feet. Results of radar altimeter in m vs. differentially corrected GPS altitude (see attached plot) indicate good linear correlation. Radar and laser altimeters correlate quite well also. Results are given below:

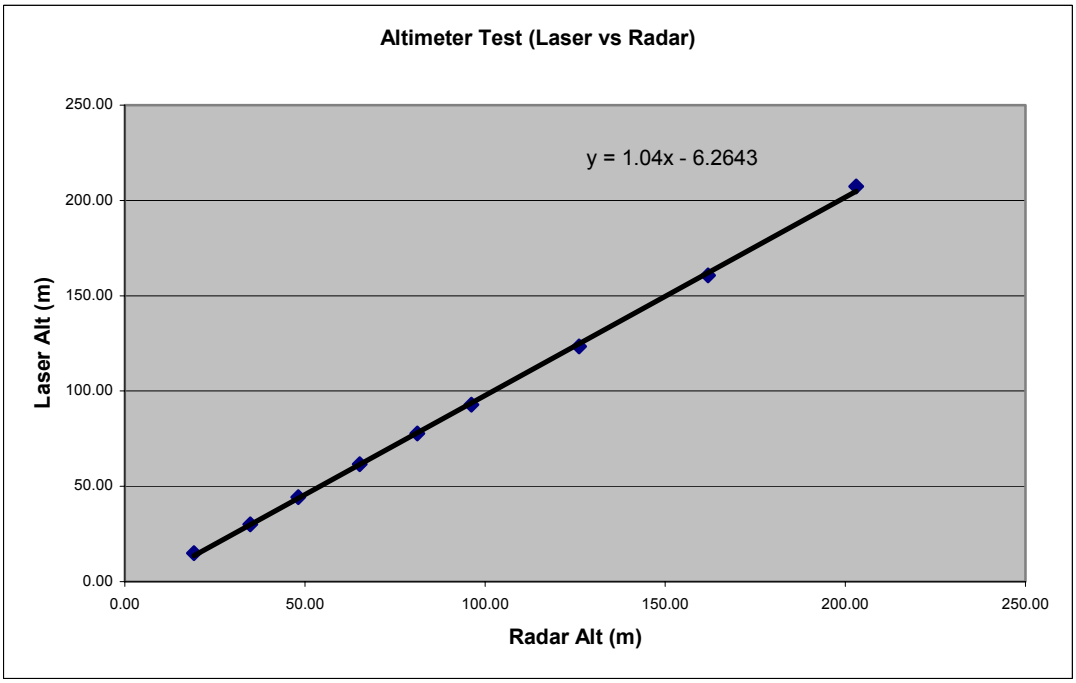
Altimeter Test

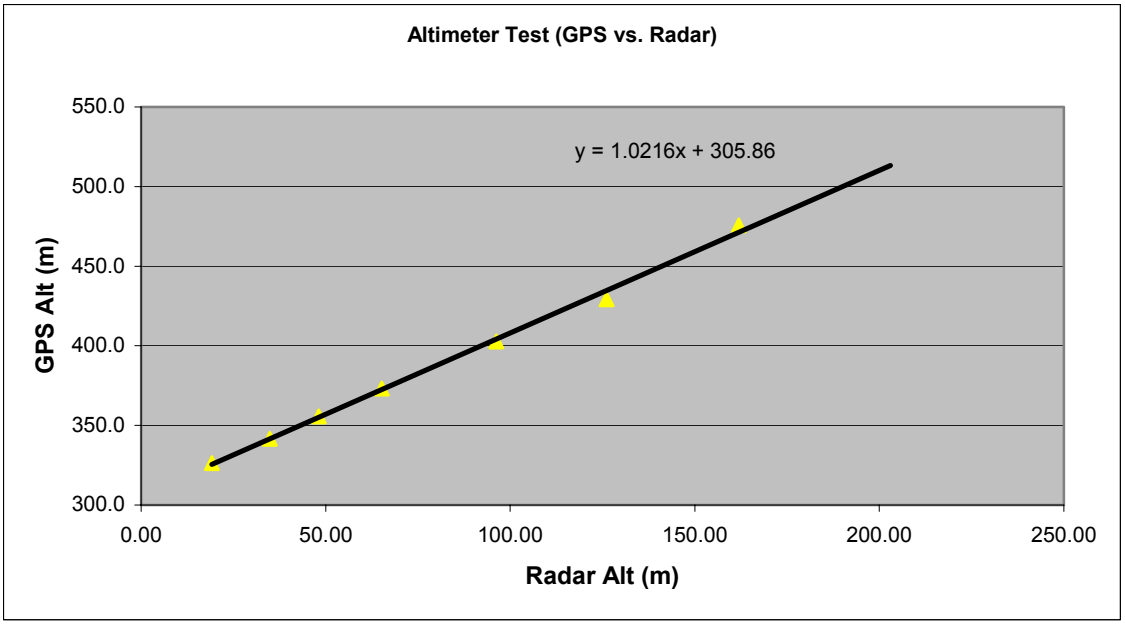
Project #:	3083	**Date**:	10/02/2004
Client:	TEDC	**Location**:	Iroquois Falls, Ontario
Pilot:	Gord Stone	**Aircraft**:	C-FFUJ
Operator:	Francois Nguyen	**Configuration**:	MIDAS
Compiled By:	Darcy McGill	**Database:**	FFUJ_ALT_feb10.GDB

Nominal altitude (ft)	**Radar (ft)**	**Radar (m)**	**Laser (m)**	**Baro (m)**	**GPS (m)**	**GPS, Base removed (m)**
50	62.812	19.15	14.87	375.0	326.4	14.9
100	114.2096	34.82	30.12	392.2	341.6	30.1
150	157.9976	48.17	44.33	402.3	355.7	44.2
200	214.02	65.25	61.60	419.2	373.1	61.6
250	266.4016	81.22	77.80	433.4		
300	315.6672	96.24	92.84	447.7	402.7	91.2
400	413.5752	126.09	123.33	475.8	429.3	117.8
500	530.9008	161.86	160.70	506.5	475.7	164.2
600	665.84	203.00	207.28	538.6		

GPS Base Elev. (m): 273.3 Ellipsoidal height
311.5 Orthometric height

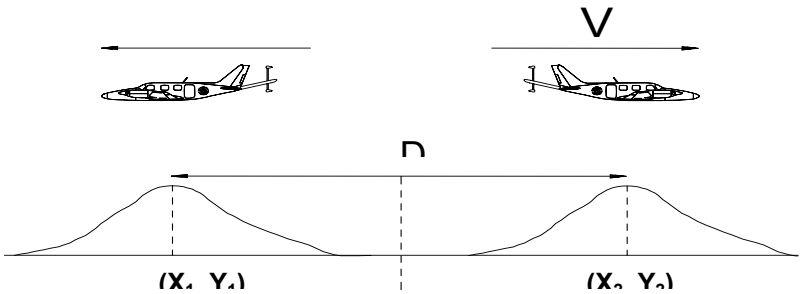

Altimeter Test (Baro vs Radar)
Baro Alt (m)
575.0
550.0
525.0
500.0
475.0
450.0
425.0
400.0
375.0
350.0
0.00
50.00
100.00
150.00
200.00
250.00
Radar Alt (m)


Altimeter Test (Laser vs Radar)
y = 1.04x - 6.2643
Laser Alt (m)
250.00
200.00
150.00
100.00
50.00
0.00
0.00
50.00
100.00
150.00
200.00
250.00
Radar Alt (m)



MAG LAG TEST

Project #:	3083	**Date**:	2/10/2004
Client:	TEDC	**Location**:	Iroquois Falls, Ontario
Pilot:	Gord Stone	**Aircraft**:	C-FFUJ
Operator:	Francois Nguyen	**Configuration**:	MIDAS
Compiled By:	Darcy McGill	**Database:**	FFUJ_LAG_feb10.GDB



Bridge

Sensor 1 (Port Sensor)

LINE #	HEADING (°)	Radar Altimeter (Feet)	FIDUCIAL (sec)	X (m)	Y (m)	SPEED (m/sec)	MAGNETIC FIELD (nT)
9001	N	175.00	17913	504738	5385077	29	57796.300

9002	S	173.40	18442.0	504777	5385082	32.6	58484.400
9003	N	175.80	20611	504777	5385092	30.1	58310.600
9004	S	172.80	21139.0	504755	5385080	29.9	58314.300

MEAN SPEED = $(V_1 + V_2) / 2$
DISTANCE = $\{(X_2 - X_1)^2 + (Y_2 - Y_1)^2\}^{1/2}$
LAG = (DISTANCE / 2) / MEAN SPEED

RESULTS:

MEAN SPEED =	30.80	m/sec	
DISTANCE =	39.29	m	
LAG =	**0.64**	**sec**	**Lines 9001-9002**
MEAN SPEED =	30.00	m/sec	
DISTANCE =	24.80	m	
LAG =	**0.41**	**sec**	**Lines 9003-9004**

Sensor 2 (Starboard Sensor)

LINE #	HEADING (°)	Radar Altimeter (Feet)	FIDUCIAL (sec)	X (m)	Y (m)	SPEED (m/sec)	MAGNETIC FIELD (nT)
9001	N	175.00	17913	504738	5385077	29	57796.300
9002	S	173.40	18442.0	504777	5385082	32.6	58484.400
9003	N	175.80	20611	504777	5385092	30.1	58310.600
9004	S	172.80	21139.0	504755	5385080	29.9	58314.300

MEAN SPEED = $(V_1 + V_2) / 2$
DISTANCE = $\{(X_2 - X_1)^2 + (Y_2 - Y_1)^2\}^{1/2}$
LAG = (DISTANCE / 2) / MEAN SPEED

RESULTS:

MEAN SPEED =	30.80	m/sec	
DISTANCE =	39.29	m	
LAG =	**0.64**	**sec**	**Lines 9001-9002**
MEAN SPEED =	30.00	m/sec	
DISTANCE =	24.80	m	
LAG =	**0.41**	**sec**	**Lines 9003-9004**

HEADING TEST:

Project #: 03083
Client: TEDC
Pilot: Gord Stone
Operator: Francois Nguyen
Geophysicist: Darcy McGill

Date: 29-Feb-04
Location: Iroquois Falls
Aircraft: C-FFUJ Bell 206 Jet Ranger
Configuration: MIDAS

Pass 1:

LINE #	HEADING	FIDUCIAL HEADING PNT(sec)	GPS ALT (m)	x (m)	y (m)	TFC1DL (nT)	TFC2DL	HEADING CORR TFC1	HEADING CORR TFC2
4000	270°	11688.0	805.9	500344.9	5381805.9	57354.80	57352.40	57353.85	57351.30
3001	90°	19007.0	750.6	500346.0	5381795.3	57353.90	57351.30	57353.85	57351.45
2000	180°	29580.0	844.1	500350.5	5381794.4	57352.40	57349.90	57353.80	57351.40
1000	0°	27228.0	836.9	500346.1	5381796.5	57354.70	57352.50	57354.30	57351.95

Pass 2:

LINE #	HEADING	FIDUCIAL HEADING PNT(sec)	GPS ALT (m)	x (m)	y (m)	TFC1DL (nT)	TFC2DL (nT)	HEADING CORR TFC1	HEADING CORR TFC2
4001	270°	16027.0	738.2	500346.2	5381805.3	57353.90	57351.90	57352.95	57350.80
3002	90°	23049.0	828.8	500347.7	5381785.2	57353.00	57350.50	57352.95	57350.65
2001	180°	34228.0	869.8	500339.8	5381795.9	57351.60	57349.20	57353.00	57350.70
1001	0°	31931.0	748.5	500351.9	5381794.7	57352.90	57350.70	57352.50	57350.15

RESULTS:

Direction	Average TFC1LD (nT)	Average of all directions (nT)	Heading correction values (nT)	Average N-S difference (nT)	Average E-W difference (nT)	Mean orthogonal difference (nT)
270°	57354.35	57353.40	-0.95	0.90		-2.70
90°	57353.45		-0.05			
180°	57352.00		1.40		-1.80	
0°	57353.80		-0.40			

Direction	Average TFC2LD (nT)	Average of all directions (nT)	Heading correction values (nT)	Average N-S difference (nT)	Average E-W difference (nT)	Mean orthogonal difference (nT)
270°	57352.15	57351.05	-1.10	1.25		-3.30
90°	57350.90		0.15			
180°	57349.55		1.50		-2.05	
0°	57351.60		-0.55			

Mean magnetometer base value = 57192.6 nT
TFC1LD Port sensor, lagged and diurnally corrected
TFC2LD Stbd Sensor, lagged and diurnally corrected

Static GPS test

Two static tests were performed to check the quality of the GPS Post Processing system on the second helicopter, C-FFUJ. These tests were performed on Dec 15th. The following figures visually demonstrate the improved accuracy between raw and post processed GPS.

System:

Airborne: Ashtech Z-surveyor with L1/L2 capability
Location: Starboard boom, 2.6 meters from centre of helicopter.

Base: Ashtech Z-surveyor with L1/L2 capability
Location: Iroquois Falls, Ontario
48° 44" 23.3443 North
80° 47.15.3013 West
273.30 m

Processing system: Waypoint Grafnav. Version 7.0

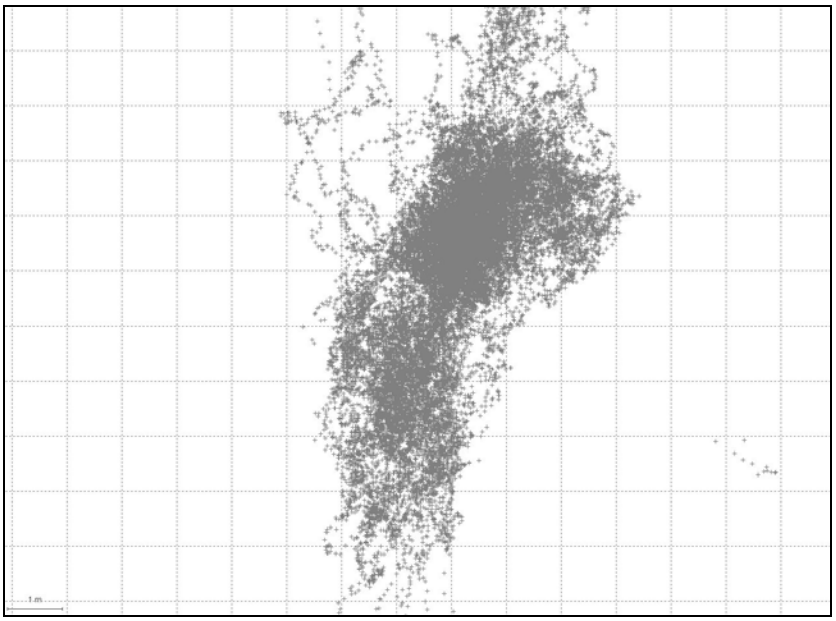


Figure 1 Raw GPS Scatter Plot, Dec 15 th. 1 square=1 m.

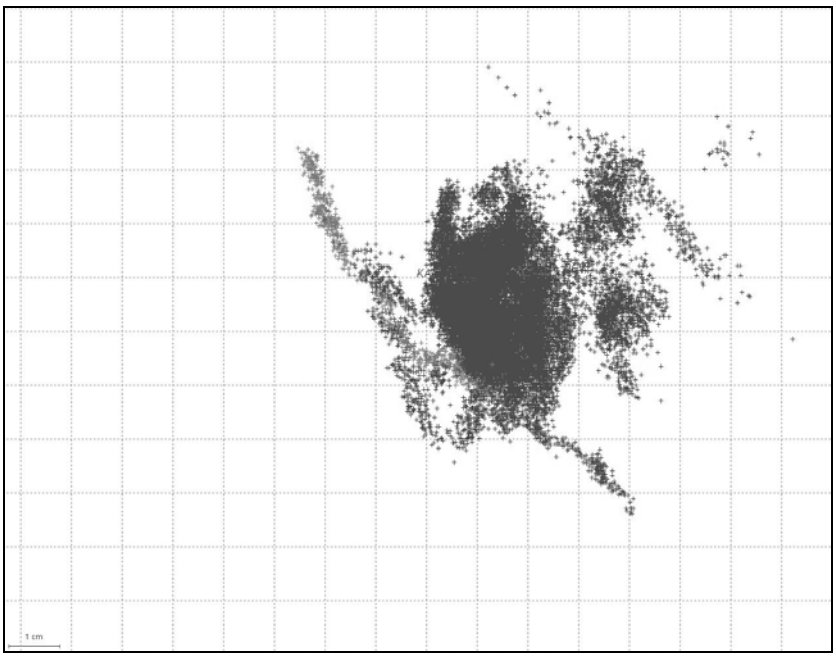


Figure 2 Post Processed GPS Scatter Plot, Dec 15th. 1 square = 1 cm.

APPENDIX B PROFILE ARCHIVE DEFINITION

Geophysical Data Set 1053 is derived from a survey carried out using the MIDAS helicopter mounted horizontal magnetic gradient system by Fugro Airborne Surveys Corp.

Data File Layout

The files for the Kirkland Lake – Larder Lake Geophysical Survey 1053 are archived on CD-ROM and sold as 4 separate products, as outlined below:
The content of the ASCII and Geosoft® binary file types are identical. They are provided in both forms to suit the user's available software. The survey data is archived as follows:

CD - 1053a

- ASCII (GXF) grids
  - IGRF corrected and GSC leveled magnetic field in both NAD27 and NAD83
  - Second vertical derivative of the IGRF-corrected magnetic field in both NAD27 and NAD83
  - Digital elevation model in both NAD27 and NAD83
- Keating correlation (kimberlite) database (ASCII CSV format)
- DXF files of entire survey block in NAD83 for:
  - Flight path
  - Keating correlation targets based on the IGRF-corrected magnetic field grid
  - Contours of GSC leveled magnetic field
- GEOTIFF images in NAD83 of the entire survey block for:
  - GSC leveled magnetic field with planimetric base
  - Colour shaded Second vertical derivative of the IGRF corrected magnetic field with planimetric base
- Project report (Word® 97 and Adobe® PDF formats)

CD – 1053b

- Geosoft® Binary (GRD) grids
  - IGRF corrected and GSC leveled magnetic field in both NAD27 and NAD83
  - Second vertical derivative of the IGRF-corrected magnetic field in both NAD27 and NAD83
  - Digital elevation model in both NAD27 and NAD83
- Keating correlation (kimberlite) database (binary GDB format)
- DXF files of entire survey block in NAD83 for:
  - Flight path
  - Keating correlation targets based on the IGRF-corrected magnetic field grid
  - Contours of GSC leveled magnetic field
- GEOTIFF images in NAD83 of the entire survey block for:
  - GSC leveled magnetic field with planimetric base
  - Colour shaded Second vertical derivative of the IGRF corrected magnetic field with planimetric base
- Project report (Word® 97 and Adobe® PDF formats)

CD - 1053c

- Profile database of magnetic data (10 Hz sampling) in ASCII (XYZ) format
- Keating correlation (kimberlite) database (ASCII CSV format)
- Project report (Word® 97 and Adobe® PDF formats)

CD – 1053d (2 CD set)

- Profile database of magnetic data (10 Hz sampling) in Geosoft® OASIS montaj (GDB) format
- Keating correlation (kimberlite) database (GDB format)
- Project report (Word® 97 and Adobe® PDF formats)

Coordinate Systems

The profile and Keating coefficient data are provided in four coordinate systems:

- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD27 datum, Canada (Manitoba; Ontario) local datum
- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD83 datum, Canada local datum
- Latitude/longitude coordinates, NAD27 datum, Canada (Manitoba; Ontario) local datum
- Latitude/longitude coordinates, NAD83 datum, Canada local datum

The gridded data are provided in two UTM coordinate systems:

- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD27 datum, Canada (Manitoba; Ontario) local datum
- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD83 datum, Canada local datum

Line Numbering

The line numbering convention for survey 1053 is as follows:

Line number x 10 + part number
i.e. Line 4001 part 1 is identified as 40011

The same convention is used for the labelling of the control lines.

Profile Data

The profile data are provided in two formats, one ASCII and one binary:

ASCII

***Zipped ASCII XYZ file of magnetic data, sampled at 10 Hz is divided into two files, one each for the east and west blocks of the survey respectively:

- KirklandLarder1.xyz : profile data for lines 10010 to 18110 and 19021 to 19201 western block
- KirklandLarder2.xyz : profile data for lines 20010 to 25040 and 19011 to 29120 eastern block

Binary

*** Geosoft® OASIS Montaj binary database file (no compression) of magnetic data sampled at 10 Hz is divided into 2 files for the east and west blocks:

- KirklandLarder1.gdb : profile data for lines 10010 to 18110; 19021 to 19201 western block
- KirklandLarder2.gdb : profile data for lines 20010 to 25040; 19011 to 29120 eastern block

The contents of kirklandlarder1.xyz/kirklandlarder1.gdb (both file types contain the same set of data channels) and kirklandlarder2.xyz/kirklandlarder2.gdb were compressed using WinZip® utility. The contents of all four files are summarized as follows:

Channel Name	Description	Units
GPS_X_REAL	REAL TIME GPS X NAD83	(METRES)
GPS_Y_REAL	REAL TIME GPS Y NAD83	(METRES)
GPS_Z_REAL	REAL TIME GPS Z NAD83	(METRES)
GPS_X_FINAL	DIFFERENTIALLY CORRECTED GPS X NAD83	(METRES)
GPS_Y_FINAL	DIFFERENTIALLY CORRECTED GPS Y NAD83	(METRES)
GPS_Z_FINAL	DIFFERENTIALLY CORRECTED ORTHOMETRIC HEIGHT	(METRES)
LON_NAD83	LONGITUDE NAD 83 DATUM	(DEGREES)
LAT_NAD83	LATITUDE NAD83 DATUM	(DEGREES)
X_NAD83	DIFFERENTIALLY CORRECTED UTM EASTING OF HELICOPTER	(METRES)
Y_NAD83	DIFFERENTIALLY CORRECTED UTM NORTHING OF HELICOPTER	(METRES)
LON_NAD27	LONGITUDE NAD 27 DATUM	(DEGREES)
LAT_NAD27	LATITUDE NAD27 DATUM	(DEGREES)
X_NAD27	DIFFERENTIALLY CORRECTED NAD27 UTM EASTING OF HELICOPTER	(METRES)
Y_NAD27	DIFFERENTIALLY CORRECTED NAD27 UTM NORTHING OF HELICOPTER	(METRES)
LASER_RAW	RAW LASER ALTIMETER HEIGHT OF MAGNETOMETER ABOVE TERRAIN	(METERS)
LASER_FINAL	CORRECTED LASER ALTIMETER - HEIGHT ABOVE TERRAIN	(METERS)
BARO_RAW	RAW BAROMETRIC HEIGHT OF HELICOPTER	(METRES)
BARO_FINAL	CORRECTED BAROMETRIC HEIGHT OF HELICOPTER	(METRES)
DEM	TOPOGRAPHIC HEIGHT ABOVE SEA LEVEL	(METRES)
FIDUCIAL	FIDUCIAL	(SECONDS)
FLIGHT	FLIGHT NUMBER	
LINE_NUMBER	FULL FLIGHTLINE NUMBER	
LINE	FLIGHTLINE NUMBER	
LINE_PART	FLIGHTLINE PART NUMBER	
TIME_UTC	UNIVERSAL TIME	(SECONDS)
TIME_LOCAL	LOCAL TIME	(SECONDS AFTER MIDNIGHT)
DATE	LOCAL DATE YYYYMMDD	
MAG_BASE_RAW	RAW MAGNETIC BASE STATION DATA	(NANOTESLAS)
MAG_BASE_FINAL	CORRECTED MAGNETIC BASE STATION DATA	(NANOTESLAS)
PORT_MAG_RAW	DESPIKED RAW PORT TOTAL MAGNETIC FIELD	(nT)
STAR_MAG_RAW	DESPIKED RAW STARBOARD TOTAL MAGNETIC FIELD	(nT)
PORT_MAG_LAG	LAGGED PORT TOTAL MAGNETIC FIELD	(nT)
STAR_MAG_LAG	LAGGED STARBOARD TOTAL MAGNETIC FIELD	nT)
PORT_MAG_DIURN	DIURNAL REMOVED PORT TOTAL MAGNETIC INTENSITY	(nT)
STAR_MAG_DIURN	DIURNAL REMOVED STARBOARD TOTAL MAGNETIC INTENSITY	(nT)
MAG	DIURNAL CORRECTED AVERAGE TMI FROM PORT AND STARBOARD SENSORS	(nT)
IGRF	INTERNATIONAL GEOMAGNETIC REFERENCE FIELD	(nT)
MAG_IGRF	IGRF CORRECTED MAGNETIC FIELD	(nT)
MAG_LEV	LEVELED IGRF CORRECTED MAGNETIC FIELD	(nT)
MAG_FINAL	MICROLEVELED IGRF CORRECTED MAGNETIC FIELD	(nT)
HGRAD	LEVELED MEASURED HORIZONTAL MAGNETIC GRADIENT	(nT/m)
LEVEL_CORR	CORRECTION FOR LEVELLING TO MASTER GRID	(nT)
MAG_GSCLEVEL	FINAL MAGNETIC FIELD LEVELLED TO MASTER GRID	(nT)
FLUXGATEX	X COMPONENT - FLUXGATE MAGNETOMETER	(bits)
FLUXGATEY	Y COMPONENT - FLUXGATE MAGNETOMETER	(bits)
FLUXGATEZ	Z COMPONENT - FLUXGATE MAGNETOMETER	(bits)

APPENDIX C KEATING CORRELATION ARCHIVE DEFINITION

Kimberlite Pipe Correlation Coefficients

The Keating kimberlite pipe correlation coefficient data are provided in two formats, one ASCII and one binary:

- klkeatingcoefficients.csv – ASCII comma-delimited format
- klkeatingcoefficients.gdb – Geosoft® OASIS montaj binary database file

Both file types contain the same set of data channels, summarized as follows:

Channel Name	Description	Units
UTME_NAD27	Easting in UTM coordinates, NAD27 datum Z17N	metres
UTMN_NAD27	Northing in UTM coordinates, NAD27 datum Z17N	metres
UTME_NAD83	Easting in UTM coordinates, NAD83 datum Z17N	metres
UTMN_NAD83	Northing in UTM coordinates, NAD83 datumz Z17N	metres
LAT_NAD27	Latitude in NAD27 datum Z17N	degrees
LONG_NAD27	Longitude in NAD27 datum Z17N	degrees
LAT_NAD83	Latitude in NAD83 datum Z17N	degrees
LONG_NAD83	Longitude in NAD83 datum Z17N	degrees
CORRELATION_COEFFICIENT	Correlation coefficient	percent*10
NORMALIZED_STANDARD_ERROR	Standard error normalized to amplitude	percent
ANOMALY_AMPLITUDE	Peak-to-peak anomaly amplitude in window	nanoTeslas
NEGATIVE_CORRELATION_COEFFICIENT	Negative Correlation Coefficient	percent
POSITIVE_CORRELATION_COEFFICIENT	Positive Correlation Coefficient	percent

APPENDIX D GRID ARCHIVE DEFINITION

Gridded Data

The gridded data are provided in two formats, one ASCII and one binary:

*.gxf - Geosoft® ASCII Grid eXchange Format (revision 3.0, no compression)

*.grd - Geosoft® OASIS montaj binary grid file (no compression)

The grids are summarized as follows:

klmagnad27.grd/.gxf	IGRF-corrected and GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD27 datum)(minimum curvature gridding)
klmagnad83.grd/.gxf	IGRF-corrected and GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD83 datum) (minimum curvature gridding)
kl2vdnad27.grd/.gxf	second vertical derivative of the IGRF-corrected and GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD27 datum) (minimum curvature gridding)
kl2vdnad83.grd/.gxf	second vertical derivative of the IGRF-corrected and GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD83 datum) (minimum curvature gridding)
klmaghgnad27.grd/.gxf	IGRF-corrected and GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD27 datum)(bidirectional transverse horizontal gradient enhanced gridding)
klmaghgnad83.grd/.gxf	IGRF-corrected and GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD83 datum) (bidirectional transverse horizontal gradient enhanced gridding)
kl2vdhgnad27.grd/.gxf	second vertical derivative of the IGRF-corrected and GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD27 datum) (bidirectional transverse horizontal gradient enhanced gridding)
kl2vdhgnad83.grd/.gxf	second vertical derivative of the IGRF-corrected and GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD83 datum))(bidirectional transverse horizontal gradient enhanced gridding)
kldemnad27.grd/.gxf	digital elevation model in metres above sea level (UTM coordinates, NAD27 datum)
kldemnad83.grd/.gxf	digital elevation model in metres above sea level (UTM coordinates, NAD83 datum)

APPENDIX E GEOTIFF AND VECTOR ARCHIVE DEFINITION

GeoTIFF Images

Geographically referenced colour images are provided in GeoTIFF format for use in GIS applications.

The images were grouped by theme as follows:

kirklandlardertmi.tif	IGRF-corrected and GSC levelled magnetic field with planimetric base (UTM coordinates, NAD83 datum)
kirklandlarder2vd.tif	shadowed second vertical derivative of the IGRF-corrected and GSC levelled magnetic field with planimetric base (UTM coordinates, NAD83 datum)

Vector Archives

Vector line work from the maps is provided in DXF(v12) ASCII format as follows:

klkeating20000.dxf	Keating correlation targets based on the IGRF-corrected magnetic field grid (UTM coordinates, NAD83 datum)
klflightpath20000.dxf	flight path of the survey area (UTM coordinates, NAD83 datum)
klmagcontours20000.dxf	contours of the IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD83 datum)