# INFILL GRAVITY SURVEY OF NORTH EASTERN TASMANIA

For MINERAL RESOURCES TASMANIA

BY Integrated Mapping Technologies Pty Ltd

Reg Court
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# 1 INTRODUCTION

Integrated Mapping Technologies Pty Ltd (IMT) has conducted the first season's work of a planned two season gravity survey over North Eastern Tasmania for Mineral Resources Tasmania (MRT). The objective of this survey is the densification of gravity observations to improve the resolution of geological models of the region. The location of the survey is defined in Figure 1 hereto.

To ensure tight control of this and subsequent surveys, IMT established, observed and adjusted a new closed network of 21 interconnected gravity base stations throughout the North East of Tasmania. Routine gravity observations were made relative to this new network at intervals of approximately one kilometer along roads and tracks (including farm tracks). Stations were located and leveled to a high level of precision and accuracy using GPS surveying techniques and the AUSPOS Space Geodesy service of GeoScience Australia.

All new gravity stations have been terrain corrected by Dr David Leaman of Leaman Geophysics Pty Ltd in Tasmania.

A total of 21 new gravity base stations and 853 new gravity stations were observed in the course of the survey. The precision of observations can be summarized as:

| | |
|---|---|
| GPS Survey Observations:- | 20mm +/- 1ppm |
| Gravity Observations:- | +/-0.01mgals |

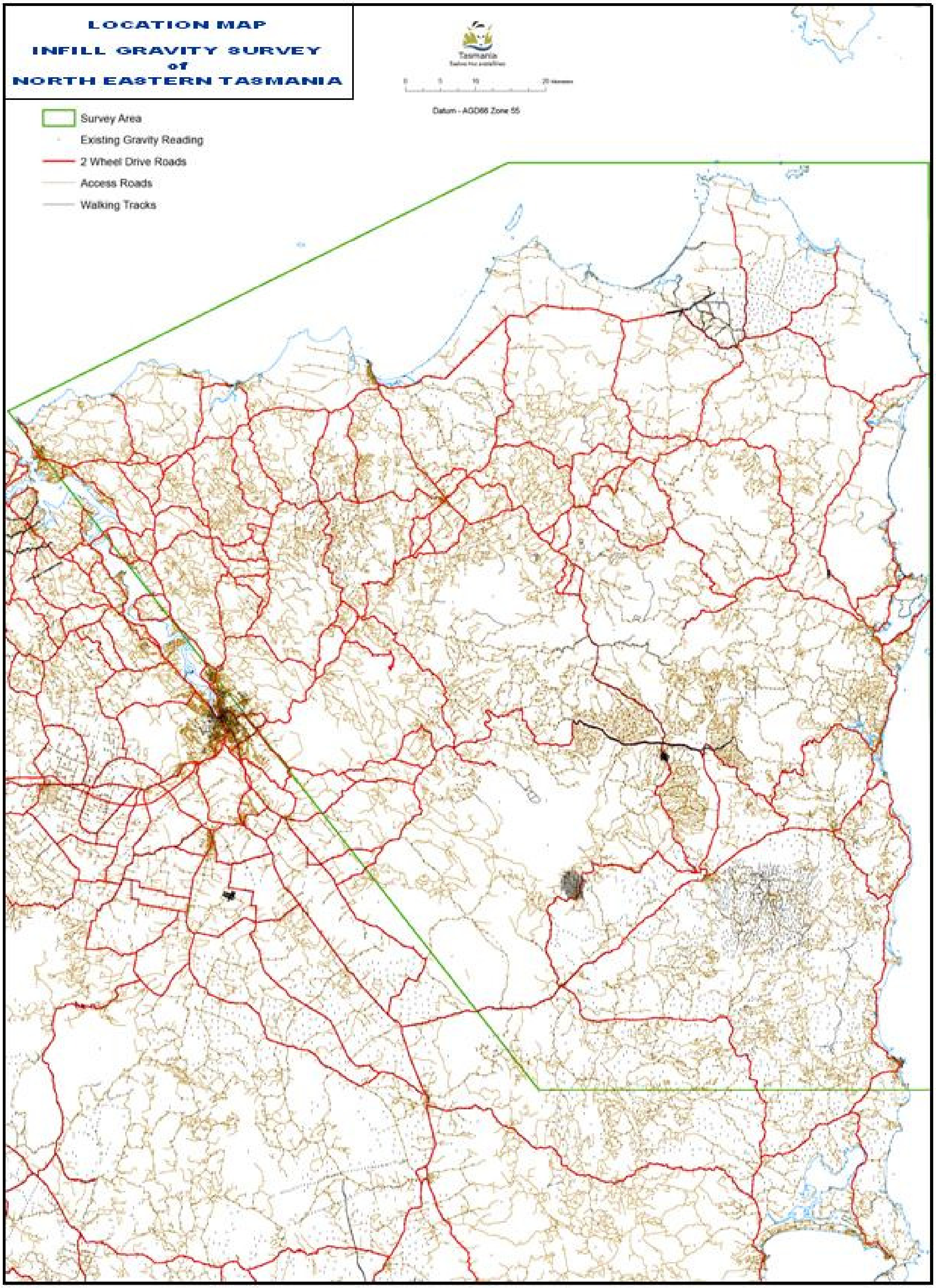


*Figure 1 - Project Location Map*

# 2 INSTRUMENTATION & EQUIPMENT

## 2.1 SURVEYING INSTRUMENTS

- 2 x Sokkia GSR2700 ISX Dual Frequency GPS/GLONASS geodetic RTK receivers with 72 universal GNSS channels, high performance RTK algorithms enabling +40km RTK baselines, in-built RTK radio comms and "Bluetooth" wireless technology.
- Survey Controller - Allegro CX with "Bluetooth" wireless technology.
- Base Radio Repeater - Satel Satteline 3AS Epic 10W Base Radio for long range RTK operations.
- A range of tribrachs, tripods, bipods and vehicle GPS antennae mounting system mounting system.
- Solar panel for charging GPS base station battery.

## 2.2 GRAVITY METER

LaCoste & Romberg Model G Land Gravity Meter Serial Number G517. Gravity observations were recorded on the Allegro CX survey data recorder.

## 2.3 FIELD COMPUTING SYSTEM

- Panasonic "Tuff Book" CF19 Mk1 computer with:-
  - Intel Pentium dual coreU2400 1.6Ghz CPU
  - 10.4" XGA daylight readable touch screen convertible to tablet mode
  - 1.5GB DDR2 SDRAM
  - Shock mounted 80GB SATA HDD
  - Serial Port, SD card slot, express card slot, Firewire Port, 2xUSB 2.0ports, internal modem, 802.11 a+b+g WLAN and integrated "bluetooth"
  - vehicle dashboard mounting
- Cannon BJC4550 A3 printer/plotter
- 120GB external HDD back-up system
- External DVD Writer

# 3 SOFTWARE

## 3.1 SURVEYING & NAVIGATION

- Sokkia SPECTRUM Versions 3.75 & 4.00 GPS post processing, analysis and network adjustment package.
- NOVATEL Convert4 package to convert GPS & GLONASS data to Rinex Format in AUSPOS compatible format.
- Carlson SurvCE Version 2 data collector software
- Carlson Field 2007 Standalone (used in this case to display GIS data for navigation and landowner database.

## 3.2 GRAVITY

The gravity reduction software utilized by IMT was a package of programs developed by Surtec Geosurveys Pty Ltd. Specific programs used in data reductions are listed and described below:-

**GRAVRED**: This program takes a field gravity file (output from GRAVIN) and computes observed gravity and normal gravity by applying corrections for instrument factor then tide and then drift against known bases (in separate file) to give observed gravity. Latitude corrections are then computed from AMG coordinates converted to UTM to give normal gravity.

The program can be used on local grids (with skewed azimuth) or with AMG co-ordinates. A local or ISOGAL84 gravity datum can be used.

Tide corrections for each gravity station are computed within the gravred program using an upgraded variation of the BMR's program ERTIDE1. Tide corrections are applied before drift corrections.

After application of tide corrections, the data is scanned for base stations (defined by co-ordinate in a base station file) or repeat stations which are then flagged (unless disabled for the purposes of testing repeatability). Each base is then examined and assigned a value that is a linear interpolation of known drift on either side of it. Each of these is then assigned a weight that is the inverse of the product of the time to the adjacent known values. For each base station, the weights are summed and a weighted average of assigned values calculated. The base with the most weight is then given the true value of the weighted average and is flagged as another known station. This process is repeated until all the repeated stations are assigned values.

These stations are then used to correct the rest of the data.

Latitude corrections are computed (in this case) using the formula:

$$\text{Latitude correction} = 978031.8(1 + 0.0053024\sin^2 q - 0.0000059\sin^2 2q)$$
(where q = latitude)

Dependant on input data and requirements, the following outputs are written to separate files

| | |
|---|---|
| nnnn.CHK | A formatted file of raw gravity observations. |
| nnnn.COR | A file listing station number, co-ordinate, elevation, tide, drift and latitude corrections with observed gravity. |
| nnnn.ABS | A file listing XY co-ordinates and observed gravity. |
| nnnn.UTM | A file listing principal facts. |
| nnnn.RED | A file listing station number, co-ordinate, elevation, Terrain corrections (output from separate program) and normal gravity - input to BOUGUER for Bouguer reductions. |
| **BOUGUER**: | This program follows GRAVRED (and TERRAIN) and calculates the free air and Bouguer effects. Provision is made for calculating the density which gives the flattest final gravity including terrain effects. |

The formula used for free air and Bouguer corrections is as defined in BMR publication No. 261 by Wellman, Barlow and Murray, 1985 (Gravity Base Station Network Values, Australia)

## 3.3 OTHER SOFTWARE

- SURFER Version 8
- TEXTPAD Version 5
- MICROSOFT Office EXCEL 2007
- MICROSOFT Office WORD 2007
- TEXTPAD Version 5

# 4 METHODOLOGY

## 4.1 PROJECT ESTABLISHMENT

On award of contract, MRT made available to IMT a GIS compatible regional database of topography, hydrography, infrastructure, the Cadastre and existing gravimetric data for the project area.

Prior to commencement of the survey, IMT personnel visited MRT's Offices in Hobart to:-

- More thoroughly define the projects objectives,
- Review and further define operating procedures,
- Define Survey and Gravity Datum's to be used,
- Review anticipated operating conditions
- Review any operational sensitivities and to
- Meet MRT personnel that would have some involvement in the project.

Before commencing fieldwork, the regional data base was imported to the "Carlson Standalone" software on the field computer system. The software was configured to provide IMT field personnel with "real time" navigation, visualization of existing gravity stations and cadastral data. Through the start up phase of the survey, MRT produced and delivered hardcopy 1:25,000 scale topographic maps and a range of Forestry Maps for use in the daily planning of fieldwork.

## 4.2 GRAVITY METER CALIBRATION

Prior to commencement of the survey, and on completion, the calibration of the gravity meter was tested on the Canberra Gravity Range by ABABA tie using station 6491.0304 (UNI CS1) and 7691.0204 at Mt Ainslie. The actual interval for this range is 54.75mGals. The interval determined before the survey was 54.75mGals and on completion of the survey was 54.73mGals. The meter displayed slightly more drift in the second calibration test. Results of the calibration tests are included in Appendix 1 hereto.

## 4.3 GRAVITY CONTROL NETWORK

The gravity base station network is defined in Figure 2. Twenty one new permanently marked gravity base stations have been established. Of these, 9 are coincident with existing permanent survey marks, 2 have been coordinated and leveled using AUSPOS Space Geodesy and the balance have been coordinated and leveled to low precision using autonomous GPS positioning. It is intended that these autonomously positioned base stations be precisely leveled over the 2008/2009 season using either AUSPOS Space Geodesy or other GPS survey techniques.

Gravity base station observations were made as a series of ABABA or ABABAB ties between new bases using a single LaCoste and Romberg gravity meter (serial number 517). Ties were made such that 6 interconnected closed blocks were formed. The network is connected to Fundamental Gravity Base Stations (FGBS's) located at Launceston and St Helens.

ABABA closed traverse base station observations were corrected for instrument factor, then tide then drift to derive 3 changes in gravity for each interval. These 3 changes in gravity for each leg were then summed and averaged. Instrument Factors for the gravity meter are listed in Appendix One and traverse leg gravity reductions are listed in Appendix Two.

Averaged changes in gravity were then summed around each closed block to obtain a misclose in observed gravity for each block

Block miscloses and errors are summarized in Table 1 below.

| Table 1. Gravity Control Loop Miscloses | | | | |
|---|---|---|---|---|
| BLOCK | Misclose (mGals) | Number of Legs | Total Change Absolute Grv | Error Rate Per mGal |
| Block 1 | 0.052 | 4 | 125.791 | 0.000413 |
| Block 2 | 0.012 | 5 | 71.584 | 0.000168 |
| Block 3 | 0.077 | 4 | 284.603 | 0.000271 |
| Block 4 | 0.065 | 8 | 523.851 | 0.000124 |
| Block 5 | 0.027 | 7 | 154.813 | 0.000174 |
| Block 6 | 0.091 | 11 | 485.315 | 0.000188 |

Because of the degree of inter-connection of closed loops, it was decided to adjust the gravity network as a series of traverses rather than individual closed loops. Traverses are summarized in Figure 2 – Adjustment of Gravity Control Network.

Traverse One connects the FGBS's at Launceston and St Helens through a northerly route through 7 traverse legs. The averaged change in gravity for each leg was summed to obtain a change in gravity for the traverse. This was then subtracted from the actual change in gravity between the 2 FGBS's to obtain a misclose for the traverse of 0.038mgals.

The misclose for Traverse 1 was then divided by the total change in observed gravity (irrespective of sign) for the traverse to determine an adjustment rate per mGal of change in observed gravity per leg of the traverse. For Traverse One, the adjustment rate determined was 0.000137mGals/mGal.

The change in observed gravity for each central block leg was then multiplied by the adjustment rate to determine an adopted value for each leg of the traverse. Using the Isogal 65 gravity value for Base 2071 (FGBS 6850.0271) as a starting value, adjusted changes in gravity for each leg of Traverse One were summed to obtain an adopted value for each new gravity base station on the traverse.

Traverse Two connects the FGBS's at St Helens and Launceston via a southerly route. This traverse was adjusted by the same process as used for Traverse One to obtain adopted values for each new gravity base on the traverse. The misclose for Traverse Two was 0.012mGals through 6 legs and the adjustment rate determined was 0.000079mGals/mGal.

Base station values on Traverses One and Two were held as fixed. Traverses Three to Seven inclusive were then summed from these fixed points to other fixed points to derive miscloses for each traverse. These miscloses were then adjusted by the same process as used for Traverses One and Two to derive adopted values for the remaider of the new bases.

The maximum adjustment applied to any one base station tie was 0.019mgal for the interval 9006 to the St Helens FGBS over which there was a change in gravity of 142.263mGals.

### 4.3.1 Rejected Base Station Connections

Originally, a traverse was observed from Stn 9000 to 9002 to 9003 in a single day. This traverse formed a closed loop through stations 9000-9002-9003-9001-9500-9000 with a calculated misclose of 0.195mGals which was considered excessive. Given that surrounding loops with common legs had acceptable miscloses, the problem had to lie in the connections from 9000-9002 and 9002-9003. No error was obvious so it was decided to re-connect 9002 by the observation of an ABABA tie to it from Stn 9500. This observation was successfully made on the 15th of December 2008. Base Station 9002 is the only gravity base not part of a closed loop or traverse.

### 4.3.2 Secondary Gravity Bases

All routine gravity observations were made relative to base stations described above. No secondary base stations were established in the course of the survey.

### 4.3.3 Table Of Base Station Values

Table 2 hereunder lists the adopted values of the new gravity base station network as well as coordinates, elevations and their status

Recovery information for new gravity base stations is set out hereunder as APPENDIX 5.

## 4.4 SURVEY CONTROL

All new gravity stations were directly coordinated and leveled from either existing Survey Control marks or from newly established marks whose position was determined with the AUSPOS Space Geodesy absolute positioning technique using logged GPS reference station observations.

No control traversing or network adjustment was attempted or was necessary.

New stations were established where there were no available existing survey marks of acceptable Class and Order. They were positioned such that base lines to gravity stations were generally kept under 10kms in length although some were up to 27kms long. Also, bases were positioned where possible to provide a clear unimpeded view of the sky and if possible a high position to improve line of sight radio coverage for Real Time Kinematic (RTK) survey procedures.

Table 2. **GRAVITY CONTROL NETWORK SUMMARY** 03- 2008

| Pt No | AGD66 E | AGD66 N | AHD71 | Mark Details | Location | Obs Gravity |
|---|---|---|---|---|---|---|
| 9000 | 510475.18 | 5419043.94 | 97.356 | SPM6300 | Rocherlea | 980279.38 |
| 9001 | 543411.49 | 5443209.28 | 193.634 | SPM7381 | Scottsdale | 980238.93 |
| 9002 | 489693.77 | 5447728.07 | 46.828 | AUSPOS | GeorgeTown | 980268.77 |
| 9003 | 533789.69 | 5458932.97 | 15.190 | SPM7769 | Bridport | 980274.70 |
| 9004 | 573501.79 | 5448496.54 | 151.088 | ST1094 | Nr Herrick | 980244.75 |
| 9005 | 584859.19 | 5465012.61 | 66.783 | SPM10508 | Gladstone | 980264.46 |
| 9006 | 580295.83 | 5435484.03 | 600.103 | Autonomous GPS | Little Plains Lookout | 980160.01 |
| 9007 | 597650.00 | 5441490.00 | 119.589 | Autonomous GPS | | 980284.24 |
| 9008 | 599361.54 | 5396314.25 | 270.233 | SPM6737 | St Mary's | 980280.20 |
| 9009 | 559886.88 | 5374074.32 | 212.295 | SPM10222 | Avoca | 980270.57 |
| 9011 | 604065.26 | 5367487.45 | 2.664 | SPM6463 | Bicheno | 980347.98 |
| 9012 | 574330.00 | 5408550.00 | 285.388 | SPM6406 | Mathinna | 980251.82 |
| 9013 | 531309.57 | 5426472.17 | 395.947 | AUSPOS | Targa | 980216.48 |
| 9014 | 563680.00 | 5423870.00 | 815.525 | SPM9351 | Ben Ridge | 980125.11 |
| 9015 | 544336.31 | 5408095.90 | 386.468 | AUSPOS (x3) | Upper Blessington | 980226.08 |
| 9500 | 518986.58 | 5441357.89 | 206.388 | SPM9962 | Lebrina | 980245.53 |
| 9501 | 561688.21 | 5442110.54 | 175.008 | SPM10495 | Branxholm | 980238.96 |
| 9502 | 578027.08 | 5388805.93 | 235.947 | SPM4378 | Fingal | 980279.11 |
| 9503 | 605402.01 | 5408923.57 | 7.165 | SPM10153 | Scamander | 980324.36 |
| 9504 | 584560.68 | 5634723.73 | 297.595 | Autonomous GPS | Reynold's Hill | 980291.90 |
| 9505 | 527667.00 | 5388320.00 | 190.000 | Autonomous GPS | Nile | 980283.46 |

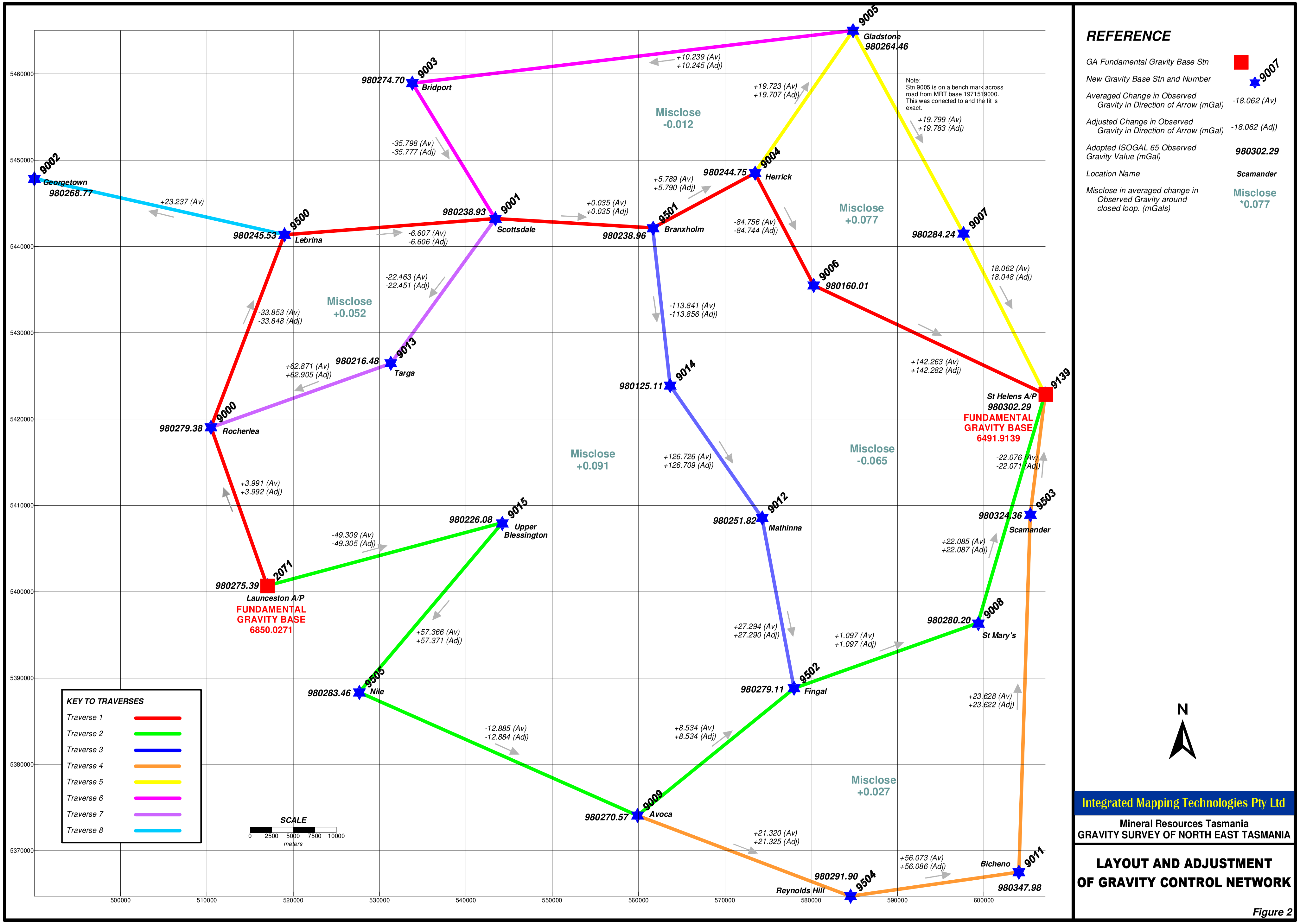


Figure 2 - Gravity Base Station Network

### 4.4.1 AUSPOS Processing.

Where a GPS base station was placed at a new mark, data were downloaded to computer after the first full days observation from the new reference station. Reference station data were converted to RINEX format using the NOVATEL program Convert4. In the process of this conversion, data was de-sampled to 30 second epochs and all GLONASS data was stripped out.

RINEX data was subsequently Emailed to GA and was processed quickly with results generally being received within a couple of hours of dispatch. The processing report was examined to evaluate the estimated coordinate precision, the Root Mean Square error and the percentage of data deleted before accepting or rejecting the AUSPOS determination of station coordinate and elevation.

AUSPOS Processing Reports are herewith as Appendix 4.

### 4.4.2 Repeatability Of AUSPOS Determinations

A number of GPS Reference Stations were occupied over a number of days. It was decided to test the repeatability of the AUSPOS determinations of station coordinates and elevations by submitting several days observations for 2 different stations, namely 8005 and 9015. The repeatability of results obtained were surprisingly good. The Standard Deviation of repeated determinations was determined to be 7mm in Easting, 6mm in Northing and 20mm in Elevation. This was inside GA's estimate of accuracy included in the various processing reports.

Table 3 **REPEATABILITY OF AUSPOS DETERMINATIONS**

**MGA Grid, GRS80 Ellipsoid, GDA94**

| Stn | East(M) | Dev'n | North(M) | Dev'n | Ellipsoidal Height(m) | Dev'n | Above-Geoid Height(m) | Date Observed | Obs'n Interval |
|---|---|---|---|---|---|---|---|---|---|
| 8005A | 515095.644 | 0.010 | 5454790.674 | 0.004 | 107.303 | 0.030 | 107.681 | 14/01/2008 | 9.0hrs |
| 8005B | 515095.622 | -0.012 | 5454790.670 | 0.000 | 107.262 | -0.011 | 107.640 | 15/01/2008 | 9.8hrs |
| 8005C | 515095.636 | 0.002 | 5454790.666 | 0.004 | 107.254 | -0.019 | 107.632 | 16/01/2008 | 9.6hrs |
| Average | 515095.634 | | 5454790.670 | | 107.273 | | | | |
| 9015A | 544336.309 | 0.002 | 5408095.914 | 0.010 | 386.696 | 0.008 | 386.475 | 02/12/2007 | 8.0hrs |
| 9015B | 544336.309 | 0.002 | 5408095.904 | 0.000 | 386.669 | -0.019 | 386.449 | 17/02/2008 | 8.8hrs |
| 9015C | 544336.303 | -0.004 | 5408095.893 | 0.011 | 386.698 | 0.010 | 386.478 | 18/02/2008 | 8.8hrs |
| Average | 544336.307 | | 5408095.904 | | 386.688 | | | | |
| **STDEV'n** | | **0.007** | | **0.006** | | **0.020** | | | |

### 4.4.3 Survey Control Summary

Table 4 below summarises the survey control used to coordinate and level new gravity stations.

Table 4 **SURVEY CONTROL SUMMARY** Mar-08

| *Pt No* | *AGD66 E* | *AGD66 N* | *AHDTas83* | *Mark* | *XY Class* | *XY Order* | *Z Class* | *Z Order* | *Location* |
|---|---|---|---|---|---|---|---|---|---|
| 9000 | 510475.18 | 5419043.94 | 97.356 | SPM6300 | GPS | 3rd | 3rd Lev | 3rd Diff | Rocherlea |
| 9001 | 543411.49 | 5443209.28 | 193.634 | SPM7381 | GPS | 3rd | 3rd Lev | 3rd Diff | Scottsdale |
| 9002 | 489693.77 | 5447728.07 | 46.828 | AUSPOS | | | | | GeorgeTown |
| 9003 | 533789.69 | 5458932.97 | 15.190 | SPM7769 | GPS | 3rd | 3rd Lev | 3rd Diff | Bridport |
| 9004 | 573501.79 | 5448496.54 | 151.088 | ST1094 | GPS | 3rd | 3rd Lev | 3rd Diff | Nr Herrick |
| 9005 | 584859.19 | 5465012.61 | 66.783 | SPM10508 | GPS | 3rd | Sat GPS | 3rd | Gladstone |
| 9009 | 559886.88 | 5374074.32 | 212.295 | SPM10222 | GPS | 3rd | Sat GPS | 3rd | Avoca |
| 9013 | 531309.57 | 5426472.17 | 395.947 | AUSPOS | | | | | Targa |
| 9015 | 544336.31 | 5408095.90 | 386.468 | AUSPOS | | | | | Upper Blessington |
| 9500 | 518986.58 | 5441357.89 | 206.388 | SPM9962 | GPS | 3rd | Sat GPS | 3rd | Lebrina |
| 9501 | 561688.21 | 5442110.54 | 175.008 | SPM10495 | GPS | 3rd | Sat GPS | 3rd | Branxholm |
| 8000 | 514279.33 | 5438723.70 | 92.456 | AUSPOS | | | | | Mt Direction |
| 8001 | 534025.69 | 5458526.34 | 14.726 | AUSPOS | | | | | Bridport A/P |
| 8002 | 552064.68 | 5469096.84 | 37.037 | AUSPOS | | | | | Waterhouse |
| 8003 | 527953.53 | 5420797.59 | 376.889 | AUSPOS | | | | | Nunamara |
| 8004 | 517351.15 | 5434673.29 | 161.827 | AUSPOS | | | | | Lilydale |
| 8005 | 514982.97 | 5454606.64 | 107.651 | AUSPOS | | | | | Pipers Brook |
| 8006 | 524822.99 | 5451995.31 | 134.190 | AUSPOS | | | | | Ferny Hill |
| 8007 | 506024.90 | 5449403.71 | 133.861 | AUSPOS | | | | | Pipers River |
| 8008 | 539858.9 | 5437332.05 | 252.825 | AUSPOS | | | | | Springfield |
| 8009 | 556323.6 | 5438568.33 | 410.397 | AUSPOS | | | | | Billycock Hill |
| 8010 | 561489.15 | 5453353.53 | 675.302 | AUSPOS | | | | | Mt Horrible |

## 4.5 ROUTINE OPERATIONS

### 4.5.1 Access & Landowner Contact

Access permits were provided by MRT for Tasmanian National Parks and State Forestry areas. In the course of conducting the survey, it was also necessary to access private land. Where this was required, IMT personnel were required to contact the landowner and seek permission to enter. The process involved in identifying landowners was:-

- Plan the work several days in advance and identify land parcels to which access was required.

- Contact MRT and request identification of relevant landowners from an internal MRT database (the "List"). Information was generally provided within 24 hours.
- The landowner was then contacted by phone and asked to give permission for access.

Where permission was denied, the planned station was abandoned.

#### 4.5.2 Overview

The field crew commenced operations on the 25th of November, 2007. Up to and including the 4th of December, the crew was initially engaged in observing a gravity base station network for the entire project area. Routine gravity survey operations commenced on the 5th of December and continued until the 23rd December excluding the 15th of December when an additional base connection was observed. The crew stood down over the Christmas – New Year holiday period then re-commenced routine operations on the 3rd of January, 2008. Routine metering continued until the 5th of February when the crew were stood down for half a day due to rain.

Rather than continue on "standown", the crew opted to change location and complete the NW Tasmania gravity survey.

The crew re-commenced metering on the NE Tasmania survey on the 17th of February and continued until the 20th of February when the allocated budget for fieldwork was expended.

Fieldwork was conducted by Senior IMT technician Richard Duggan and trainee technician Chris Jackson. Operations were based from hotels and motels across North Eastern Tasmania and were conducted using a Toyota Landcruiser trayback 4WD fitted with an on-board computer based navigation and GIS for transport.

The nature of the topography, vegetation coverage and a frequent lack of telecommunications infrastructure throughout much of the project area provided a number of challenges to both the field crew and their planned operational procedures. Difficulties included:-

- The range of (line of sight) radio communication systems used in Real Time Kinematic (RTK) surveying was severely limited by the topography. This resulted in very few stations being coordinated using RTK which generally has a 3 second observation time.
- Frequent high timber along access roads (often overhanging) induced large numbers of cycle slips in logged GPS/GLONASS data which in turn largely rendered the use of trajectory processing (2-3 mins data per station) unusable.
- Survey observations had to be made using Static Surveying techniques that required significantly longer occupations than RTK or Trajectory techniques. Typically, a minimum observation time of 10 minutes was used plus an additional 1min observation for each kilometer of base line length greater than 10km. This in turn made repeat survey observations impractical by time constraints.
- Mobile phone coverage was very poor. This meant it was often difficult to phone landowners until the crew returned to their hotel or motel.

- Access to Broadband Internet services was limited to Launceston and Scottsdale. This impacted on data transmittal to the Geoscience Australia AUSPOS processing service and to IMT's Sydney office.

### 4.5.3 Typical Daily Routine

The typical daily routine of the field crew under ideal conditions may be summarized as:-

- The crew would depart their operations base and move to the gravity base station from which they planned working from for the day.
- At the base station, the operator would check the adjustment of the gravity meter, then read and record 2 gravity observations at intervals of around 5 minutes.
- The crew would then drive to the planned location for the GPS reference station (if not coincident with the gravity base), set the base receiver up and switch it on to record 1 second epochs of data in Kinematic survey mode. If a new base was being set up. A recovery sketch would be made and photos of the location would be taken.
- The Gravity operator would then commence observation of routine stations within a radius of generally less than 10km (but up to 27km) of the GPS reference station.
- The length of GPS observations was determined by the distance from the Reference Station, the number of observable satellites and satellite geometry.
- Navigation to planned stations was by means of the GPS survey system, an onboard computer and a GIS data base of the regions topography, cadastre and existing gravity stations.
- After approximately 1.5 hours of routine observation, the operator would move to the last repeat station observed the previous day (RptA)and re-observe gravity (RptB) then resume routine operations. In nearly all repeat gravity observations, only an autonomous GPS fix was attempted so as to minimize time lost in the repeat observation process.
- After a further period of approximately 1.5hrs gravity observation, a gravity station was marked for repeat observation in the next loop and gravity was observed (rpt A).
- After a further 1.5hrs of observation, the operator returned to the base station he was operating from (or an alternative) and observed gravity to close the gravity loop then had a short break for lunch.
- After lunch, observation of the next gravity loop was commenced and routine observations were conducted for 1.5 hours followed by return to the last repeat station observed in the morning loop (rpt A) at which a repeat gravity observations was made (RptB).
- Routine observations were then conducted for a further 1.5 hours at which time a station was marked as a repeat station for re-observation of gravity in the first loop of the following day (RptA).
- Routine gravity observations were then made for a further 1.5hrs followed by a return to the GPS Reference Station which was then shut down and packed up.
- If not coincident with the GPS Base, the crew next travelled to the Gravity base in use and twice observed gravity to close the second loop of the day.

- Operators then returned to base to download and process data.

- As processing was being carried out by one operator, the other operator was generally engaged in planning access routes for work over the next few days, in contacting landowners regarding permission to access their land and identifying land parcels for which contact details were required.

Note 1:-
The repeat observation procedure ensures, as far as it is practically possible, that each gravity loop is tied to both the last and next loop providing a rigorous test of repeatability. The process also provides opportunities to recover data within a loop in the event of a tare in the gravity data.

Note 2:-
Initially, GPS Observations at routine gravity stations comprised 60-90 x 10 second epochs of data with an elevation mask of 10° on base lines up to 27km. Frequent cycle slips in data captured between stations meant that data processing options were restricted and a number of stations could not be processed to “FIXED” status. Some stations achieved a “FLOAT” status with a low Standard deviation. These were generally accepted to the data base but flagged as being of lower quality. Stations with high Standard Deviation were either re-observed or abandoned.

Note 3:-
The GPS observation strategy was changed on the 17th of December to reduce the length of base lines and increase occupation times. This significantly improved the number of “FIXED” solutions achieved.

Note 4:-
The GPS observation procedure was changed again on the 3rd of January such that
GPS observations at routine gravity stations comprised 600-900 x 1 second epochs of data with a 2° elevation mask and PDOP mask of 5. This further improved the number of “FIXED” solutions being achieved. The measurement precision of such observations on a 15km line is generally 10mm +/- 15mm. Routine observations were generally made from a purpose built roof bar.

Note 5:
GPS observations were made in kinematic mode (with continuous recording of data between stations) but processed as Static observations. - this strategy allows us to achieve a higher level of precision with short occupation times and facilitates several different processing strategies in the event of poor data.

Note 6:-
The recently released (April 08) Version 4.00 of the SPECTRUM GPS post processing software has created opportunities to re-process GPS data and potentially recover some of the abandoned stations.

### 4.5.4 Data Processing On Site

For a number of reasons (see 4.5.2 above), it was not feasible to do any more than basic processing of gravity data on site to test drift levels and check for the presence of tares in the data.

The onsite processing stream was therefore limited to:-

- Downloading of GPS receivers to computer
- Downloading of the Allegro data logger  on which RTK observations and gravity observations were stored.
- Formatting and processing of gravity data using "autonomous' GPS coordinates and elevations to check for excessive drift and/or tares.
- Copying of files to disk for posting to Sydney Office.

# 5 DATA PROCESSING IN SYDNEY

## 5.1 GENERAL

Data was generally received in Sydney office on a daily basis when broadband internet services were available to the field crew and 10 second epoch GPS data was being logged. Once logging of data at 1 second intervals was commenced on the 3rd of January, 2008, it was no longer feasible to transmit 35-40mb of data by E-mail every night. From then on, data was dispatched twice weekly by Express Post.

As data was received, it was downloaded to individual day directories; each with sub directories for paperwork, gravity data, GPS data and GPS Processing. Data logged at new GPS reference stations was identified and processed to RINEX Format using the Novatel CONVERT4 software then dispatched to GA for determination of a station coordinate and elevation using the AUSPOS Space Geodesy service (see section 4.4)

## 5.2 ROUTINE SURVEY DATA PROCESSING

Once the results of AUSPOS processing were received, a SPECTRUM "Project" was created in the relevant "day" directory. GPS Data were imported to the project. Vectors from the reference station to each gravity observation were developed then checked and edited. After fixing the coordinates and elevation of the reference station (AUSPOS coordinates and height), GPS vectors were processed and adjusted to derive coordinates and elevations for each gravity station.

A processing summary was automatically generated for checking and was subsequently saved and printed. The summary detailed, on a vector by vector basis, the type of processing solution achieved, the length of the vector, the percentage of GPS data used, the Ratio, Root Mean Square (RMS) error and the Standard Deviation (SD).

This summary information was examined and, where solution type or statistics indicated a poor solution for a vector, a range of evaluations were carried out to see whether there may be an alternative processing strategy available for individual problem vectors. Evaluations included:-

- Number of satellites
- Raw satellite data
- Vector residuals
- Frequency and timing of cycle slips etc

Depending on the evaluation of each problem vector, processing parameters were varied in an attempt to achieve a FIXED solution for each vector and/or improve each solution achieved. Some of the processing parameter variations included start and end time of observation, varying the elevation mask and in some cases, switching off specific satellites.

Once GPS processing solutions had been optimized, a summary solution file listing point number, AMG Zone 55 – AGD66 easting and Northing and AHD (Tas) 1983 orthometric heght was exported to the "day" directory as a *.CSV file.

It should be noted that where stations achieved an RTK "FIXED" solution, the data was manually adjusted by an XYZ Block shift within an EXCEL Spreadsheet when daily data was being merged into blocks (see below). This was because there was insufficient data to process the raw data through SPECTRUM.

## 5.3 ROUTINE GRAVITY DATA PROCESSING

Raw gravity observations were periodically merged to a "Block" file (of which there were four). The start and end dates of these block files related to logical work periods, breaks in observation and MRT requirements for data to be periodically delivered to Dr David Leaman for calculation of terrain corrections.

For each block, a summary data file was compiled as an EXCEL Spreadsheet for each block. These files were used to merge processed and adjusted survey data with gravity observations. They listed gravity observations and adjusted station coordinates and elevations, adjustment calculations for RTK survey observations, repeat gravity observations, the type of survey observation/solution achieved for each station, the location of the GPS reference station and gravity base station and any modifications made to data after it was received in Sydney (corrections). These files are appended hereto as Appendix 6.

Block gravity observations were next exported from the summary spreadsheet in a space delimited file ready for processing in the Surtec gravity reduction program GRAVRED.

Before processing, however, coordinates used on *gravity only* repeat observations were varied by a few centimeters to ensure they were not treated as secondary base stations as Surtec gravity reduction software recognises base stations by co-ordinate. If repeat observations have the same coordinate, they are treated as being secondary bases.

Merged gravity and survey observations were then corrected for instrument factor, then tide and then drift against adopted base station values using the program GRAVRED which output files of corrections applied and observed gravity (.COR), normal gravity (.RED) and a listing of observed gravity values with geographic coordinates (.UTM). Repeat gravity and GPS observations were noted then averaged in the RED files.

RED files were then shipped to Dr Leaman for the computation of Terrain Corrections.

## 5.4 REPEAT GRAVITY OBSERVATIONS

A total of 186 observations were made at repeated gravity stations A listing of repeat gravity station observations is appended hereto as Appendix 7. Observed gravity values for each repeat station are listed along with the average value of each repeat station and the deviation of each repeat. The Standard Deviation of repeat observations was computed to be 0.020mGals.

## 5.5 COMPILATION OF DATA IN MRT FORMAT

Once final terrain corrections were received, a space delimited TXT file was compiled listing Station Number, Easting and northing (AMGZ55, AGD66 in meters), Orthometric Height (AHD 1983 Tas. In meters), Observed Gravity (ISOGAL65 in mGals) and Terrain Correction computed at a density of 2.67g/cc in mGals.

# 6 ESTIMATED PRECISION & ACCURACY

## 6.1 PRECISION OF OBSERVATIONS

The precision of observations can be summarized as:

| | |
|---|---|
| GPS Survey Observations:- | 20mm +/- 1ppm |
| Gravity Observations:- | +/-0.01mgals |

## 6.2 ESTIMATED ACCURACY OF CONTROL NETWORKS

- Based on an examination of miscloses and error distribution in closed gravity control loops, the estimated accuracy of gravity base stations is +/-0.01mgals.
- Based on an examination of repeated processing of GPS Base Station data using the AUSPOS Space Geodesy Processing Service, the estimated accuracy of GPS Reference Stations is +/-15mm in coordinate and +/-30mm in elevation

## 6.3 ESTIMATED ACCURACY OF ROUTINE OBSERVATIONS

- Based on the standard deviation of repeated gravity observations, the estimated accuracy of routine gravity stations is +/-0.02mGals.
- No meaningful attempt was made to obtain repeat determinations of gravity station coordinates and elevations because of time constraints. The accuracy of all static survey observations was estimated and reported in summary form by the processing software. In general terms, the accuracy of FIXED 3D solutions is better than 10mm and of FLOAT solutions is better 250mm.

# 7 DATA DISK

A data disc has been prepared and is inserted at the rear of this report. The contents of the disc are summarized below:

**TABLE 5: COMPUTER FILES**

| DIRECTORY | FILE NAME | CONTENTS |
|---|---|---|
| 00_Data_MRT_Format | MRT_NETAS_07-08_Comp@267 | Text file listing ISOGAL65 Observed Gravity in mGals and |
| | | Terrain Corrected Gravity using a density of 2.67g/cc |
| 01_Block_Compilations | B1comp.XLS | Compilation of Block 1 Gravity Observations and survey sol'n |
| | B2comp.XLS | Compilation of Block 2 Gravity Observations and survey sol'n |
| | B3comp.XLS | Compilation of Block 3 Gravity Observations and survey sol'n |
| | B4comp.XLS | Compilation of Block 4 Gravity Observations and survey sol'n |
| 02_AUSPOS | 19 *.PDF Files - 8000 to 9013 | 19 AUSPOS Processing Reports: File No = Stn No |
| 03_Base_Network_Obs | Basenet.txt | Compilation of raw gravity observations - base network |
| | Basenet.COR | Ins't factor, tide and drift corrections, obs'd gravity - base net |
| | Adopted_Base_Values.txt | Adopted gravity base station values |
| | Adjustment.XLS | Adjustment of gravity base network |
| 04_Report | Sub-Directory Appendices | Multiple Files |
| | Sub-Directory Recovery Sketches | Multiple Files |