ADELAIDE RESOURCES
ROVER GRAVITY SURVEY

APRIL - JUNE 2009

Report Number 09018

Written by: G.A. Coopes

CLIENT

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1. INTRODUCTION

Daishsat Geodetic Surveyors carried out a precision GPS-Gravity survey between April and June 2009 for Adelaide Resources. A total of 4,430 new stations were surveyed at the Rover project in the Northern Territory.

Gravity data was acquired using a Scintrex CG-5 digital gravity meter. Position and level data was obtained using Leica GPS units to produce precise real-time kinematic locations. All data was acquired using Daishsat foot-borne methods.

Gravity data was reduced using standard reductions on the ISOGAL84 gravity network. GPS data were reduced to MGA coordinates with levels expressed as meters above the Australian Height Datum.

2. SURVEY OVERVIEW

The Rover project was located approximately 75km southwest of the town of Tennant Creek, Northern Territory. The project consisted of two separate grids – Rover East and Rover West.

The Rover East survey was designed to infill on an existing survey. Data was acquired initially on a detailed grid consisting of 100m stations measured along north-south lines spaced 200m apart. Data was then acquired on a regional grid consisting of 250m stations measured along north-south lines spaced 500m apart. A small area of 100m x 200m infill was completed in the northern area of the grid.

On the Rover West survey data was acquired on a detailed grid consisting of 100m stations measured along north-south lines spaced 200m apart.

The terrain and vegetation encountered during the survey was typical of the Tennant Creek area – mainly flat ground covered in termite mounds, with Spinifex and thick stands of Kerosine Bush.

Figure 1 shows the location of the survey, Appendix A contains a station plot of the survey and specifications for the survey are contained in Appendix C.

Photos 1-3 Data acquisition and typical vegetation

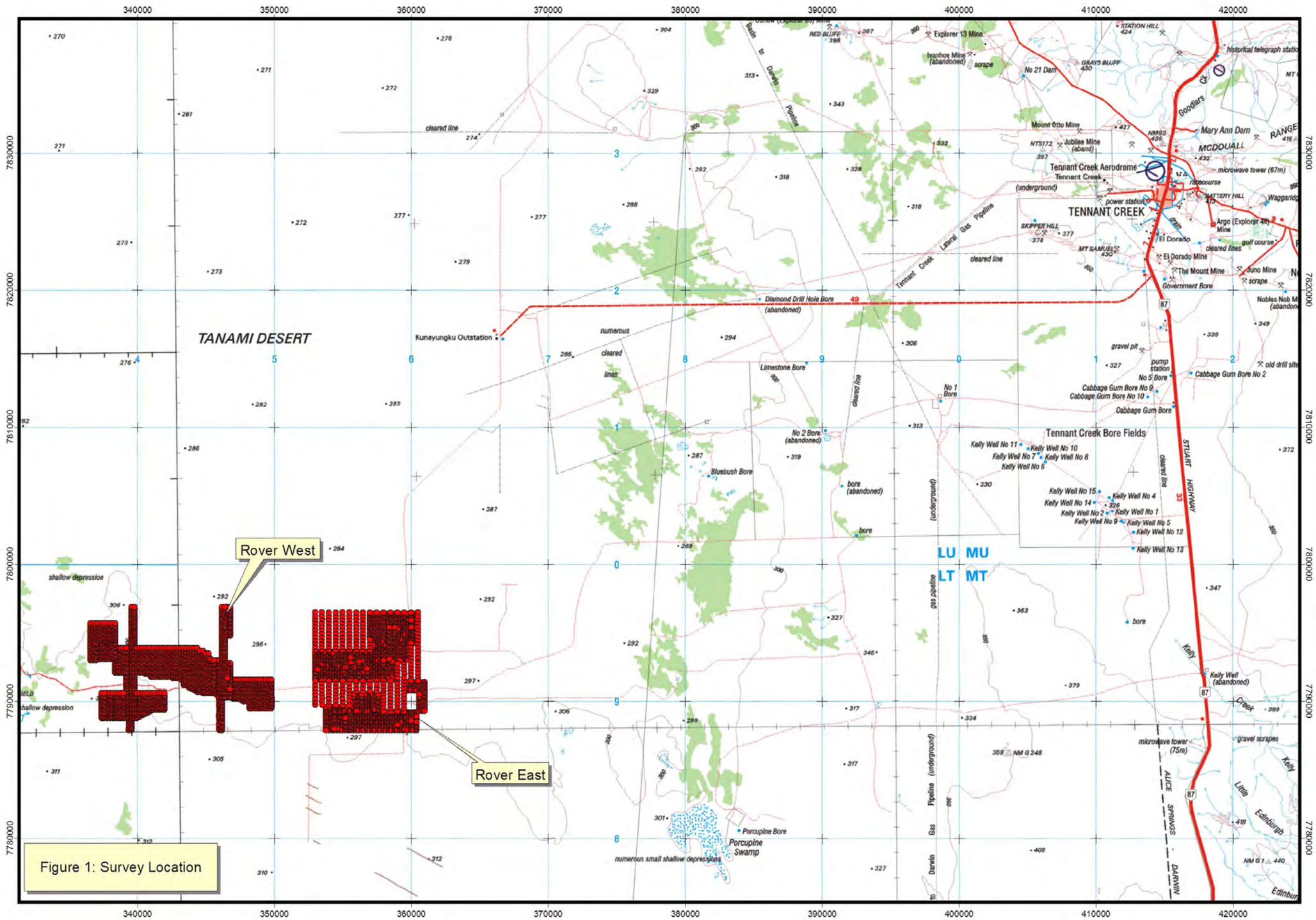


Figure 1: Survey Location

3. PERSONNEL AND EQUIPMENT

3.1 Personnel

The supervisors in charge of the project were Malcolm Field and Max Fry. They were responsible for daily management of the job and for nightly data processing to ensure quality and integrity. Data acquisition was carried out by:

Malcolm Field, Crew Leader	Max Fry, Crew Leader
Steve Doyle, Crew Leader	Nick Tanner, Field Technician

Final data reduction, image processing and inspection were performed by the company geophysicist, Grant Coopes.

3.2 Survey equipment

- Scintrex CG-5 Gravity meter
- Leica System 1200 & 500 dual frequency GPS receivers
- UHF Pacific Crest Data Modem/Radios
- Garmin Handheld GPS receivers for navigation
- IBM notebooks for data processing and backup
- Various chargers, surveying equipment and batteries

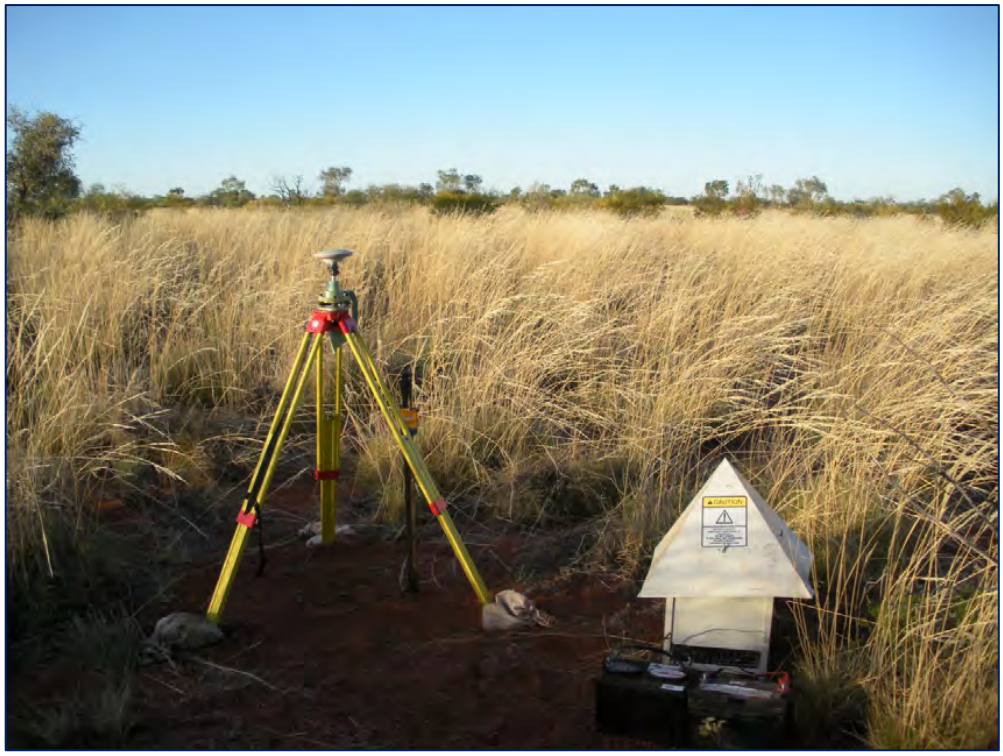


Photo 4: Leica Real-Time-Kinematic GPS Base.

3.3 Vehicles

A Daishsat Toyota Landcruiser 4WD was used for transport to and from the survey areas.
To maintain the high Daishsat safety record, the vehicle was fitted with a range of safety equipment including:

- Omnitrack GPS tracking / communications system
- Dual fuel tanks
- Spare tires, tubes and tyre repair kit
- Satellite phone and UHF Radio
- Self-recovery equipment including, on board winch, snatch straps and rope
- Tools and spares to enable field repairs as necessary
- Survival kit with EPIRB emergency locator beacon

3.4 Accommodation

The crew stayed at Westgold Resources Rover exploration camp for the duration of the survey.

3.5 Communications

The survey crew was equipped with hand-held satellite phones when working away from the vehicle. “Omnitrack” satellite based tracking was used on all vehicles to enable asset monitoring via a web interface. Scheduled communication and data exchanges with the Perth and Murray Bridge offices were ongoing for the duration of the job.

4. GPS SURVEYING AND PROCESSING

4.1 Set out of the grid

This was done concurrently with the gravity data acquisition using the Leica 1200 GPS operating in real-time kinematic mode. Where possible, the readings were taken as close to the ideal coordinates as possible. Some stations were offset or omitted due to the nature of the terrain, e.g. hilly or thickly vegetated areas. As the Leica system was operating in precise RTK mode, set out accuracy was better than 5cm. At the repeat stations, a washer tied to pink flagging, marked with the station number, was used for identification. At each station, the station number, position and RL were recorded digitally by the GPS crew.

4.2 Survey datum and control

The gravity surveying, and hence any gravity reductions, used the Australian Height Datum (AHD) as the reference datum. All new GPS/Gravity base stations were established using two days worth of static data, and connections to ITRF stations using Geoscience Australia's online GPS processing system, AUSPOS. For more information on this system, please visit http://www.ga.gov.au/geodesy/sgc/wwwgps/index.jsp. Final deviations of better than 5mm were obtained for x, y and z, for all occupations. Appendix D contains the GPS base station information.

4.3 Processing of the position and level data

The real-time kinematic GPS data was recorded on a removable CF card which was downloaded daily. All data was processed in real-time, so no further processing was required. Simple transformations to MGA and AHD were done using the GPS derived WGS84 positions.

MGA94 coordinates were obtained by projecting the GPS-derived WGS84 coordinates using a UTM projection with zone 53S. For all practicable purposes, the WGS84 geodetic coordinates are equivalent to GDA94 geodetic coordinates, so no transformation is necessary. For more information about GDA94 and MGA94, please visit http://www.ga.gov.au/geodesy/datums/.

AHD heights were calculated using Leica's premier GPS software package – Leica Geo Office – which utilises the latest geoid model for Australia, AUSGEOID98. Information about the geoid, and the modelling process used to extract separations (N values) can be found at http://www.ga.gov.au/geodesy/ausgeoid/.

5. GRAVITY ACQUISITION AND PROCESSING

5.1 Gravity data acquisition

Gravity observations were made simultaneously with the GPS observation. Two observations were made for each station so that any seismic or instrumental noise could be immediately detected. Each observation consisted of a 20-second or greater stacking time. The accepted tolerance between readings was limited to 0.030 of a dial reading to ensure accuracy. Vertical and horizontal levels were restricted to 10 arc seconds at all times.

At each station, the station number, time and two gravity readings (in dial units) were recorded in Daishsat carbon-copy gravity field books. The Scintrex CG-5 also automatically records the station, time and readings digitally to allow for downloading to computer.

5.2 Gravity base stations

Gravity base stations were used for calculation of absolute gravity and drift determination. New gravity bases were established within close proximity to each of the survey areas to coincide with the GPS bases. These bases were tied to AFGN gravity base 6796.0134 at the Tennant Creek Airport. Details of these bases are contained in Appendix D.

When in the field, a base station reading was taken in the morning before observing, and at evening after the last observation. When taking a base station reading, the observed gravity values were stacked over 120 seconds to ensure accuracy. Observations were repeated until the readings repeated to 0.010 of a dial reading or less.

5.3 Gravity data processing

Raw gravity data were processed on a daily basis to check for quality and integrity. This interim process produced a set of Bouguer Gravity values, which were contoured and imaged to provide a check for any anomalous readings that would need repeating. Geosoft GRAVRED software was used for the gravity reduction in the field.

Other software used on this project includes ArcView, ChrisDBF, and Oasis Montaj. The formulae used in the gravity reduction are listed below:

Instrument scale factor: This correction was used to correct a gravity reading (in dial units) to a relative milliGal value based on the meter calibration.

Tidal correction: This correction was used to correct for background variations due to changes in the relative position of the moon and sun. The Scintrex calculated ETC was removed and a new ETC calculated using Geosoft Formulae and the surveyed GPS latitude. The formula is too complex to list here.

Instrument Drift: Since gravity meters are mechanical, they are prone to drift (extension of the spring with heat, obeying Hooke's law). If two base readings are taken one can assume that the drift between the two readings is linear and can therefore be calculated. The drift and tidal corrected value is referred to as the *observed gravity*.

Theoretical Gravity: The theoretical value of gravity was calculated using the 1967 variant of the International Gravity Formula and used to latitude correct the observed gravity.

$$Gt=978031.856 *(1+0.005\ 278\ 895*\sin^2\phi+0.000\ 023\ 462*\sin^4\phi)$$

where ϕ represents degrees of latitude

Free-Air Correction: Since gravity varies inversely with the square of distance, it is necessary to correct for changes in elevation between stations to reduce field readings to a datum surface (in this case, AHD).

$$FA = 0.308596 \times h_{AHD}$$

Bouguer Correction: This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. A value of 2.67 gm/cc was used in the correction.

$$BC = 0.0419088 \times \rho \times h_{AHD}$$

where ρ = density (2.67 gm/cc)

Free Air Gravity: This is obtained by applying the free air correction (FAC) to the observed gravity reading.

$$FAG=G_{OBSG84}-Gt+FAC$$

Bouguer Gravity: This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$BG267=G_{OBSG84}-Gt+FAC-BC$$

5.4 Gravity meter calibration and scale factors

The gravity meter used had previously been calibrated on either the South Australian or Western Australian gravity calibration ranges. A derived scale factor from these calibrations is shown below:

Meter	Serial Number	Scale Factor
K	40372	1.000246

6. RESULTS

Raw and processed GPS and gravity data are contained on CDROM as Appendix E. Hardcopy plots of station location/images are contained in Appendix A.

6.1 Stations Surveyed and Survey Progress

In total 4,430 new stations were acquired during the project. A brief production summary for the area is shown in Table 1 below. Production varied depending on the type of terrain and access to the area, but the crews were typically able to achieve rates of between 100 and 130 stations per day.

Baramine		
Gravity stations acquired (including repeats)	**4,607**	stations
Gravity station repeats	**177**	4%
New gravity stations acquired	**4,430**	stations
Total accidents	**0**	accidents
Total hours lost from accidents	**0**	hours

Table 1: Production Summary

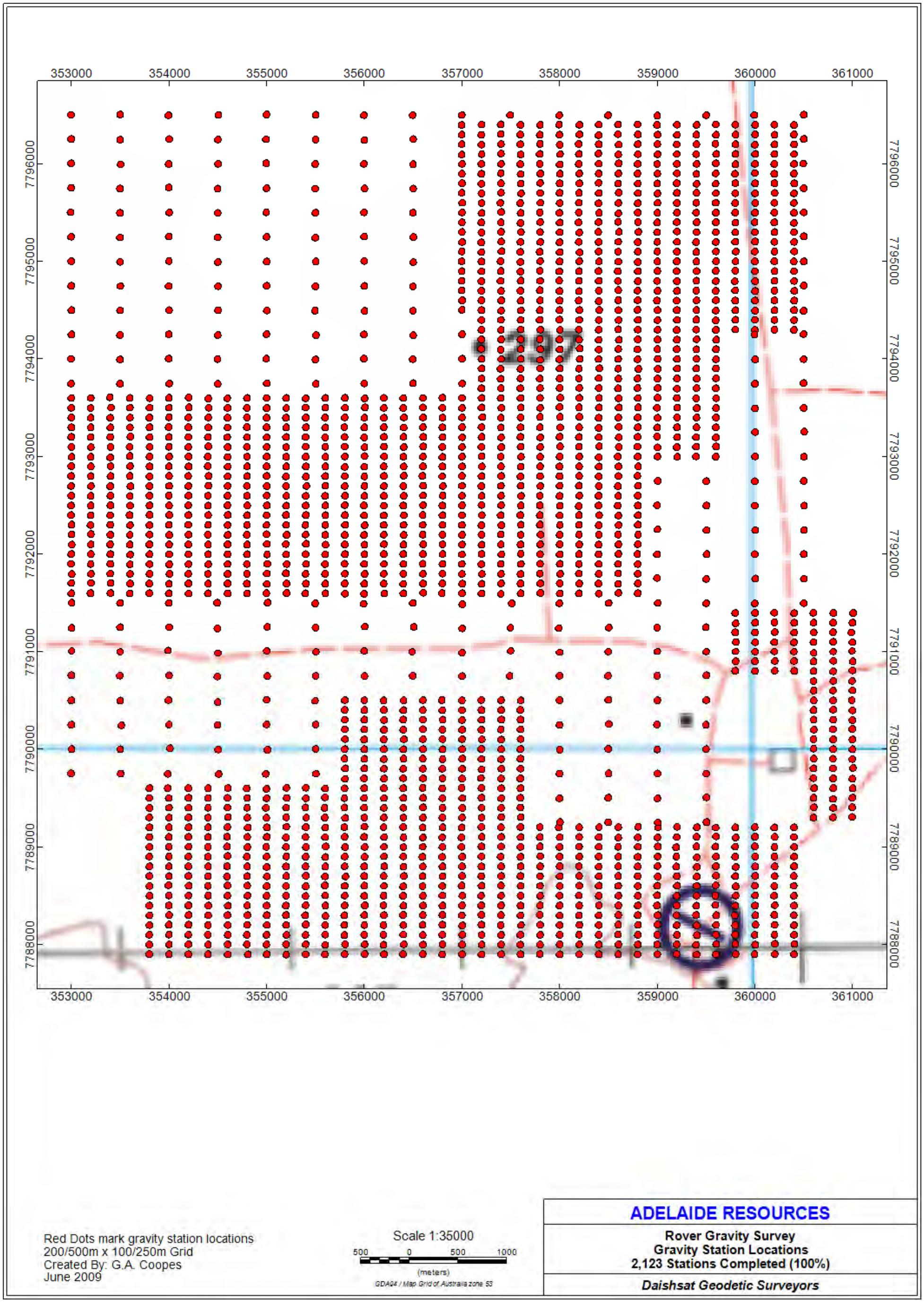
6.2 Data Repeatability

Analysis of the repeat data shows that measurement repeatability is excellent for both GPS and Gravity observations. A combined analysis for each of the surveys is included in Appendix B. Based on the repeat data, one can assume the following typical accuracies for the observables:

Z position observation: < 0.014 m
Gravity observation: < 0.021 mGals

APPENDIX A

Plots of station location / Images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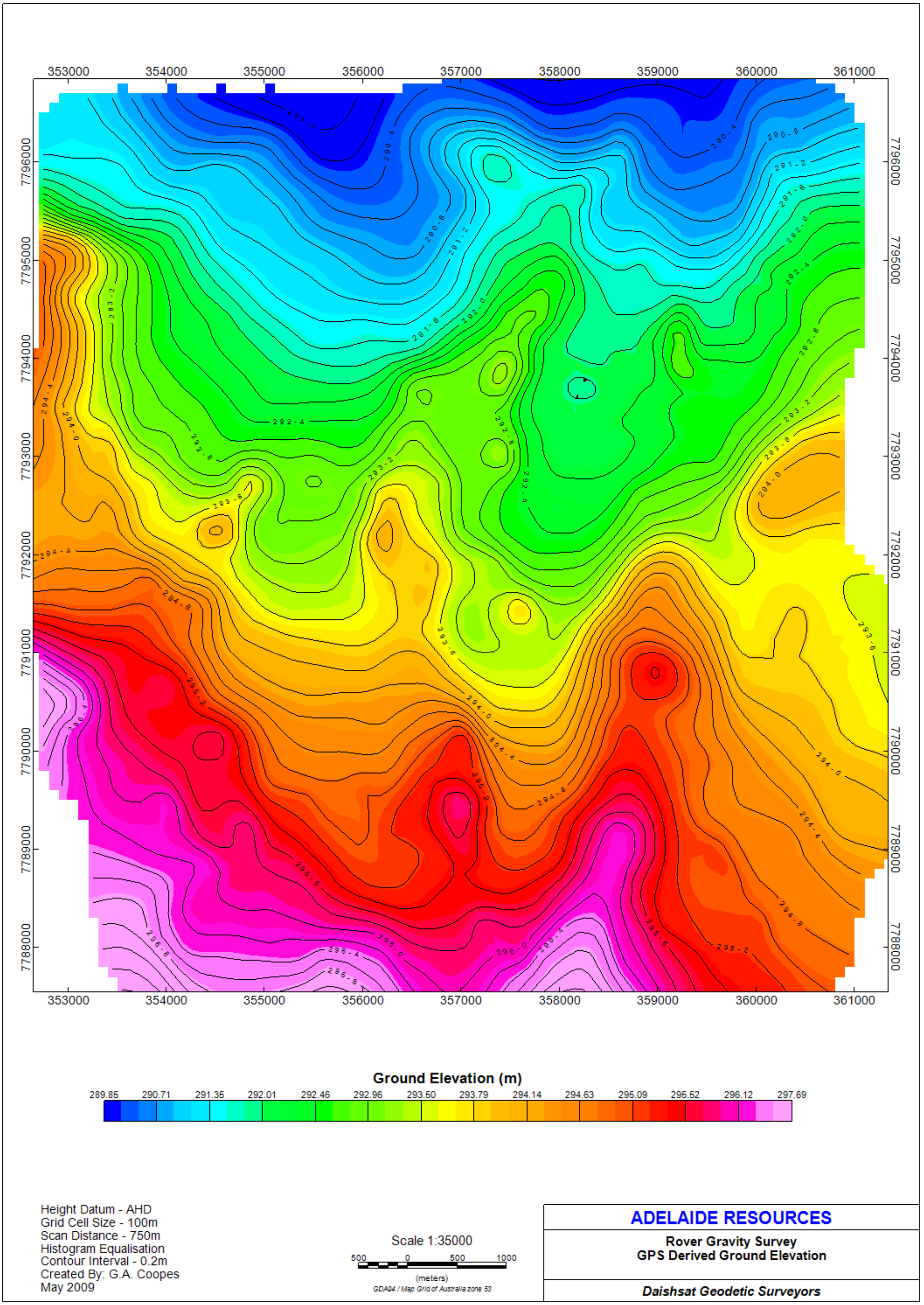
Red Dots mark gravity station locations
200/500m x 100/250m Grid
Created By: G.A. Coopes
June 2009
Scale 1:35000
500 0 500 1000
(meters)
GDA94 / Map Grid of Australia zone 53
ADELAIDE RESOURCES
Rover Gravity Survey
Gravity Station Locations
2,123 Stations Completed (100%)
Daishsat Geodetic Surveyors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Ground Elevation (m)
289.85
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292.01
292.46
292.96
293.50
293.79
294.14
294.63
295.09
295.52
296.12
297.69
Height Datum - AHD
Grid Cell Size - 100m
Scan Distance - 750m
Histogram Equalisation
Contour Interval - 0.2m
Created By: G.A. Coopes
May 2009
Scale 1:35000
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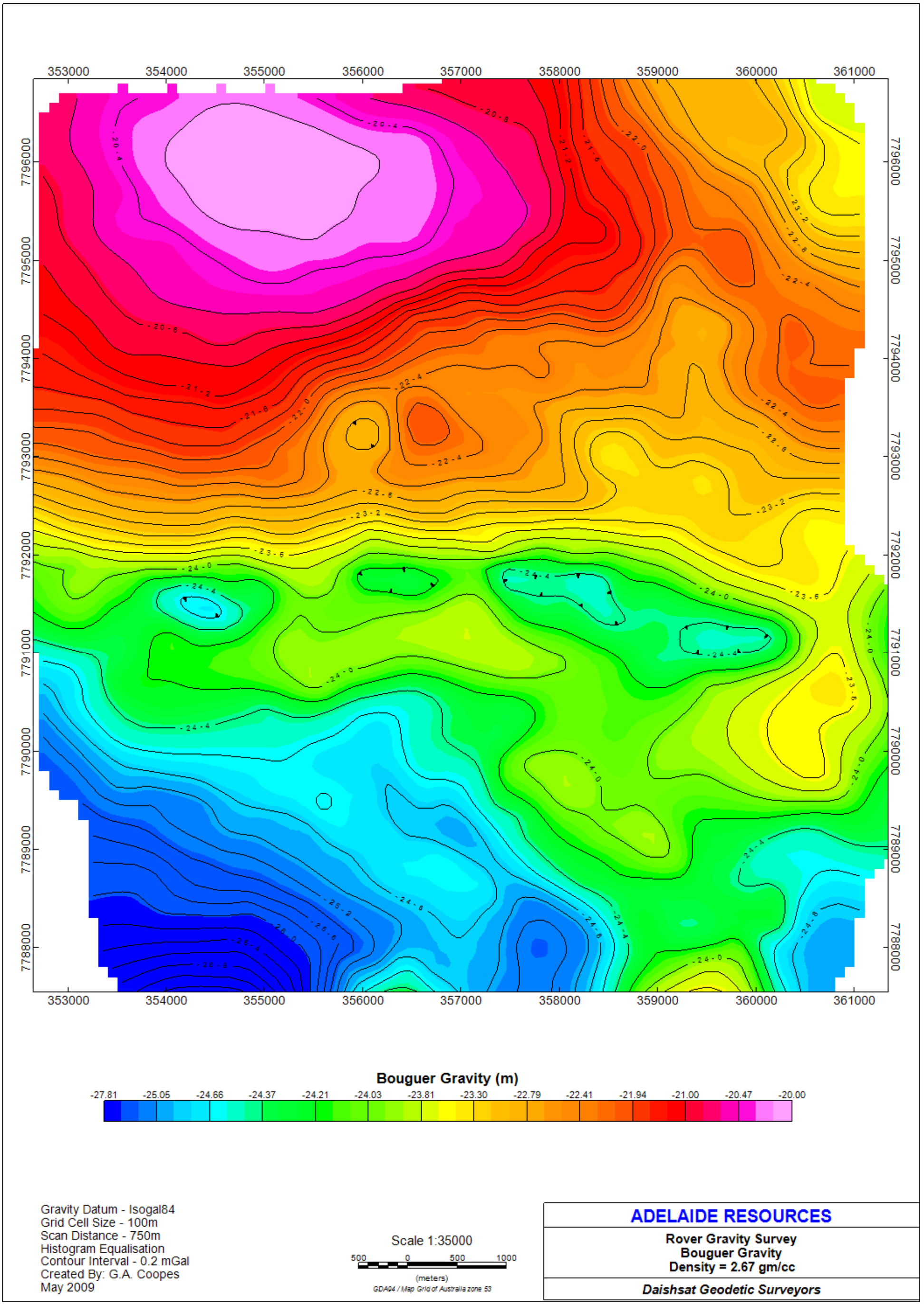
GDA94 / Map Grid of Australia zone 53
ADELAIDE RESOURCES
Rover Gravity Survey
GPS Derived Ground Elevation
Daishsat Geodetic Surveyors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Bouguer Gravity (m)
-27.81
-25.05
-24.66
-24.37
-24.21
-24.03
-23.81
-23.30
-22.79
-22.41
-21.94
-21.00
-20.47
-20.00
Gravity Datum - Isogal84
Grid Cell Size - 100m
Scan Distance - 750m
Histogram Equalisation
Contour Interval - 0.2 mGal
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May 2009
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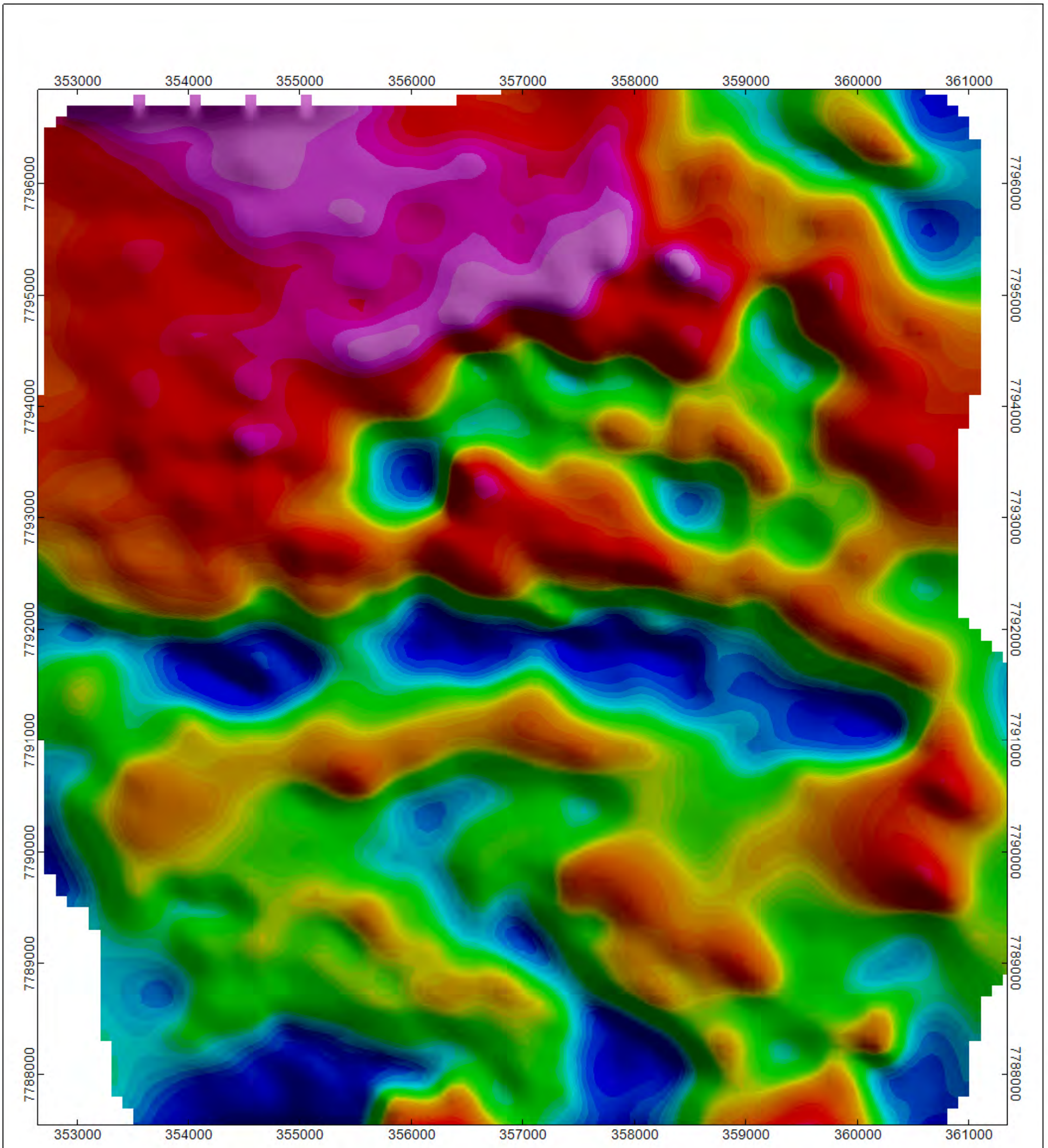
(meters)
GDA94 / Map Grid of Australia zone 53
ADELAIDE RESOURCES
Rover Gravity Survey
Bouguer Gravity
Density = 2.67 gm/cc
Daishsat Geodetic Surveyors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Gravity Datum - Isogal84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Northeast Sunshading
Created By: G.A. Coopes
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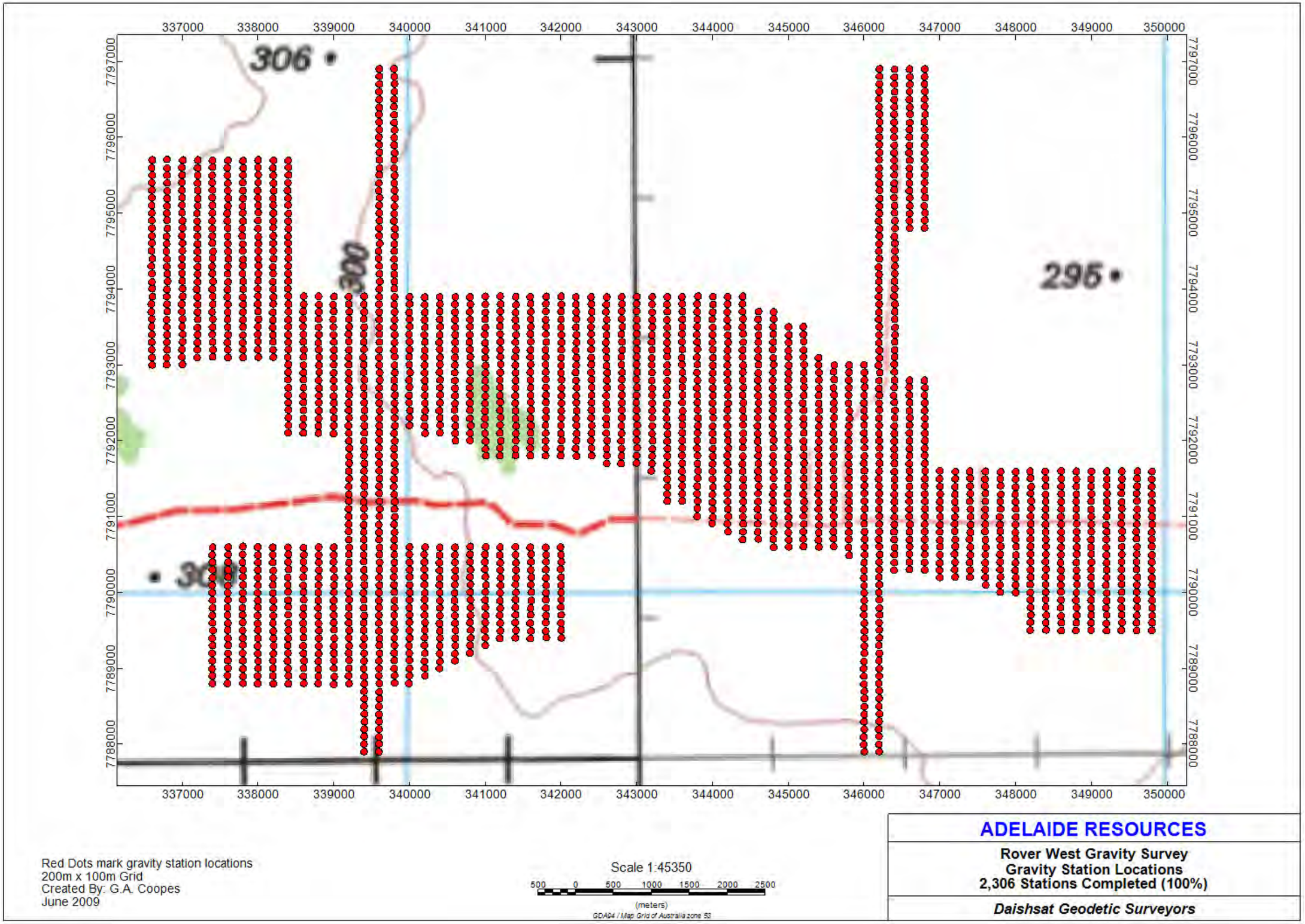
ADELAIDE RESOURCES
Rover Gravity Survey
Vertical Derivative
Density = 2.67 gm/cc
Daishsat Geodetic Surveyors



Red Dots mark gravity station locations
200m x 100m Grid
Created By: G.A. Coopes
June 2009

Scale 1:45350

500 0 500 1000 1500 2000 2500

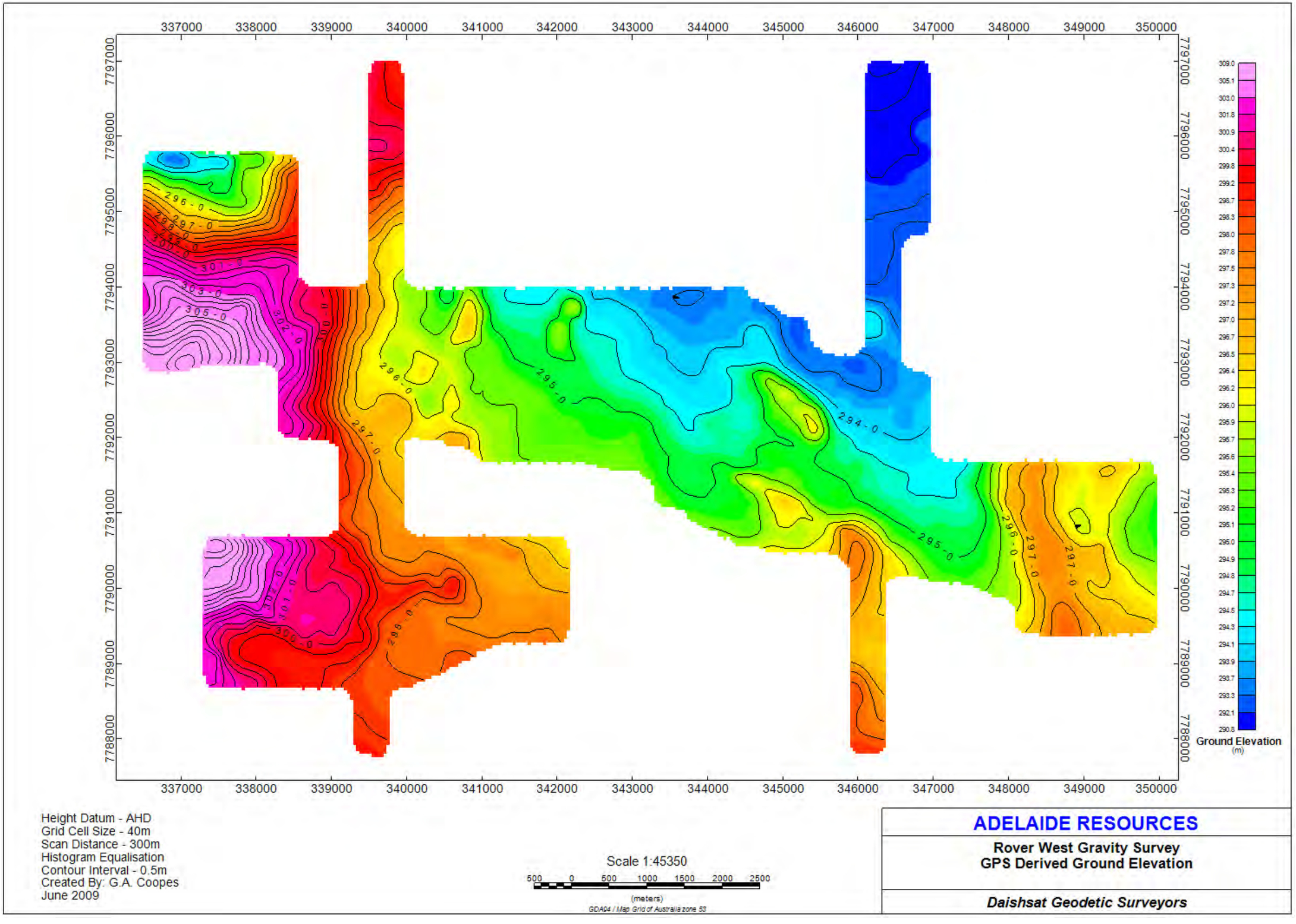
(meters)

GDA94 / Map Grid of Australia zone 53

ADELAIDE RESOURCES

Rover West Gravity Survey
Gravity Station Locations
2,306 Stations Completed (100%)

Daishsat Geodetic Surveyors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Ground Elevation
(m)
Height Datum - AHD
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.5m
Created By: G.A. Coopes
June 2009
Scale 1:45350
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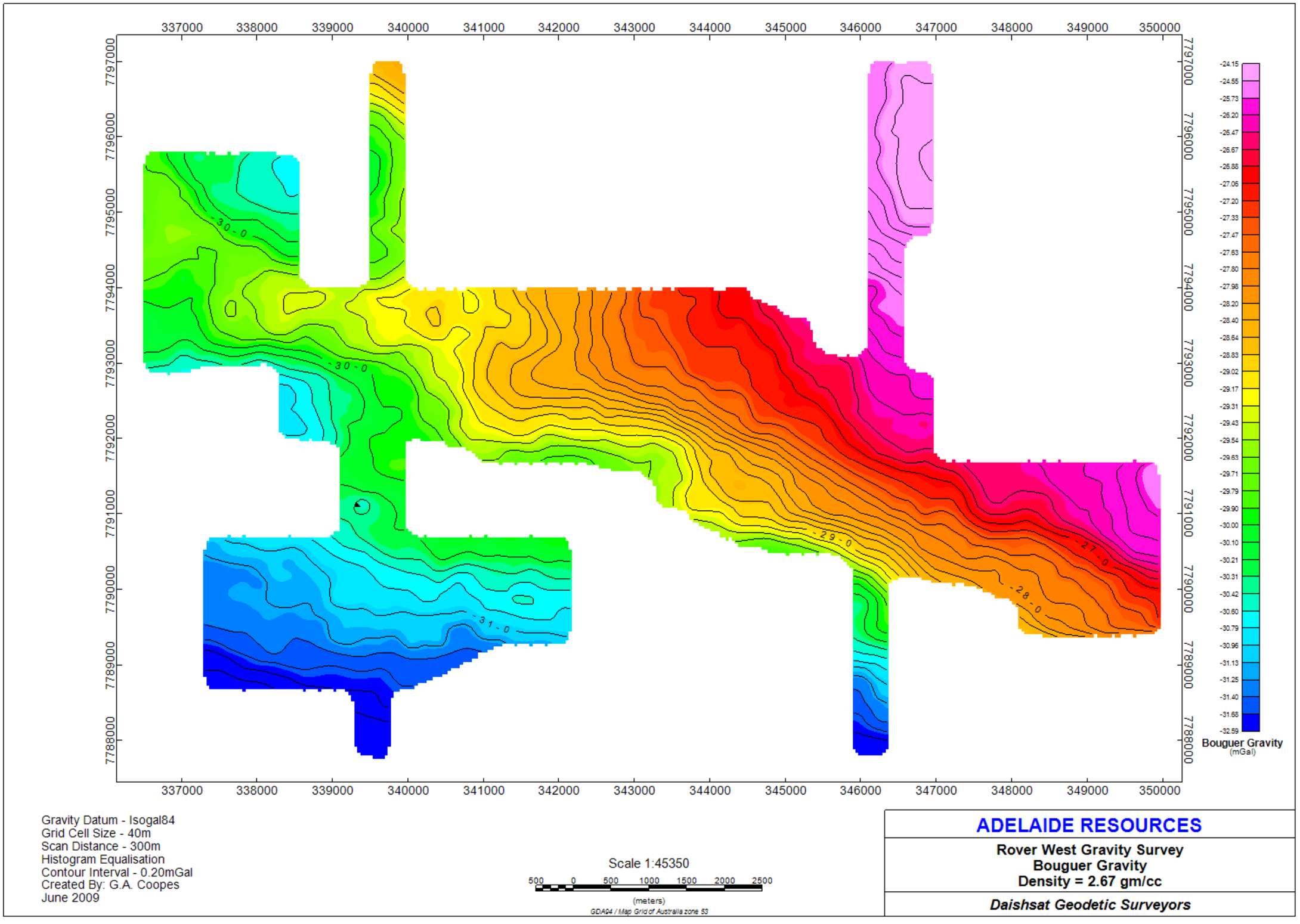
GDA94 / Map Grid of Australia zone 53
ADELAIDE RESOURCES
Rover West Gravity Survey
GPS Derived Ground Elevation
Daishsat Geodetic Surveyors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(mGal)
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Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.20mGal
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June 2009
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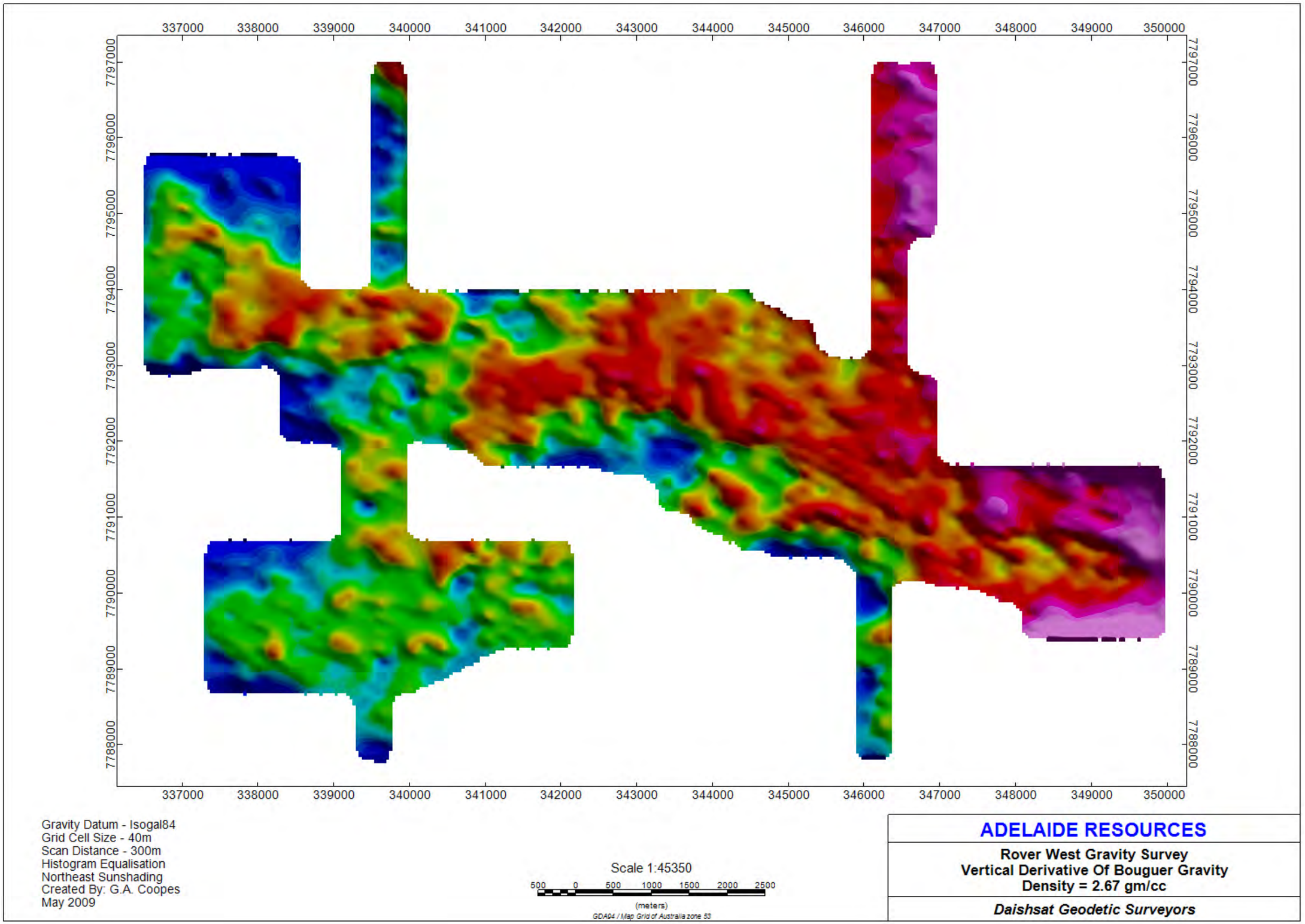
ADELAIDE RESOURCES
Rover West Gravity Survey
Bouguer Gravity
Density = 2.67 gm/cc
Daishsat Geodetic Surveyors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Gravity Datum - Isogal84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Northeast Sunshading
Created By: G.A. Coopes
May 2009
Scale 1:45350
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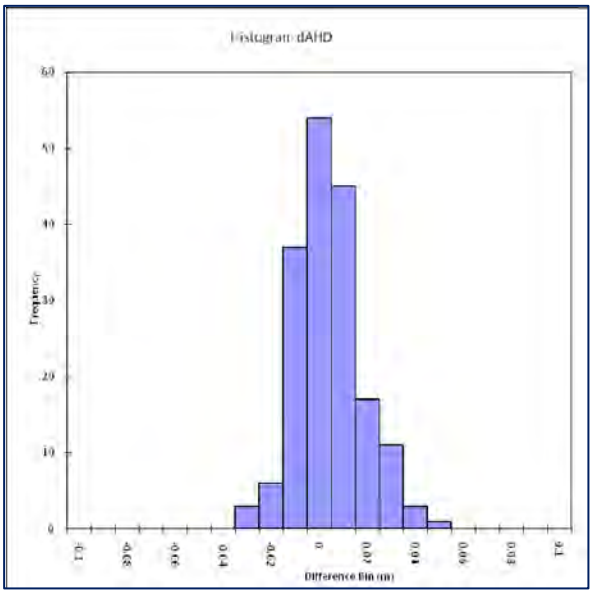
(meters)
GDA94 / Map Grid of Australia zone 53
ADELAIDE RESOURCES
Rover West Gravity Survey
Vertical Derivative Of Bouguer Gravity
Density = 2.67 gm/cc
Daishsat Geodetic Surveyors

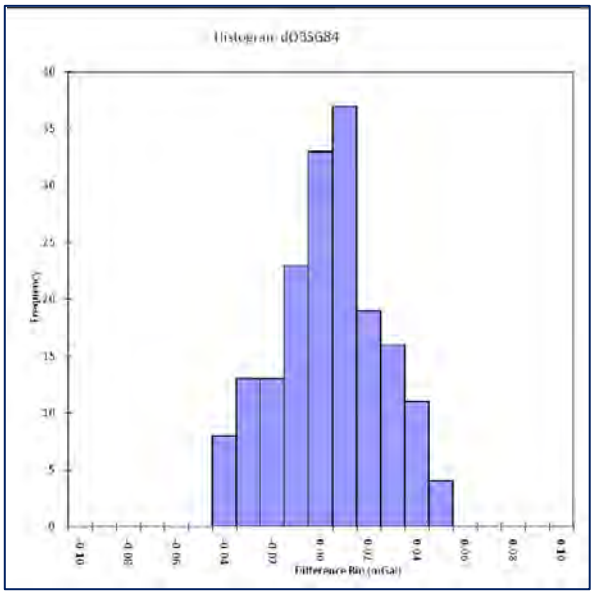
APPENDIX B

Repeat Tabulation and Analysis

Repeatability of OBSG84



Repeatability of AHD



Summary Statistics

Summary Table	*dAHD*	*dOBSG*
Mean	-0.001	-0.001
Standard Error	0.001	0.002
Median	-0.001	0.000
Mode	-0.012	0.003
Standard Deviation	0.014	0.021
Sample Variance	0.000	0.000
Kurtosis	0.433	-0.451
Skewness	0.238	-0.076
Range	0.081	0.095
Minimum	-0.037	-0.049
Maximum	0.044	0.046
Sum	-0.111	-0.149
Count	**177**	**177**

APPENDIX C
Survey Specifications

Rover East Gravity Survey

Client	Adelaide Resources
Operators	Malcolm Field, Steve Doyle, Nick Tanner
Techniques Employed	RTK GPS, Ground Gravity
Station Spacing	100m / 250m
Line Spacing	200m / 500m
Gravity Meter	Scintrex CG5, K – SN: 40372
GPS Units	Leica 500 (Base) & Leica 1200 (Rover)
Number of Points Surveyed	2,211 total, includes 2,123 new and 88 repeats
Gravity Bases	Daishsat Bases 0166
GPS Bases	Daishsat Bases 0166
Date of Survey	30th April to the 21st May 2009

Rover West Gravity Survey

Client	Adelaide Resources
Operators	Max Fry, Nick Tanner
Techniques Employed	RTK GPS, Ground Gravity
Station Spacing	200m
Line Spacing	400m
Gravity Meter	Scintrex CG5, K – SN: 40372
GPS Units	Leica 500 (Base) & Leica 1200 (Rover)
Number of Points Surveyed	2,396 total, includes 2,307 new and 89 repeats
Gravity Bases	Daishsat Bases 0167
GPS Bases	Daishsat Bases 0167
Date of Survey	3rd to the 24th June 2009

APPENDIX D

Base Station Information

Daishsat GPS/Gravity Base 0166 Rover East

MGA94		GDA94	
EASTING (m)	357109.008	LATITUDE (DMS)	19° 58' 18.3137" S
NORTHING (m)	7791062.690	LONGITUDE (DMS)	133° 38' 03.6271" E
ZONE (UTM)	53 South	ELL HT (WGS84,m)	323.875
HEIGHT (AHD, m)	293.450	N (AUSGEOID98, m)	30.425

OBSERVED GRAVITY

978553.011 mGals

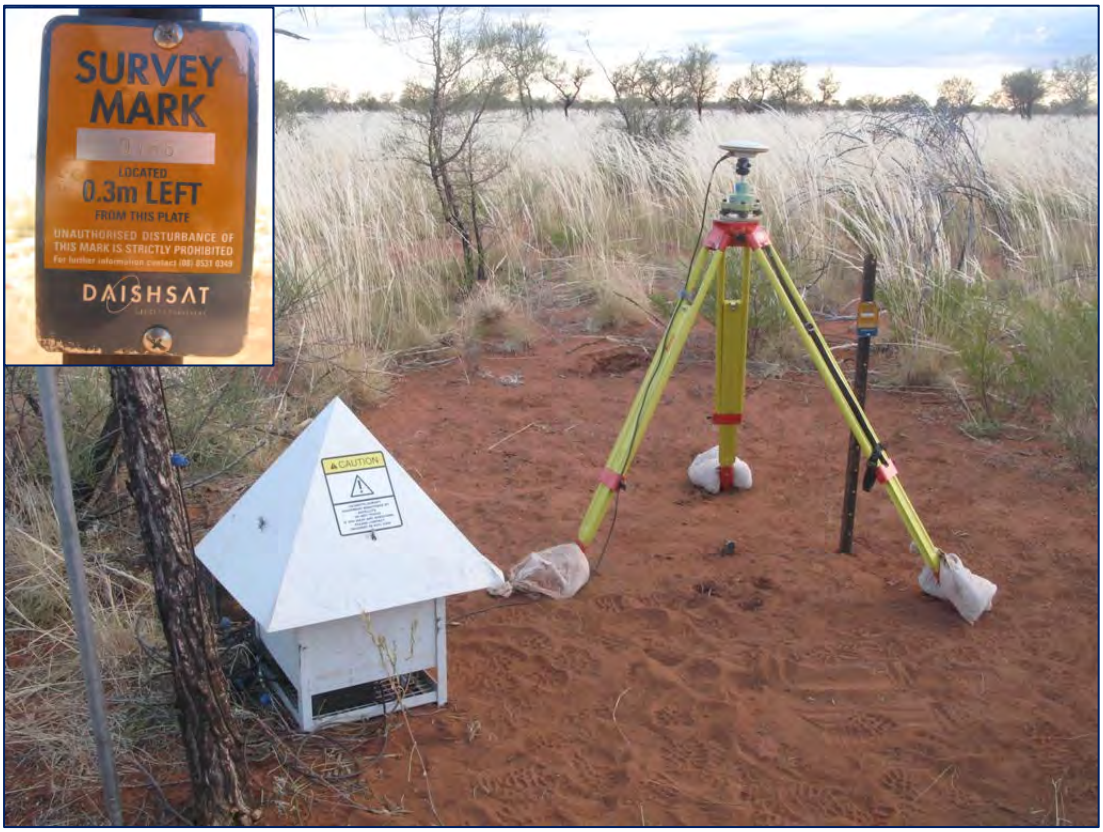
SURVEYED BY

GPS – Daishsat AUSPOS with multiple connections over three days. Expected accuracy better than 0.01m for x, y, z observations.

Gravity – Daishsat, using A-B-A ties to AFGN station 6793.0134 at the Tennant Creek Airport. Expected accuracy better than 0.01 mGals.

MISCELLANEOUS DETAILS

This station consists of a small steel pin protruding from the ground by 30mm and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The station is located approximately 3km northwest of Westgold Resources Rover Exploration Camp and can be accessed by heading south from Tennant Creek on the Stuart Hwy. After 6.4km turn right onto a graded dirt track and continue for 79.1km (crossing first a rail line then two cattle grids) then turn right onto another track which the base is located 2.7km along, adjacent to the track on its right hand side.



Photos of Daishsat Base0166 with distinguishing features in background

Daishsat GPS/Gravity Base 0167 – Rover West

MGA94		GDA94	
EASTING (m)	342982.342	LATITUDE (DMS)	19° 58' 20.2408" S
NORTHING (m)	7790882.716	LONGITUDE (DMS)	133° 29' 57.6424" E
ZONE (UTM)	53 South	ELL HT (WGS84,m)	327.087
HEIGHT (AHD, m)	297.198	N (AUSGEOID98, m)	29.889

OBSERVED GRAVITY

978546.070 mGals

SURVEYED BY

GPS – Daishsat AUSPOS with multiple connections over three days. Expected accuracy better than 0.01m for x, y, z observations.

Gravity – Daishsat, using A-B-A ties to Daishsat base 0166. Expected accuracy better than 0.01 mGals.

MISCELLANEOUS DETAILS

This station consists of a small steel pin protruding from the ground by 30mm and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The station is located approximately 3km northwest of Westgold Resources Rover Exploration Camp and can be accessed by heading south from Tennant Creek on the Stuart Hwy. After 6.4km turn right onto a graded dirt track and continue for 79.1km (crossing first a rail line then two cattle grids) then turn right onto another track which the base is located 17km along, adjacent to the track on the left hand side.

Photos of Daishsat Base0167 with distinguishing features in background

APPENDIX E

Data CD
(Attached to back cover)