GEMPART (NT) PTY LTD

ILLOGWA CREEK 2018 GRAVITY SURVEY PROCESSING AND LOGISTICS REPORT

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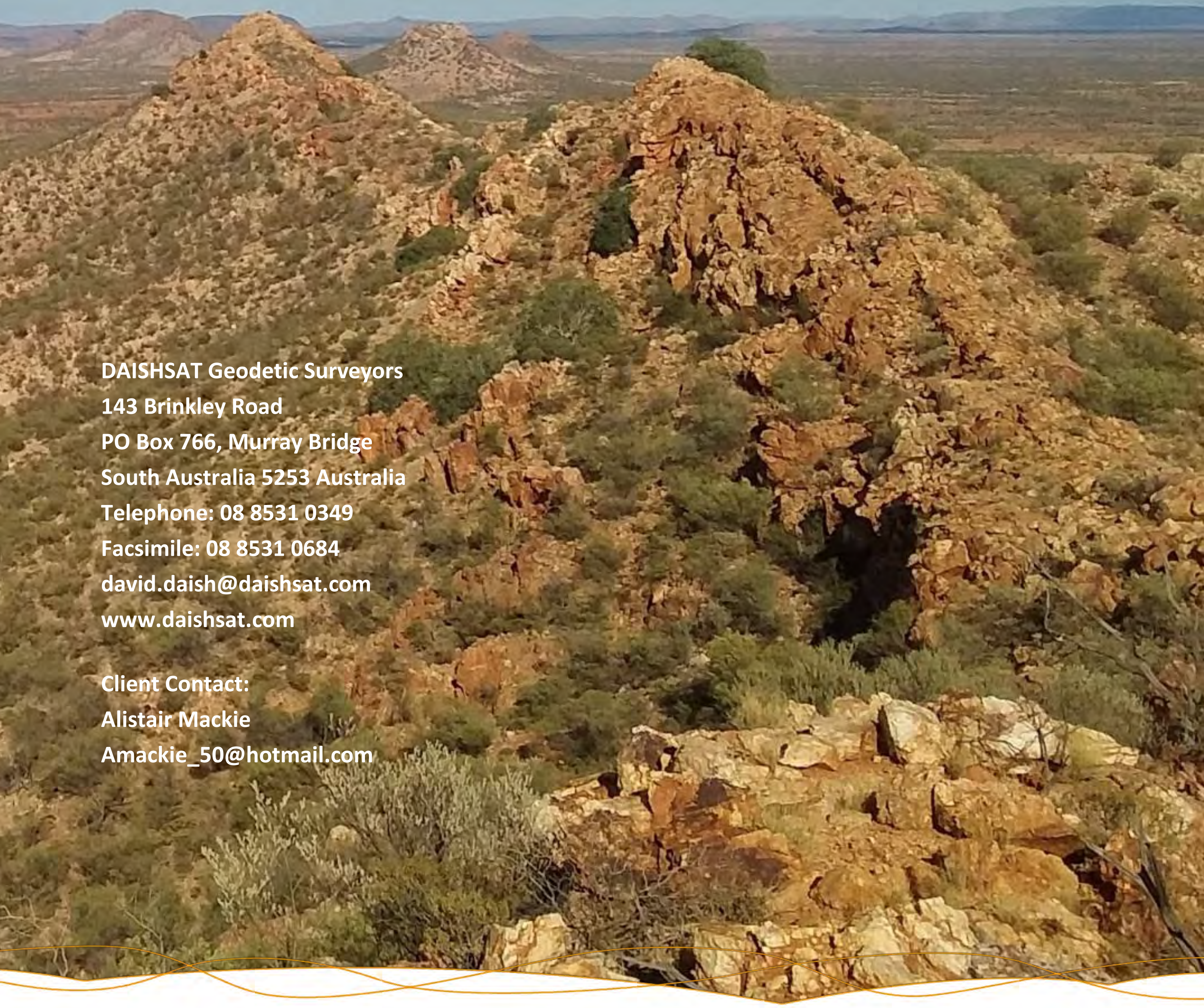

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DAISHSAT GEODETIC SURVEYORS

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1.0 INTRODUCTION

Daishsat Geodetic Surveyors successfully carried out a precision ground gravity survey during October 2018 for Gempart (NT) Pty Ltd, with a total of 1,060 new gravity stations surveyed in the south east region of the Northern Territory.

Scintrex CG-5 Autograv gravity meters were used for gravity data acquisition and base station control. Leica GX1230 differential GNSS receivers were used for gravity station positional acquisition. Gravity and GNSS data were acquired using Daishsat ATV and walking methods.

The survey was conducted using two ATV crews and was completed safely, on time and within contract specifications. The crews merged to form a single crew when walking was required.

Photo 1 – A Daishsat DATV, a highly modified all-terrain vehicle at Illogwa Creek

2.0 SURVEY OVERVIEW

The gravity survey was conducted on Gempart (NT) Pty Ltd's Illogwa Creek project, approximately 180km east of Alice Springs, on the edge of the Simpson Desert.

The survey consisted of one area with gravity stations spaced 200m along 200m spaced lines running east-west. During the survey it was decided by Gempart (NT) Pty Ltd to infill areas of interest at 100m and 50m spaced stations.

The terrain encountered in the survey area was generally flat, low to medium vegetation. Along the southern boundary of the survey a steep and rocky ridge was encountered, for which acquisition had to be undertaken on foot. This ridgeline was approximately 80m higher than the surrounding flat terrain.

The survey was reasonably remote, with crews obtaining fuel and supplies from Alice Springs before heading into site. The crews were fully self-supporting, conducting vehicle and equipment maintenance as required and on site during the duration of the project.

Photo 2 – Typical terrain found throughout the majority of the survey area

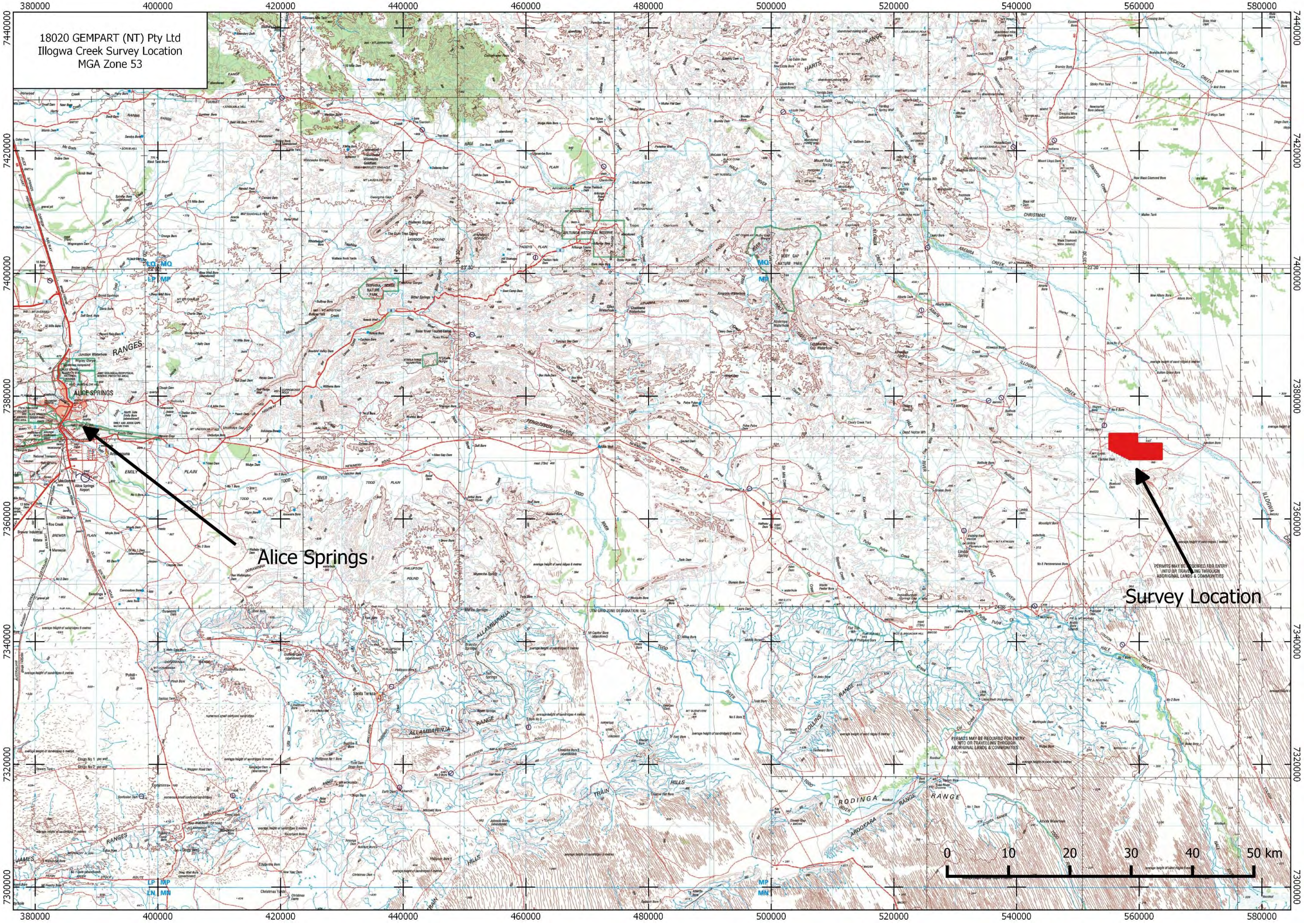


Figure 1 – Survey Location

3.0 PERSONNEL AND EQUIPMENT

3.1 Personnel

Gravity surveying, final data reduction, image processing and reporting was conducted by Daishsat Surveyors and Geophysicists. A full description of the personnel involved in the survey is listed in Appendix C – Survey information.

Photo 3 – Daishsat ground gravity crews with their acquisition equipment

3.2 Survey equipment

Surveying equipment utilised on this survey included:

- Scintrex CG-5 Gravity meters
- Leica System GX1230 dual frequency DGNSS receivers
- Garmin vehicle-mounted GNSS receivers for navigation
- Notebooks for data processing and backup

3.3 Vehicles

Toyota Landcruisers were used for transport to and from site with heavily customised John-Deere Gator 4WD all-terrain vehicles (ATV's) used to acquire gravity stations.

The Landcruisers are fitted with a range of safety equipment including:

- Dual fuel tanks
- Spare tyres, tubes and tyre repair kit
- Satellite phone and UHF Radios
- Garmin inReach satellite tracking device
- Self-recovery equipment including winch and snatch straps

- Tools and spares to enable field repairs as necessary
- Survival kit with EPIRB emergency locator beacon
- First Aid kits

The Daishsat ATV's used were equipped with the following survey and safety equipment:

- Garmin inReach satellite tracking device
- 10L jerry can of spare fuel
- Spare tyres, tubes and tyre repair kit
- Satellite phone and UHF Radio
- Personal First Aid Kit
- Self-recovery equipment including winch, snatch straps
- Tools and spares to enable field repairs as necessary
- Survival kit with EPIRB emergency locator beacon

3.4 Accommodation

To minimise daily travel times, crews set up a fly camp as close to the survey area as possible.

Our fly camps consist of a small tent and swag for each person, and a small area for the vehicles and ATV's. All equipment and rubbish were removed upon demobilisation from site, causing minimal impact on the surrounding environment.

3.5 Communications

The survey crews were equipped with hand-held Iridium satellite phones, vehicle-mounted UHF radios and Garmin inReach satellite tracking and messaging devices. The inReach system allows for real time monitoring of the crews' location (whether in a vehicle or on foot) via a web interface, and two-way messaging between the office and other crews onsite. Scheduled daily communication and data exchanges with the Murray Bridge office were ongoing for the duration of the job and this enabled survey updates and interim data to be reported to the client on a regular basis.

Photo 4 – Survey acquisition on foot due to steep terrain

4.0 GNSS SURVEYING AND PROCESSING

4.1 Set out and surveying of the grid

Set out of the survey grid was done concurrently with the gravity data acquisition using Leica GX1230 dual-frequency GNSS units operating in autonomous mode. Where possible, the readings were taken as close as possible to the nominated coordinates. Some stations were moved from their nominated coordinates for various reasons including inaccessible trees and scrub, topographical features that could introduce severe local gravity terrain effects and other topographical issues making access to the station difficult or unsafe. Raw kinematic GNSS data was logged by a Leica GX1230 receiver during the gravity observations to determine the precise location of the GNSS antenna. Repeat gravity stations were strategically placed throughout the survey to monitor and control gravity meter performance and positional accuracy.

4.2 Survey datum and control

A new GNSS base station (with gravity base located coincident), numbered 1538, was established for use in the survey.

A typical Daishsat base station consists of a star picket witness post with an affixed Daishsat plaque along with a short star picket driven to refusal about 10cm above ground level and emplaced about 30cm to the left of the witness post. All bases are photographed to create a permanent record that will ensure accurate access to this site as a future resource.

Base 1538 is described further in Appendix D – Base station location and information.

Photo 5 – Base 1538 used for the survey

Coordinates for base station 1538 have been calculated using three days' worth of static GNSS data connected to Australian based IGS (International GNSS Service, formerly the International GPS Service) stations using Geoscience Australia's online GNSS processing system, AUSPOS. The base positions obtained from AUSPOS usually show final accuracy standard deviations (SD) of better than 5mm obtained for x, y and z, and can be considered first order.

4.3 Processing of the position and level data

Raw kinematic GNSS data were logged at 5 second intervals on the Leica GX1230 GNSS receiver and static GNSS data was logged at 5 second intervals on a Leica GX1230 GNSS receiver set up on the GNSS base station. Surveys are planned such that base to rover baseline lengths are kept as short as possible to maintain reliable and accurate positional resolution. At times additional GNSS receivers are placed in the field at temporary unmarked locations to shorten the baseline lengths.

At the end of each day all raw GNSS data was downloaded onto a laptop, compressed and transferred to the Daishsat FTP site. The data was processed using Waypoint's (Novatel) GrafNav GNNS post-processing software to produce positions accurate to within a couple centimetres for the antenna location at every 5 second epoch.

Photo 6 – A Leica GX1230 GNSS receiver set up over base 1538 with a redundant base set up nearby

4.4 Quality control of the position and level data

The GNSS data was processed using Waypoint's (Novatel) GrafNav GNNS post-processing software. This software has many tools and applications that assist our Surveyors and Geophysicists processing and analysing the data to ensure quality positional data is reliably and consistently obtained for all gravity stations throughout the project. Experience is required in structuring the field observations to collect reliable and accurate data in different conditions. Trees, scrub, long baseline lengths, different satellite windows and other factors can affect the GNSS observations and these need to be taken into account when planning and processing a survey. Repeat analysis on the survey data had demonstrated that accurate and reliable positional data has been collected and processed for this project.

5.0 GRAVITY ACQUISITION AND PROCESSING

5.1 Gravity data acquisition

Scintrex CG-5 Autograv gravity meters were used exclusively for the field acquisition. For each gravity observation the CG-5 gravity meter was carefully placed on its tripod and levelled, restricting the vertical and horizontal levels to 5 arc seconds. Once the meter was level, two gravity observations of 20-second stacking time were read and recorded. The instrument was monitored for any seismic or instrumental noise and the X/Y tilts, temperature and tolerance between readings was monitored during the reading by the Surveyor. The tolerance between readings is set at 0.030 of a dial reading and any readings falling outside of this were re-read. Field readings were also manually recorded by the field crews in Daishsat gravity field books along with any observations that may affect the reading.

During the day the field crews monitored any internal repeat gravity stations collected for abnormal drift and tares as well as the drift closure at the end of the day. If the meter received a bump or knock the previous station was revisited in order to detect if a tare had occurred.

5.2 Gravity base stations

The gravity base used for this survey was located coincident with the new GNSS base station, numbered 1538, as described in section 4.2. Gravity base 1538 was tied with multiple loops to one of Daishsat's existing gravity bases, 1287, which was previously tied to the AFGN station at Alice Springs Airport in 2015. Base 1538 is described further in Appendix D – Base station location and information.

When in the field during field acquisition, a base station reading was taken in the morning before surveying commenced, and after the last field observation of the day. 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

At the end of each day the raw gravity data was downloaded from the CG-5 instruments onto a laptop where preliminary quality control was carried out. Any erroneous station numbers were corrected and readings that fell outside of tolerance were removed. Once this was done Daishsat's in-house software was used to average the two 20-second readings for each gravity station, remove the Scintrex Earth Tide Correction and assign each gravity station reading an easting and northing co-ordinate and a ellipsoidal elevation. Geosoft GRAVRED software was then used to perform gravity reductions to produce a set of observed gravity values that can be used for gridding, imaging and further analysis.

The following corrections were applied to the raw gravity data using Geosoft's GRAVRED software:

Instrument Scale Factor (SF): This correction is applied to correct each raw gravity reading (in dial units) to a relative gravity unit value based on the meter calibration.

$$R_{SF} = r_d \times SF$$

Where:

R_{SF} = scale factor corrected reading in milliGals

r_d = raw gravity meter reading in dial units

SF = instrument scale factor (dial units/milliGal)

Earth Tide Correction (ETC): This correction is applied to correct for regular variations in the Earth's gravitational field due to changes in the relative position of the moon and sun. The Scintrex calculated ETC was removed and a new ETC was calculated using Geosoft Formulae.

$$r_{ETC} = r_{SF} + ETC$$

Where:

r_{ETC} Earth Tide Corrected reading in milliGals

r_{SF} Scale Factor Corrected reading in milliGals

ETC Earth Tide Correction (ETC) in milliGals

Instrument Drift Correction (IDC): This correction is applied to compensate for the daily changes in the gravity meter due to mechanical stresses and strains encountered during surveying. The extension and contraction of the gravity meter spring with slight variations in temperature (obeying Hooke's Law) are the major cause of drift. The drift is assumed to be linear and is calculated by measuring the difference between the last and first base readings.

$$ID = \frac{r_{B2} - r_{B1}}{t_{B2} - t_{B1}}$$

Where:

ID Instrument Drift in milliGals/hour

r_{B2} 2nd Gravity Base reading in milliGals

r_{B1} 1st Gravity Base reading in milliGals

t_{B2} Time of 2nd Gravity Base reading

t_{B2} Time of 1st Gravity Base reading

Observed Gravity (G_{OBS}): The preceding corrections are applied to each of the raw gravity readings to calculate the earth's relative gravitational attraction at each of the field gravity stations. Absolute gravity values are determined relative to a known Observed gravity value at each base. Observed Gravity values were calculated for both the ISOGAL84 and AAGD07 gravity datum's.

$$G_{BOS} = G_{B1} + (r_{ETC} - r_{B1}) - (t - t_{B1}) \times ID$$

Where:

G_{B1} Gravity Base Observed Gravity in milliGals

r_{ETC} Earth Tide Corrected reading in milliGals

r_{B1} Gravity Base reading in milliGals

t Time of field reading

t_{B1} Time of Gravity Base reading

ID Instrument Drift in milliGals/hour

Once Observed Gravity values were produced, an Excel spreadsheet was used to calculate Infinite Slab Bouguer Anomaly and Spherical Cap Bouguer Anomaly for each gravity station.

The following corrections were applied to produce Infinite Slab Geoidal Bouguer Anomaly values:

Theoretical Gravity (G_{T67}): As the Earth is not a perfect sphere, with the polar radius being smaller than the equatorial radius, gravity values vary with latitude. This is due to the differences in the distance from the centre of the Earth's mass and differences in centrifugal accelerations at varying latitudes. The theoretical value of gravity was calculated using the 1967 variant of the International Gravity Formula and used to latitude correct the observed gravity.

$$G_{T67} = 978031.8456 \times (1 + 0.005278895 \times \sin^2\phi + 0.000023462 \times \sin^4\phi)$$

Where:

ϕ GDA94 latitude in decimal degrees

Infinite Slab Free-Air Correction (ISFAC): 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.

$$ISFAC = (0.3087691 - 0.0004398 \times \sin^2\phi) \times h_{AHD} - 0.0000001442 \times h_{AHD}^2$$

Where:

h_{AHD} Height of the gravity meter above the Geoid (Ausgeoid09) in meters

Infinite Slab Bouguer Correction (ISBC): 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 t/m^3 was used in the correction to represent solid earth.

$$ISBC = 0.04191 \times \rho \times h_{AHD}$$

Where:

P Earth density in gm/cc

h_{AHD} Height of the gravity meter above the Geoid (Ausgeoid09) in meters

Infinite Slab Free Air Anomaly (ISFAA): This is obtained by applying the Infinite Slab Free Air Correction (ISFAC) to the Observed Gravity reading.

$$ISAA = G_{OBSG} - G_{T67} + ISFAC$$

Infinite Slab Bouguer Anomaly (ISBA): This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$ISBA = G_{OBSG} - G_{T67} + ISFAC - ISBC$$

Terrain Correction (TC): This correction accounts for the attraction of material above the assumed Bouguer slab and for the over-correction made by the Bouguer Correction when in valleys. An earth density value of 2.67 t/m^3 was used in the correction to represent solid earth. See Section 5.5 for a more in-depth discussion on Terrain Corrections.

Complete Geoidal Bouguer Anomaly (CGBA): This was obtained by adding the terrain correction to the Geoidal Bouguer Anomaly.

$$CGBA = G_{OBSG} - G_{T67} + GFAC - GBC + TC$$

The following corrections were applied to produce Spherical Cap Ellipsoidal Bouguer Anomaly values:

Theoretical Gravity (G_{T80}): The theoretical gravity value for each gravity station was calculated using the closed form of the 1980 International Gravity Formula (Moritz, 1980) and used to latitude correct the observed gravity.

$$G_{T80} = 978032.67715 \times ((1+0.001931851353 \times \sin^2\phi)/\sqrt{}(1 - 0.00669438002290 \times \sin^2\phi))$$

Where:

ϕ GDA94 latitude in decimal degrees

Atmospheric Correction (AC): This correction removes the effect of the change in mass of the atmosphere above the ellipsoid by shifting it vertically into the interior of the geoid.

$$AC = 0.874 - 0.000099 \times h_{ELL} + 0.00000000356 \times h_{ELL}^2$$

Where:

h_{ELL} Height of the gravity meter above the ellipsoid (GRS80) in meters

Ellipsoidal Free-Air Correction (EFAC): 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. The free air correction was calculated using GRS80 ellipsoidal heights and the second order approximation equation (Heiskanen and Mortiz, 1969):

$$EFAC = -1 \times (0.3087691 - 0.0004398 \times \sin^2\theta) \times h_{ELL} + (7.2125 \times 10^{-7}) \times h_{ELL}^2$$

where:

h_{ELL} Height of the gravity meter above the ellipsoid (GRS80) in meters

ϕ GDA94 latitude in decimal degrees

Spherical Cap Bouguer Correction (SCBC): This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. The Bouguer correction uses the closed form equation for the gravity effect of a spherical cap of radius 166.7 km based on a spherical Earth with a mean radius of 6,371.0087714 km, height relative to the GRS80 ellipsoid, and an earth density of 2.67 t/m^3 was used in the correction to represent solid earth.

$$\mathbf{SCBC = 2 \times \pi \times (6.67428 \times 10^{-11}) \times \rho \times ((1 + \mu) \times h - \lambda \times R)}$$

Where:

π pi

ρ Earth density in gm/cc

h height of the gravity meter above the GDA94 ellipsoid in meters

μ & λ are dimensionless coefficients with following definitions

$\mu = ((1/3)*\eta^2 - \eta)$

where:

$\eta = h/R$

$\lambda = (1/3)\{(d + f\delta + \delta^2)[(f - \delta)^2 + k]^{1/2} + p + m*\ln(n/(f - \delta + [(f - \delta)^2 + k]^{1/2})\}$

where:

$d = 3*\cos^2\alpha - 2$

$f = \cos\alpha$; Please Note this "f" is NOT the same as the parameter "f" in Free Air Correction above.

$k = \sin^2\alpha$;

$p = -6*\cos^2\alpha\sin(\alpha/2) + 4*\sin^3(\alpha/2)$;

$\delta = R_o /R$;

$m = -3*\sin^2\alpha\cos\alpha = -3*k*f$ *Note "m" is NOT the same as the parameter "m" in Free Air Correction above.

$n = 2*[\sin(\alpha/2) - \sin^2(\alpha/2)]$

$\alpha = S/R_o$, with S = Bullard B Surface radius = 166.735 km.

Ellipsoidal Free Air Anomaly (EFAA): This is obtained by applying the Atmospheric Correction (AC) and Ellipsoidal Free Air Correction (FAC) to the observed gravity reading.

$$\mathbf{EFAA = G_{OBS} - (G_{T80} - AC) - EFAC}$$

Spherical Cap Bouguer Anomaly (SCBA): This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$\mathbf{SCBA = EFAA - SCBC}$$

Terrain Correction (TC): This correction accounts for the attraction of material above the assumed Bouguer slab and for the over-correction made by the Bouguer Correction when in valleys. An earth density value of 2.67 t/m^3 was used in the correction to represent solid earth. See Section 5.5 for a more in-depth discussion on Terrain Corrections.

Complete Spherical Cap Bouguer Anomaly (CSCBA): This was obtained by adding the terrain correction to the Bouguer Gravity Anomaly.

CSCBA = SCBA + TC

5.4 Gravity meter calibrations and scale factors

All the company gravity meters undergo regular calibrations over the Kensington to Norton Summit calibration range in Adelaide. Meters are also calibrated upon return from repair by the manufacturer (Scintrex in Canada).

Along with calibrations we also conduct regular tilt tests, sensor drift calibrations and temperature adjustments in our technical workshops in Murray Bridge.

The gravity meters used on the survey along with their most recent calibration factors are described in Appendix C – Survey information.

5.5 Terrain Corrections

Due to extreme variations in terrain within close proximity to the survey grids, terrain corrections (TC or TC's) were calculated and applied to the final data. The Terrain Correction software, RASTERTC, was used to calculate near zone to far zone corrections. RASTERTC was coded by Geophysical Software (http://www.geopotential.com/).

The terrain correction procedure corrects gravity measurements for the effect of terrain from a distance Rmin to a distance Rmax. Each gravity station is processed independently, and therefore corrections calculated for a particular station do not depend upon possible location errors of other stations. The correction procedure divides the circular area enclosed by Rmax into an inner zone and an outer zone; the radius separating the inner and outer zone is denoted Rmed.

A surface is fitted to the elevations between Rmin and Rmed; this surface is numerically integrated to calculate that portion of the terrain correction that is due to the terrain located in the interval Rmin <= R <= Rmed. Figure 5 below illustrates the subdivision of areas used in the calculation.

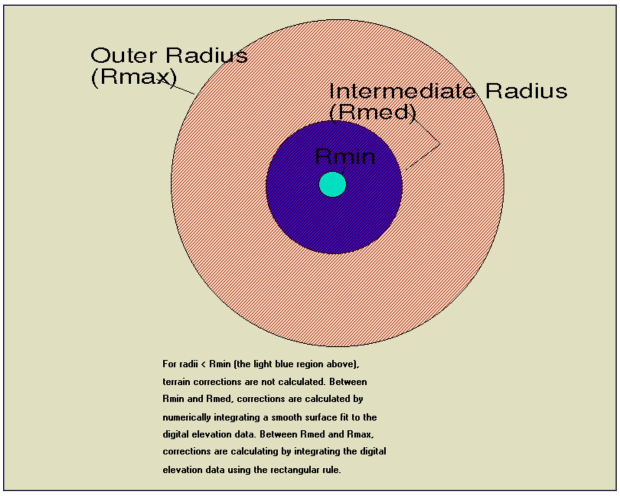


Figure 2: Calculation areas used by RASTERTC

RASTERTC uses triangulation and interpolation procedures to interpolate elevations between Rmin and Rmed. Between Rmed and Rmax, the terrain effect is calculated by assuming that each elevation sample represents the elevation of a rectangular compartment; a line element formula is used to calculate the effect of each such compartment. Terrain compartments lying between Rmed and Rmax that partially intersect the circular radius Rmed are treated in such a way that only the effect of that portion lying outside Rmed is added to the overall terrain effect. A similar procedure is applied to those compartments that partially intersect the outer radius Rmax.

Note that the numerical integration procedure used to calculate the effect of terrain lying between Rmin and Rmed essentially integrates the effect of a line element between the two radii. This integration is repeated to obtain the effect of all the terrain lying within the circular region. The radial portion of the integration is performed using an adaptive technique called QUAN8.

A terrain surface is used close to the station location because the elevations provided by the GNSS are samples and do not actually represent mean elevations of rectangular compartments. The use of a surface provides a terrain representation that should be much closer to reality than the use of compartments of constant mean elevation.

At a certain distance from the station, the procedure of considering the elevation samples as representing the mean elevation of a rectangular compartment should yield numerical results that are not distinguishable from the results that would be obtained by actually using mean elevations of compartments whose size would necessarily be larger than 25m on a side.

In fact, the method used is equivalent to numerically integrating the terrain effect (at distances greater than Rmed) using a rectangular rule. Because the compartment size is relatively small, use of the rectangular rule should be rather accurate.

The elevation of each gravity station is not directly used during the computation of the effect of terrain effects. Instead, the elevation at the horizontal location of the gravity station is calculated from the multiquadric representation of the terrain surface, and this calculated elevation is used in the computation of the effect of terrain. The actual elevation of the gravity station is not used at all.

Numerically, the procedures used for the calculation of the terrain effect are extremely accurate, especially when compared to terrain corrections calculated using template methods. However, the corrections calculated are no better than the terrain data that are used to represent the terrain about each gravity station.

All terrain corrections were performed using a rock density of 2.67 tm^{-3}.

5.5.1 Digital Elevation Model (DEM) Preparation

Digital elevation data was sourced from Geoscience Australia's 1 arc-second SRTM product for all surveys (approximately 30m ground resolution as explained below).

SRTM (Shuttle Radar Topography Mission) digital elevation data was sourced from Geoscience Australia as a mosaic grid covering the entirety of Australia's landmass, and is approximately equivalent to 30m ground resolution. SRTM consisted of a specially modified radar system that flew on-board the Space Shuttle Endeavour during an 11-day mission in February of 2000, which obtained elevation data on a near global scale to generate high resolution, digital topographic elevation models of Earth. For more information regarding the data set please visit http://www.ga.gov.au/scientific-topics/national-location-information/digital-elevation-data.

From the SRTM mosaic, an area was extracted with a buffer of >30km from the outer extents of the survey to be terrain corrected, which was then used to export a section of the SRTM mosaic and reproject it to the same datums used in the data processing (MGA zone 53 and AHD).

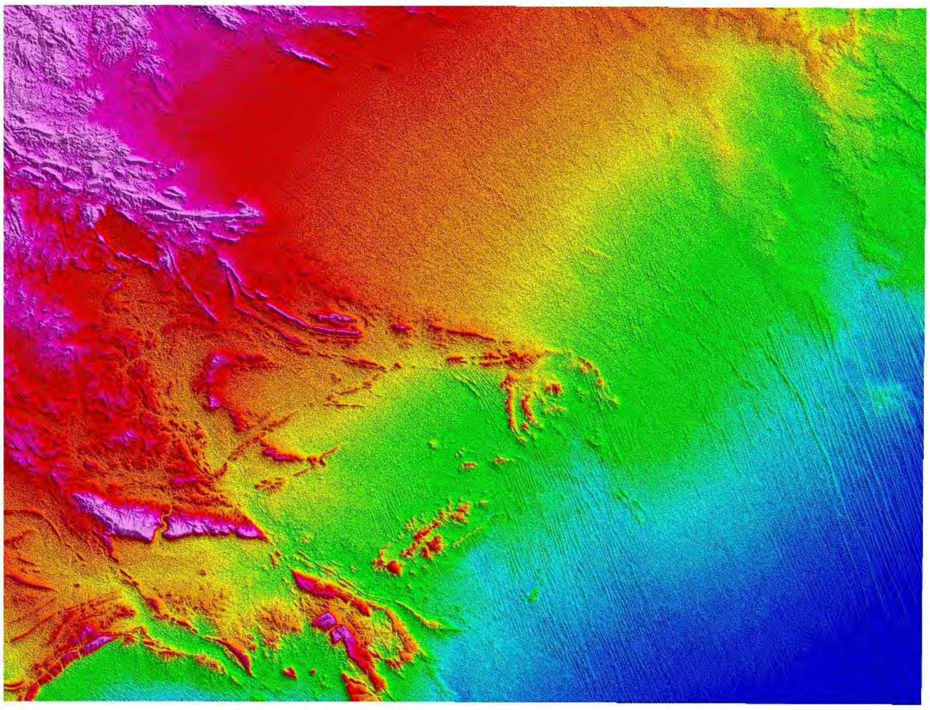


Figure 3: Example 1 arc-second SRTM Elevation grid used for Terrain Corrections

5.5.2 RASTERTC Corrections

Terrain Correction using SRTM DEM data were calculated using RASTERTC with the following radius parameters:

Rmin = 30m (SRTM only) / 10m (LiDAR & SRTM)
Rmed = 450m
Rmax = 25000m
Azimuthal Integration Angle = 4 degrees

Rmin was selected to correct for all terrain in the immediate vicinity of the station and coincided with the cell size of the SRTM grid (30m) or LiDAR grid (10m). Rmax was specified to allow correction for the extreme terrain at large distances from the station (outer zone). Rmed was chosen so that the terrain would be "sampled" at an interval close to that of the grid cell size dependent upon the azimuthal integration angle ϕ. During the radial integration, near the maximum radial portion of the integration, the terrain surface is being sampled at approximately Rmed(sin(ϕ)), where R is the maximum radius chosen for the surface integration. For example, at $\phi = 4°$ and Rmed = 450m, the terrain surface is sampled at 31.4m which is close to the 30m SRTM resolution.
When calculating the RASTERTC correction, the station GNSS elevations were not used. Instead, the elevation at the horizontal location of the gravity station was calculated from the multiquadric representation of the terrain surface, and this calculated elevation was used in the computation of the effect of terrain. The actual elevation of the gravity station is not used at all. The use of the actual elevation, rather than one consistent with the SRTM terrain, effectively leads to gravity stations being located in deep holes or on very steep hills, whereas in fact such terrain features probably do not exist in the immediate vicinity of the gravity station.

5.5.3 Accuracy of the corrections

The terrain correction procedure produced highly accurate corrections for the most part. As with any terrain correction procedure, the accuracy of the final correction is dependent on the accuracy of the DEM used.

Indicators of quality are provided for both the inner and outer-most terrain correction as an error code. In the RASTERTC output files, these QF codes are listed under the column headings "QF-Inner" and "QF-Outer", respectively for each processed gravity station. The quality factors should be 0 for both the inner and the outer zones, with other codes described in the following paragraphs.

The QF-Inner error codes provide a rough indicator of how well the terrain in the immediate vicinity of a gravity station is represented by the available elevation samples. In the radial interval Rmin to Rmed, RASTERTC counts the number of samples falling within the 8 octants surrounding the station. If any of these octants are missing elevation samples, the error code notes how many of octants are missing (as described in Table 4 on the following page).

The QF-Outer codes are simple to interpret. A result of 0 means that the outer-zone calculation proceeded successfully. If a portion of the outer-zone terrain is missing from the elevation grids supplied, the value of QF-Outer will reflect the per cent of terrain that was available (rounded to the nearest per cent). For example, if the QF-Outer error code is 91, 9% of the terrain in the outer zones was missing, and that the terrain correction calculated for that particular station is too small.

Upon any error codes being detected, DEM's, data and parameters were checked and recreated to recalculate the erroneous terrain correction.

QF-Inner	Meaning of Error Code
0	Inner-zone terrain calculation OK
1	No elevation samples occur in 1 octant surrounding the gravity station
2	No elevation samples occur in 2 octants surrounding the gravity station
3	No elevation samples occur in 3 octants surrounding the gravity station
4	No elevation samples occur in 4 octants surrounding the gravity station
5	No elevation samples occur in 5 octants surrounding the gravity station
6	No elevation samples occur in 6 octants surrounding the gravity station
7	No elevation samples occur in 7 octants surrounding the gravity station
22	Duplicate elevation nodes encountered while calculating terrain gradients
23	All elevation nodes collinear or triangulation structure corrupted
24	Invalid parameters passed to gradient calculation routine
26	Convergence not attained in calculation of terrain gradients
48	Internal logic error while attempting to delete duplicate nodes
49	Unable to allocate memory while deleting duplicate nodes
96	Internal error occurs while attempting to triangulate nodes near station
99	Less than 3 elevation samples are available near station
101	Duplicate nodes occur in elevation samples near station
-99	Unable to allocate sufficient memory for inner-zone TC calculation

Table 1: QF-Inner Error Codes

5.6 Quality control of the processed gravity data

Following the reduction of the gravity data, quality control was carried out to check the repeatability of the positional and gravity observations.

The elevation and gravity data were gridded at a cell size of 40m (1/5th of the 200m line spacing) using ChrisDBF to produce ERMapper compatible grid files of the AHD Elevation, Infinite Slab Bouguer Anomaly and Complete Infinite Slab Bouguer Anomaly (terrain corrected data). A Remove Regional filter (using a First Order Polynomial) and a First Vertical Derivative Filter were both applied to the Infinite Slab Bouguer Anomaly and Complete Infinite Slab Bouguer Anomaly grids to produce Residual Anomaly grids and a First Vertical Derivative grids respectively. These grids were imaged using Oasis Montaj where they were checked for any anomalous points. A plot of the acquired gravity stations was regularly monitored to make sure no stations were missed.

The Infinite Slab Bouguer Anomaly and First Vertical Derivative (including the complete calculations) were also gridded at a cell size of 20m to account for the smaller spacing in the infill areas (1/5th of the 100m line spacing).

Photo 7 – A Surveyor levelling a Scintrex CG5 gravity meter

6.0 RESULTS

Raw and processed GNSS and gravity data are contained on a USB drive as Appendix E. A hardcopy plot of station locations and gridded data images are contained in Appendix A.

6.1 Stations surveyed and survey progress

In total 1,060 new gravity stations were acquired during the project and of these, 51 (4.8%) were revisited for survey quality control.

The crews averaged a combined production rate of 150 stations per day, completing the survey in approximately 7 days.

6.2 Data repeatability

Analysis of the repeat data shows that measurement repeatability was excellent for both GNSS and Gravity observations. An analysis of the survey data is included in Appendix B. Based on the repeat data, one can assume the following typical accuracies for the observables:

Gravity standard deviation (SD) of repeats:	SD < 0.022 mGal
Height standard deviation (SD) of repeats:	SD < 0.058 m

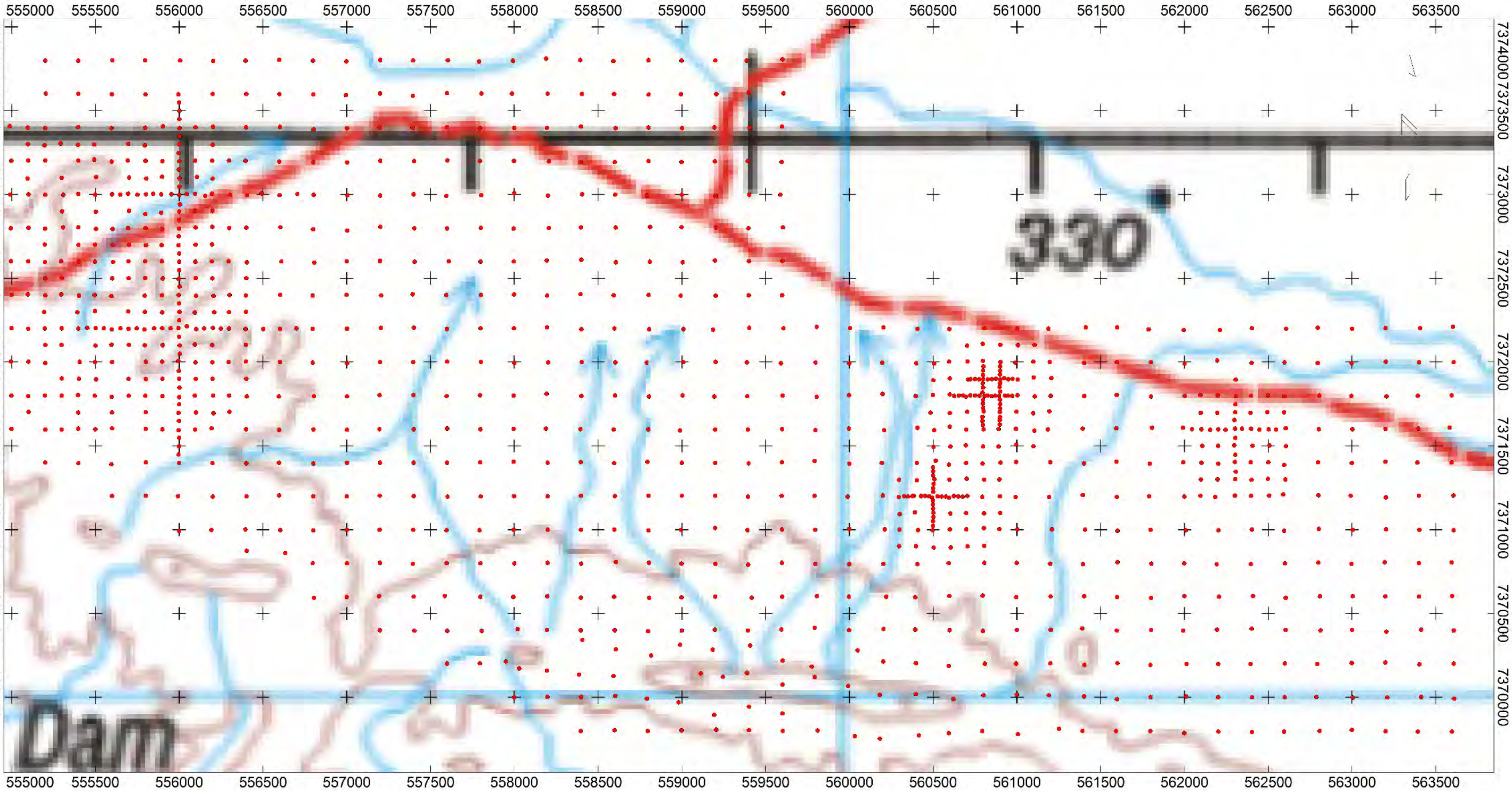
7.0 CONCLUSION

Daishsat Geodetic Surveyors successfully carried out a precision ground gravity survey during October and November 2018 for Gempart (NT) Pty Ltd.

The survey was conducted safely, without incident and with minimal environmental impacts. Final results have been demonstrated to be accurate, reliable and conducted to the highest standards with modern calibrated acquisition equipment, professional experienced staff, proven acquisition techniques and quality control procedures.

Appendix A

Station location plot and gridded data images



Scale 1:24750

250 0 250 500 750 1000 1250 1500

(meters)

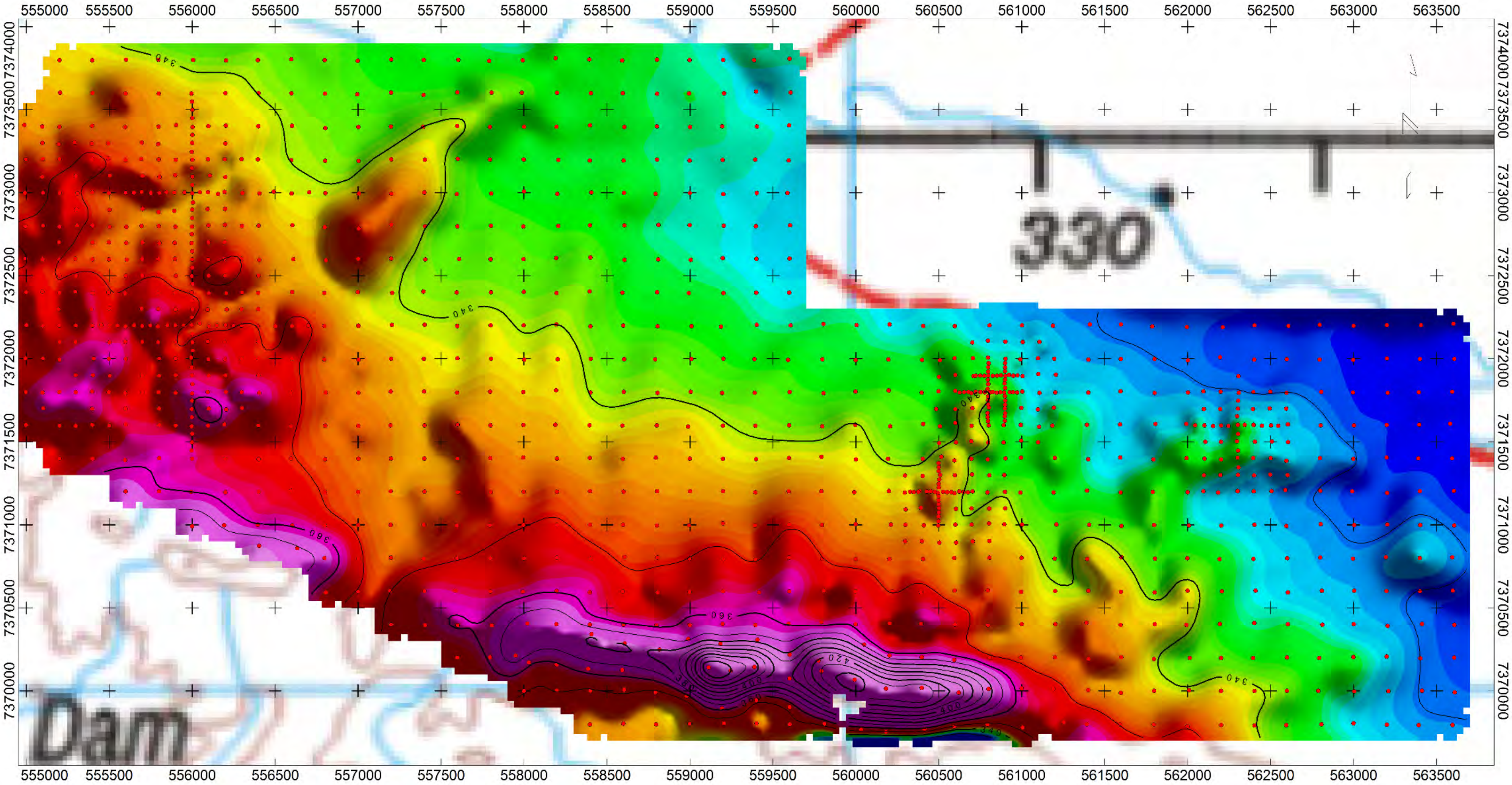
GDA94 / Map Grid of Australia zone 53

Red Dots = Surveyed stations

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Station location plot
1,060 stations surveyed

Survey by Daishsat Geodetic Surveyors



Orthometric Height
(m)

327.74 330.21 332.60 334.08 335.03 336.00 337.15 338.38 339.52 340.79 342.13 343.55 344.94 346.37 348.40 350.60 352.87 355.91 363.86

Red Dots = Surveyed stations

Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 10m
Northeast Sunshaded

Scale 1:24750

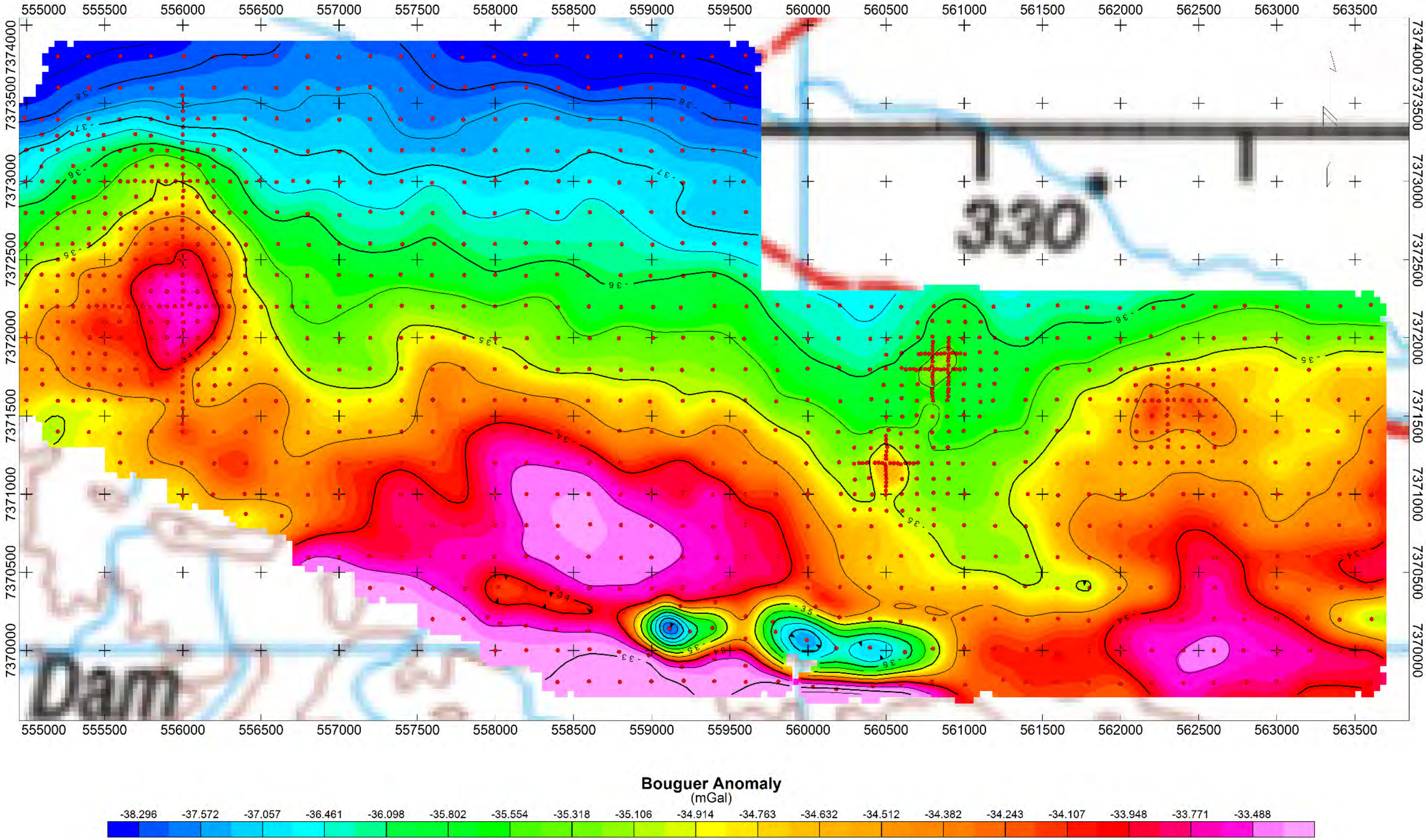
250 0 250 500 750 1000 1250 1500
(meters)

GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Orthometric Height
AHD (AusGeoid09)

Survey by Daishsat Geodetic Surveyors



Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.5mGal

Scale 1:24750

250 0 250 500 750 1000 1250 1500

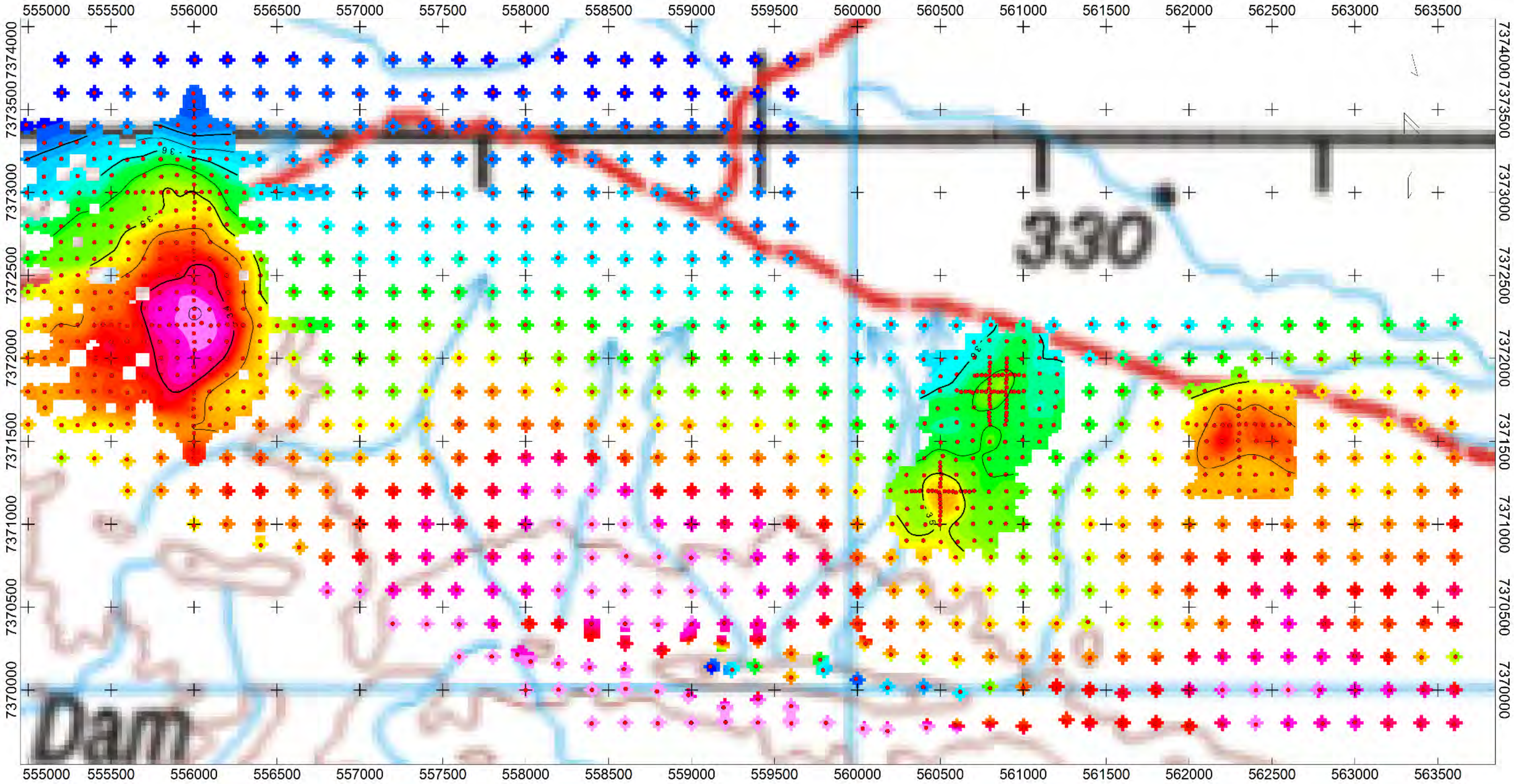
(meters)

GDA94 / Map Grid of Australia zone 53

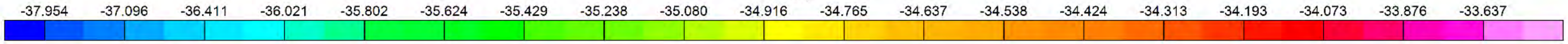
Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Bouguer Anomaly
(mGal)



Red Dots = Surveyed stations

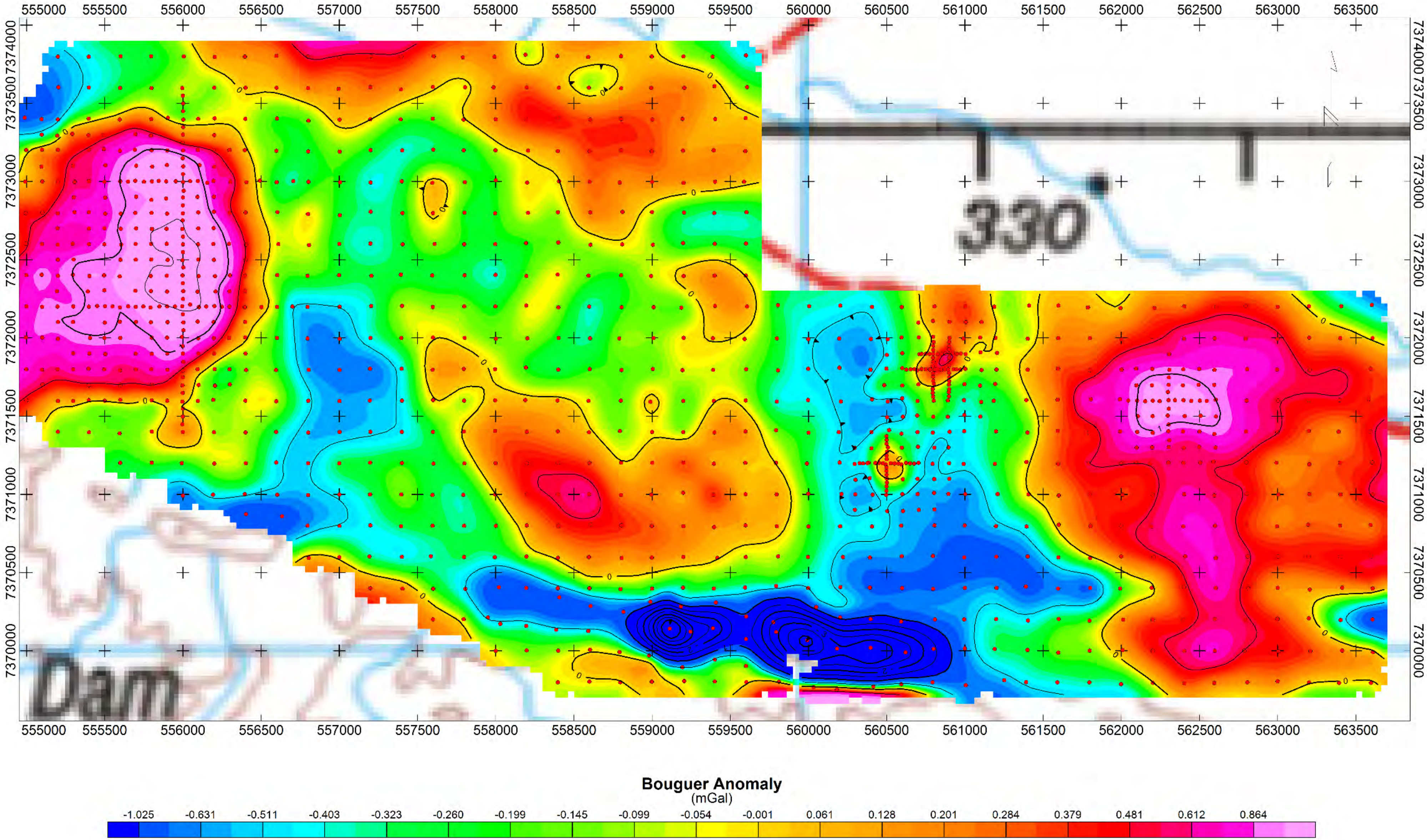
Gravity Datum - ISOGAL84
Grid Cell Size - 20m
Scan Distance - 150m
Histogram Equalisation
Contour Interval - 0.5mGal

Scale 1:24750
250 0 250 500 750 1000 1250 1500
(meters)
GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.5mGal

Scale 1:24750

250 0 250 500 750 1000 1250 1500

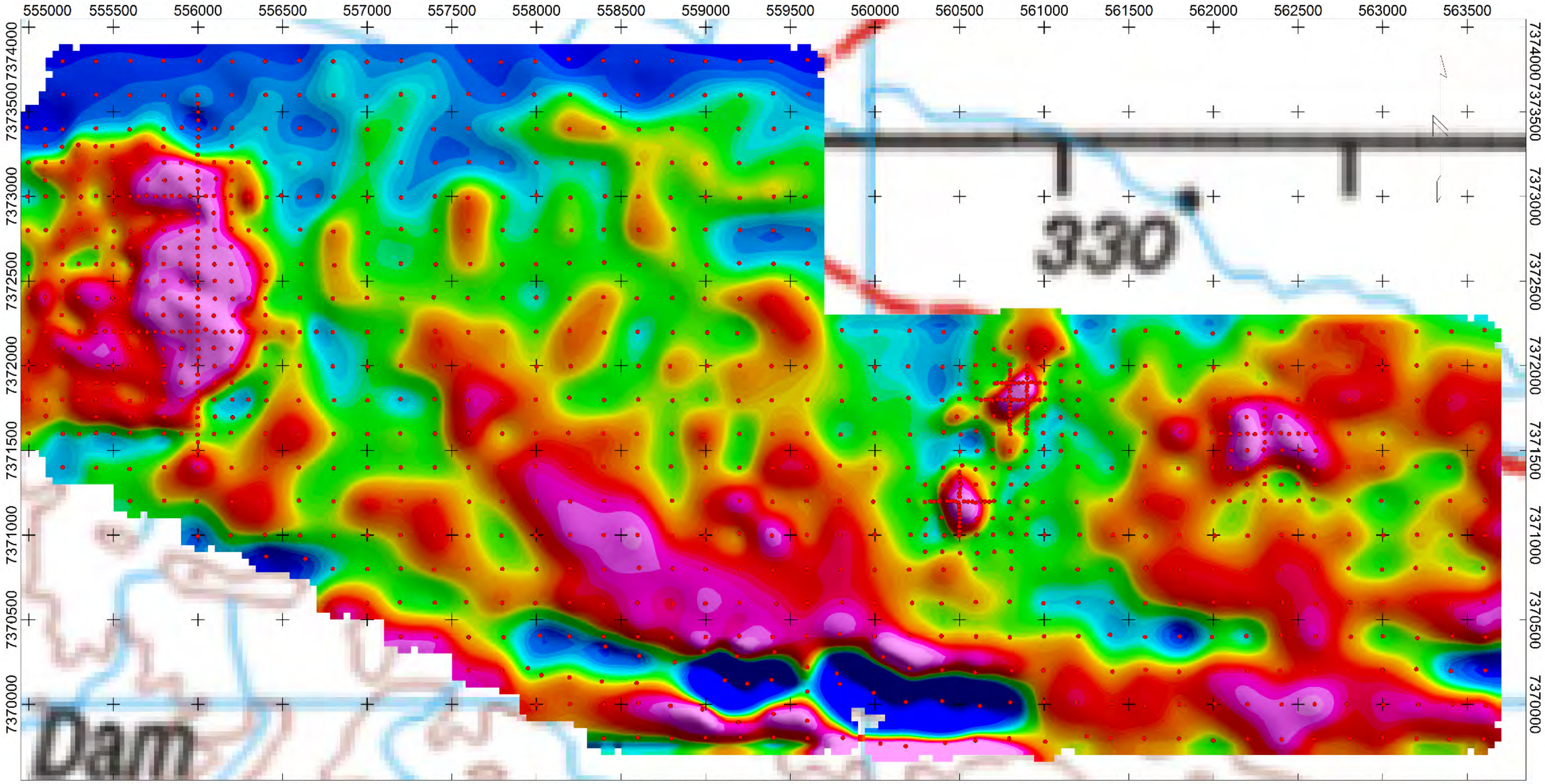
(meters)

GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Residual Gravity
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Vertical Derivative
(Eotvos)

-0.00405 -0.00230 -0.00159 -0.00113 -0.00079 -0.00052 -0.00029 -0.00008 0.00013 0.00032 0.00052 0.00074 0.00096 0.00119 0.00143 0.00168 0.00199 0.00238 0.00299

Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Northeast Sunshaded

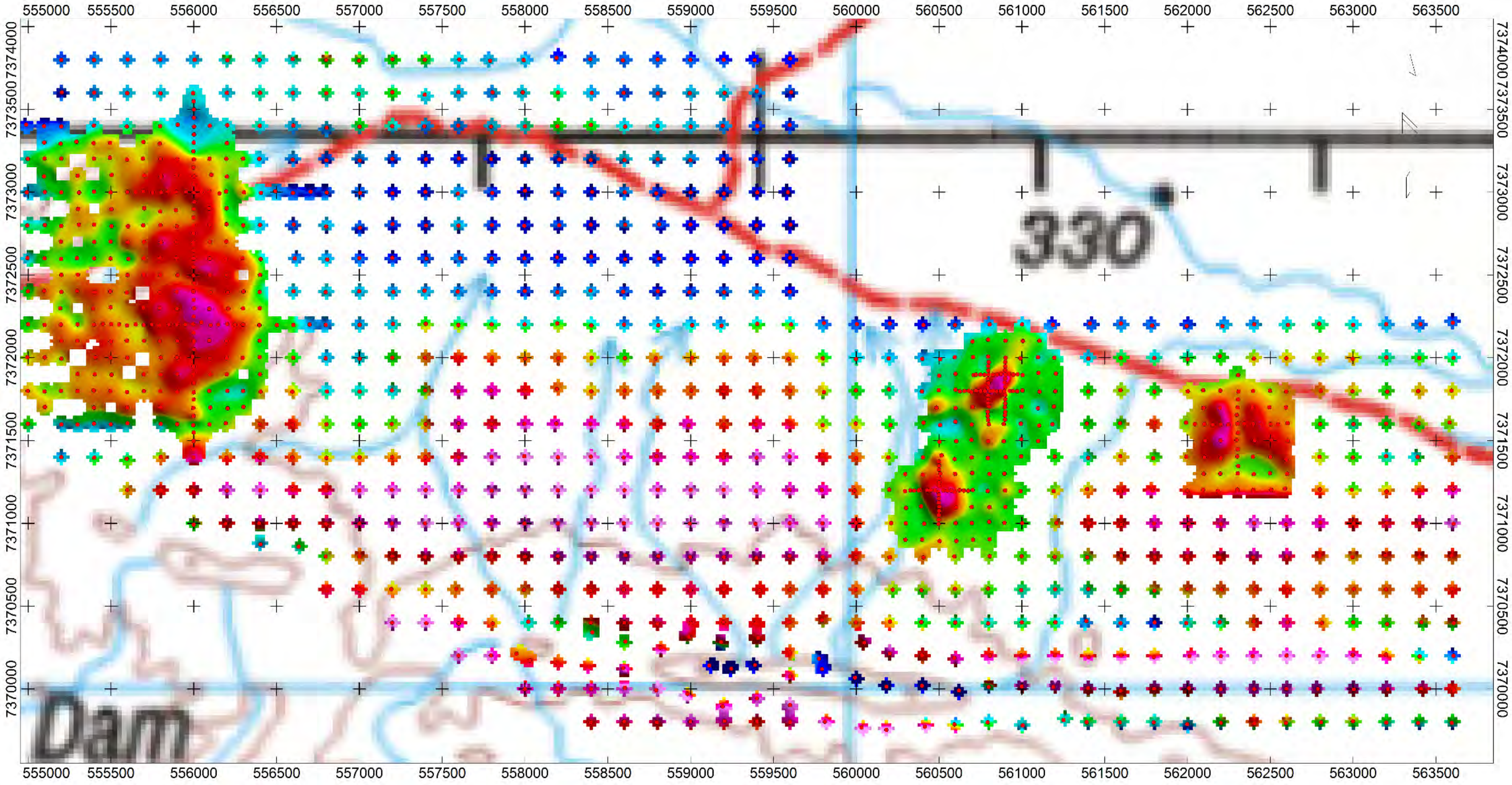
Scale 1:24750

250 0 250 500 750 1000 1250 1500
(meters)
GDA94 / Map Grid of Australia zone 53

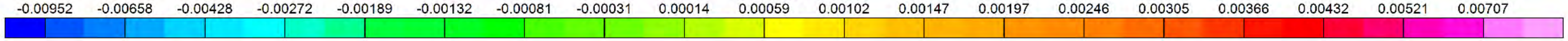
Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
1st Vertical Derivative of Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Vertical Derivative
(Eotvos)



Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 20m
Scan Distance - 150m
Histogram Equalisation
Northeast Sunshaded

Scale 1:24750

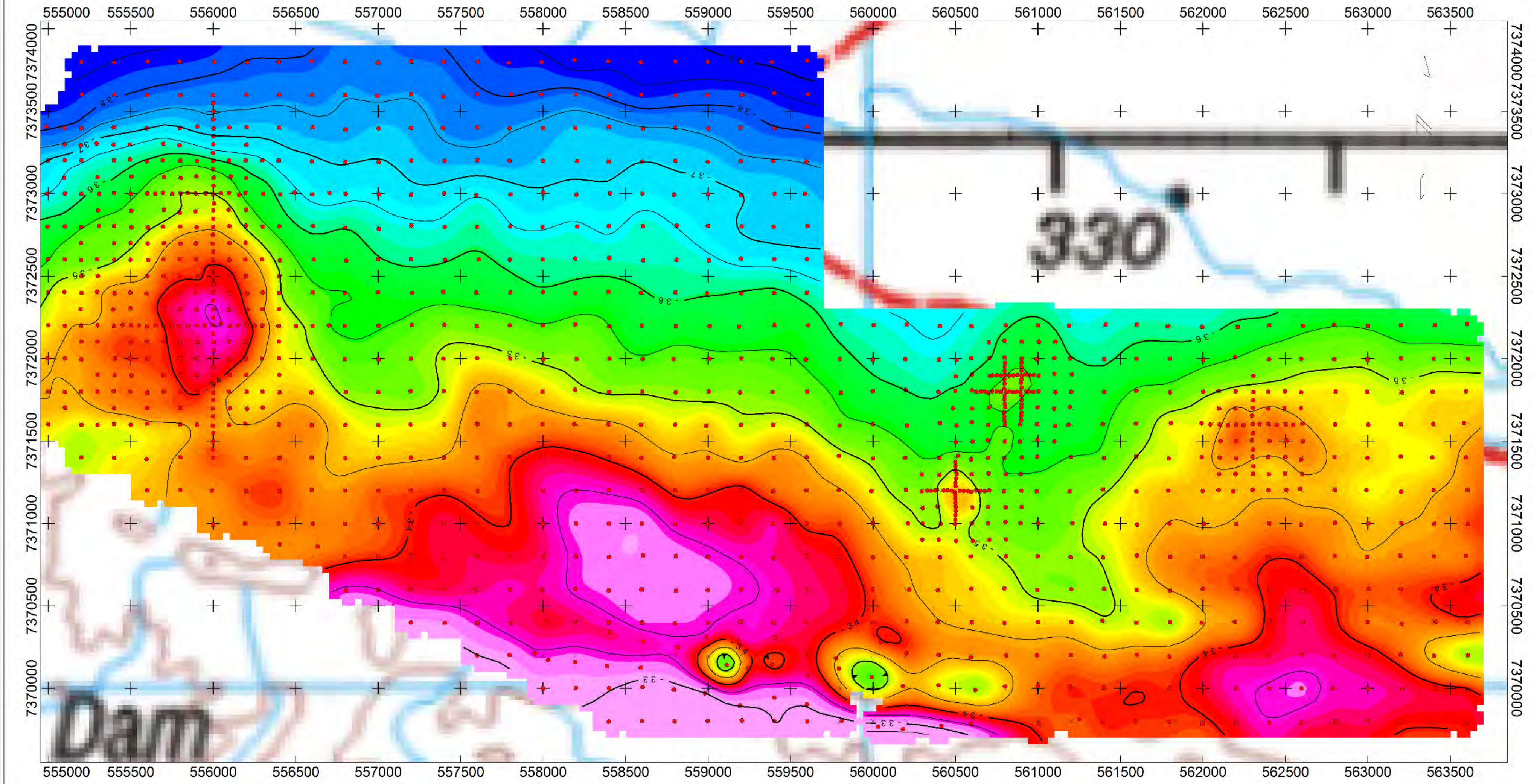
250 0 250 500 750 1000 1250 1500
(meters)

GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
1st Vertical Derivative of Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Bouguer Anomaly
(mGal)

-38.284 -37.554 -37.026 -36.400 -36.027 -35.739 -35.486 -35.237 -35.025 -34.833 -34.690 -34.559 -34.431 -34.304 -34.169 -34.037 -33.860 -33.677 -33.373

Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.5mGal

Scale 1:24750

250 0 250 500 750 1000 1250 1500

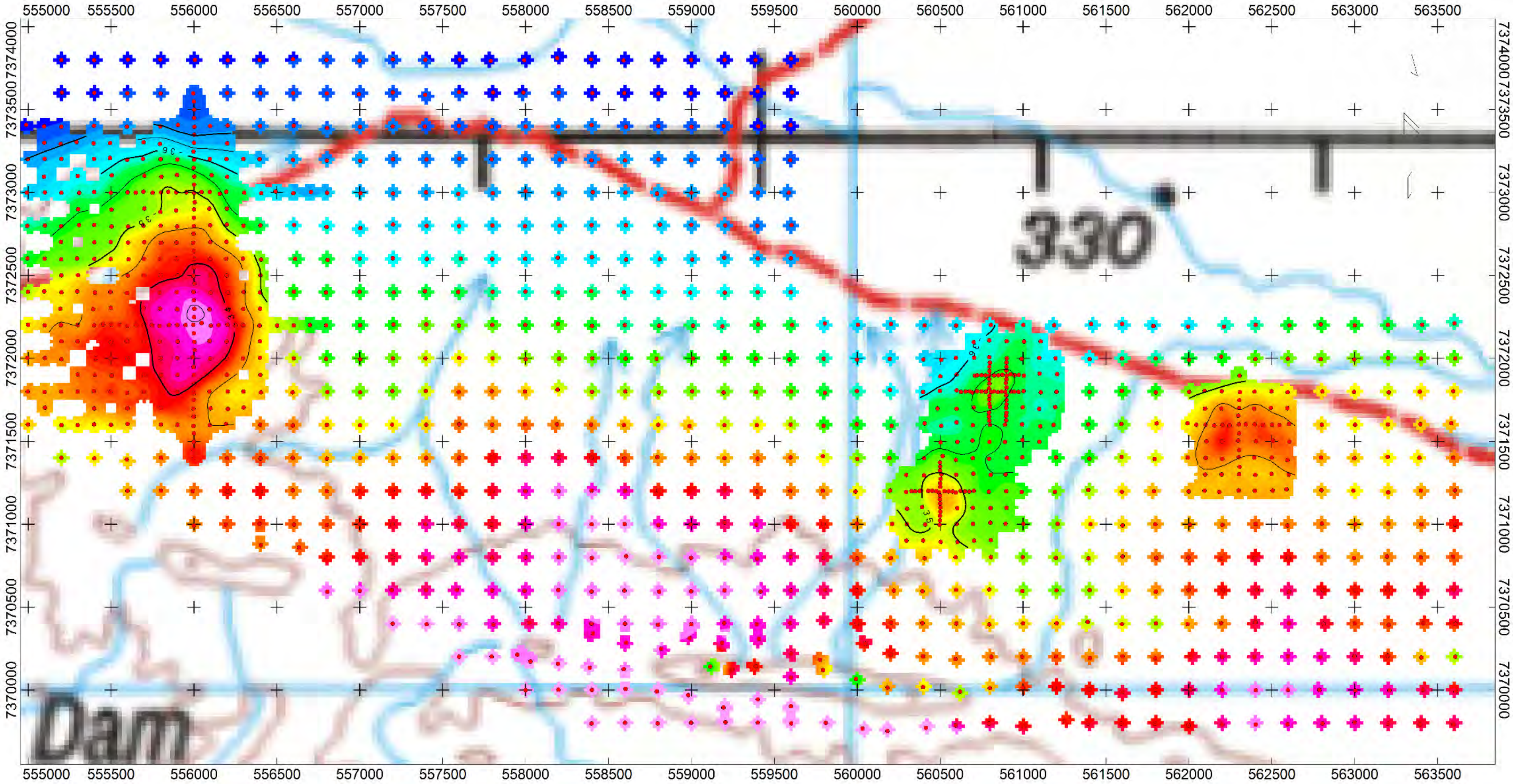
(meters)

GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Complete Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Bouguer Anomaly
(mGal)

-37.935 -37.047 -36.355 -35.970 -35.768 -35.574 -35.383 -35.193 -35.039 -34.869 -34.722 -34.600 -34.493 -34.379 -34.271 -34.145 -34.019 -33.802 -33.567

Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 20m
Scan Distance - 150m
Histogram Equalisation
Contour Interval - 0.5mGal

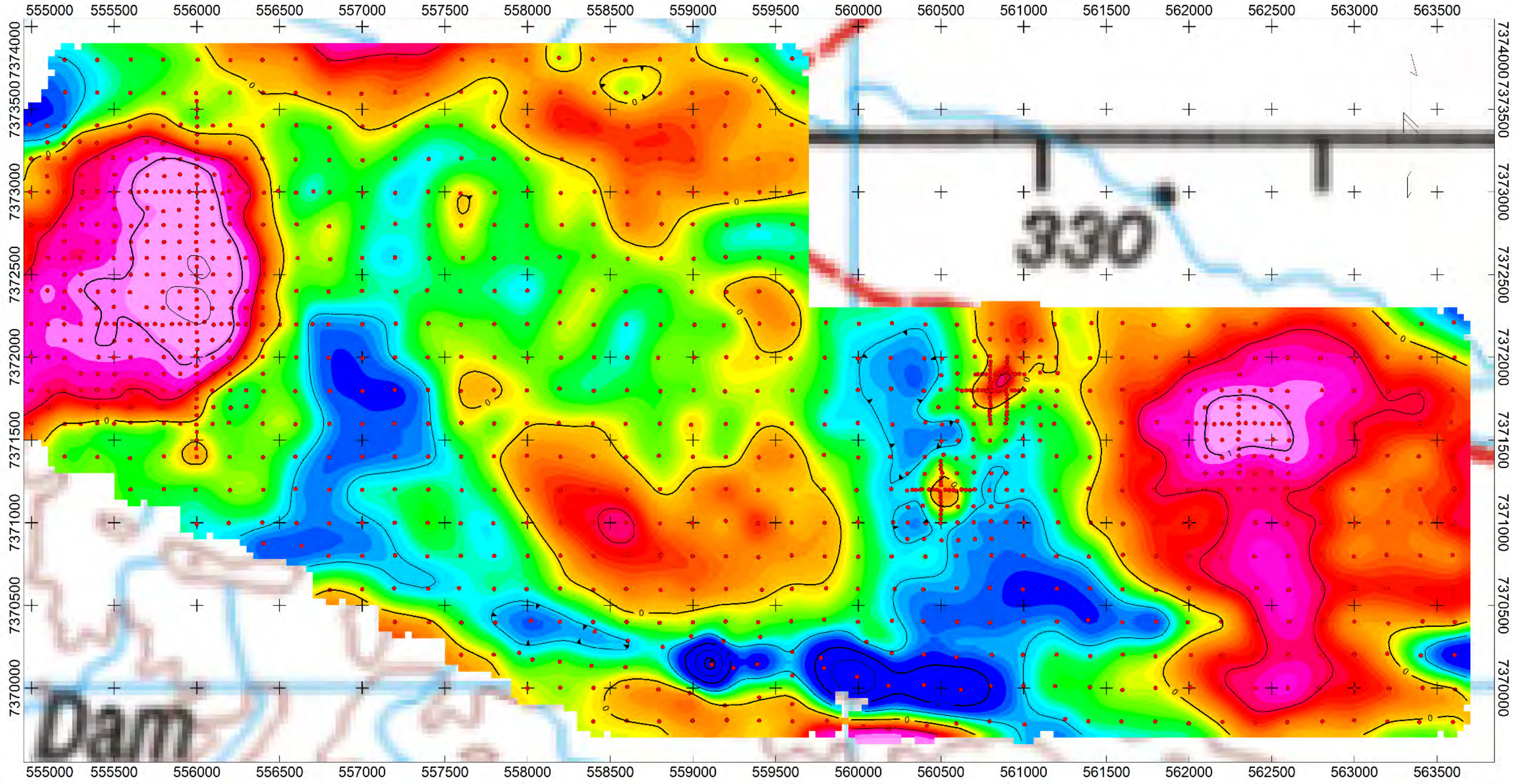
Scale 1:24750

250 0 250 500 750 1000 1250 1500
(meters)
GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Complete Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors



Bouguer Anomaly
(mGal)

-0.735 -0.587 -0.483 -0.401 -0.341 -0.279 -0.226 -0.177 -0.127 -0.075 -0.016 0.050 0.116 0.187 0.266 0.363 0.466 0.597 0.828

Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Contour Interval - 0.5mGal

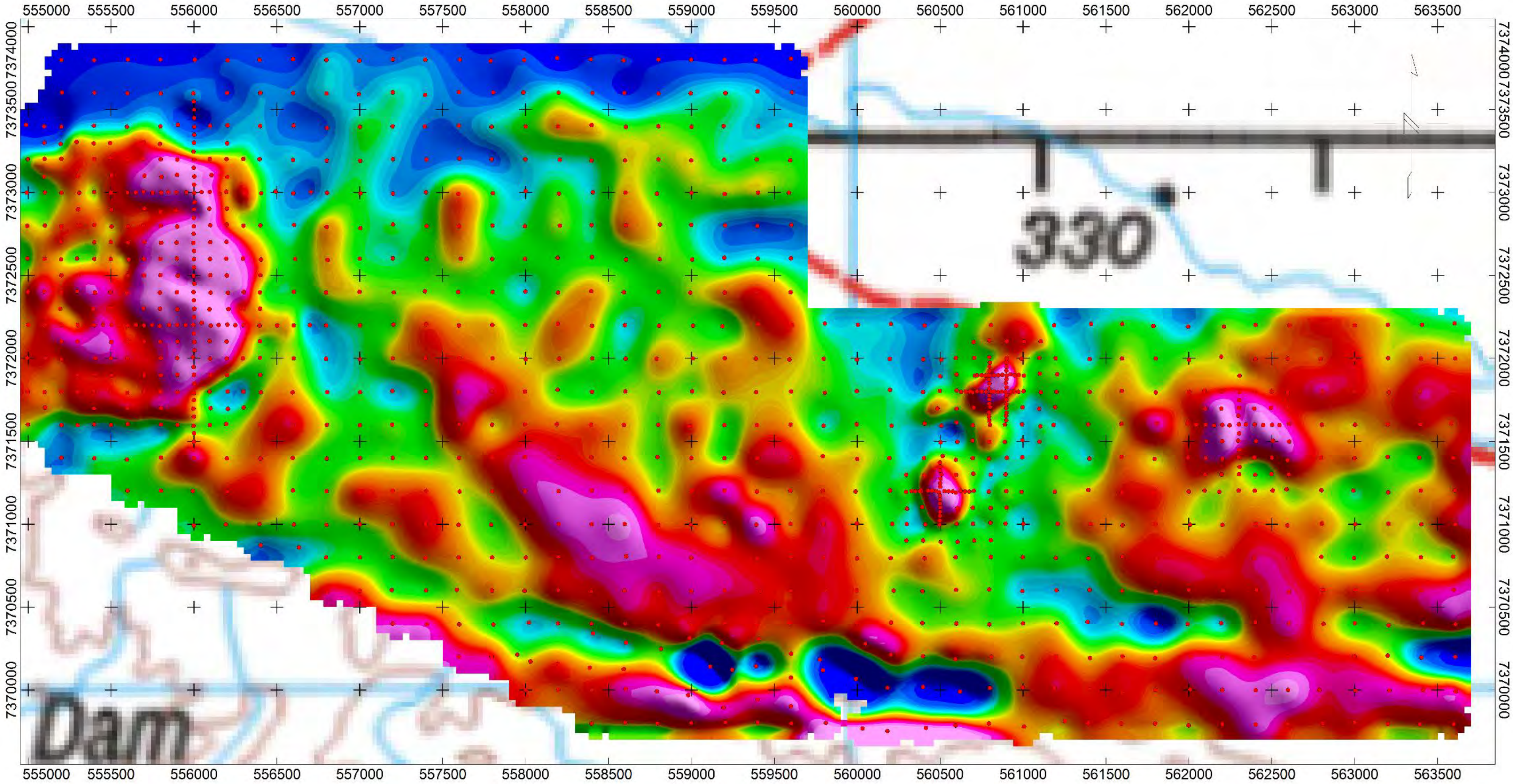
Scale 1:24750

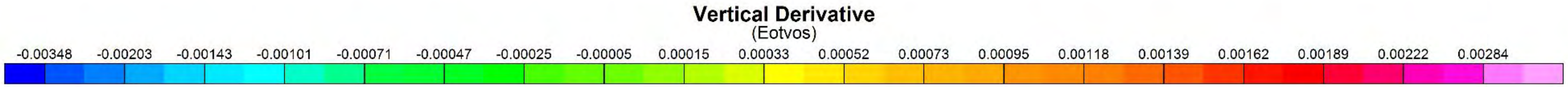
250 0 250 500 750 1000 1250 1500
(meters)
GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
Complete Residual Gravity
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors





Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 40m
Scan Distance - 300m
Histogram Equalisation
Northeast Sunshaded

Scale 1:24750

250 0 250 500 750 1000 1250 1500

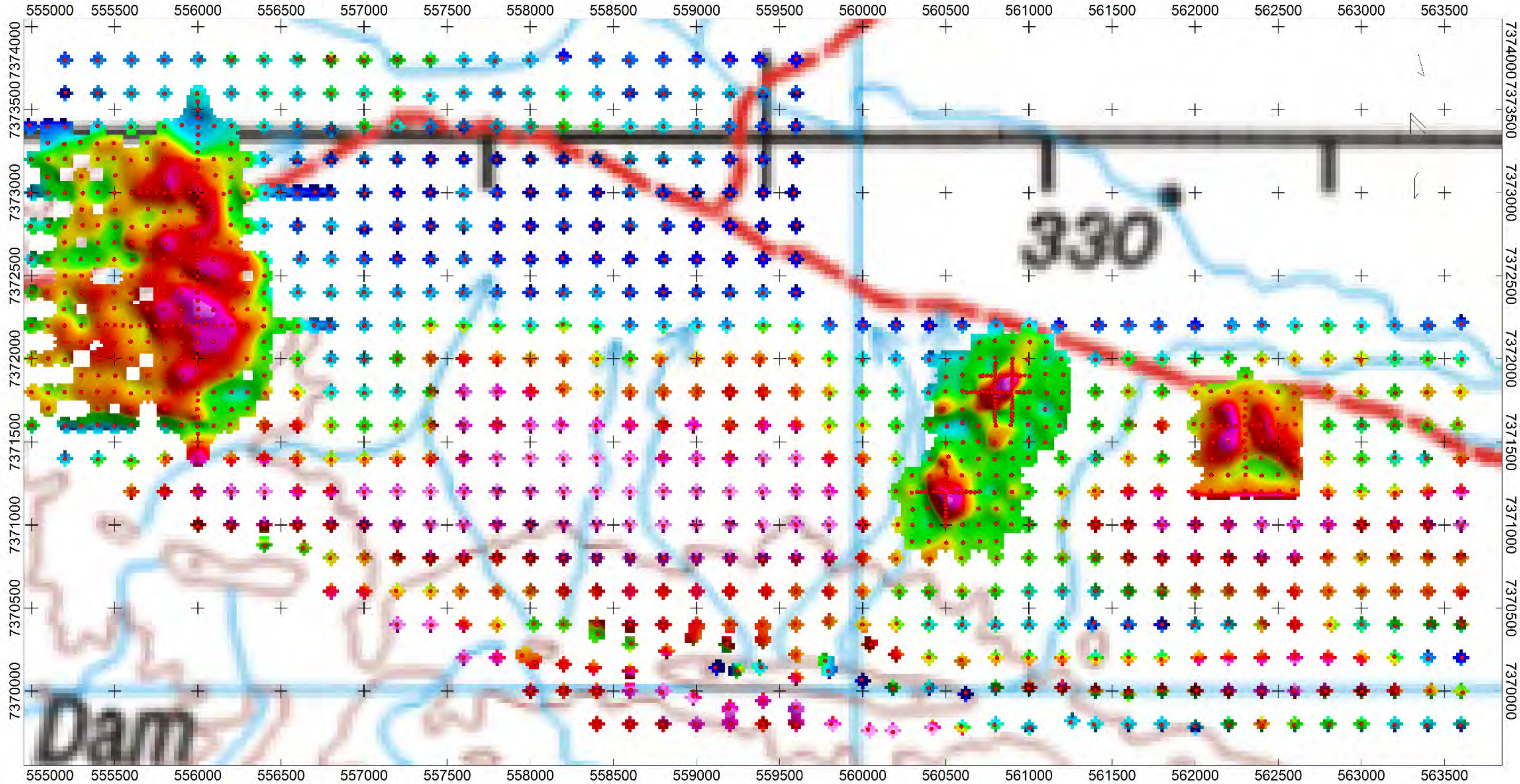
(meters)

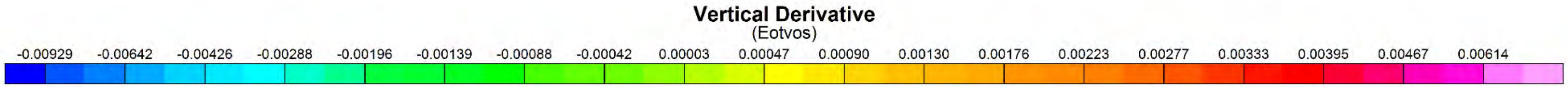
GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

18020 Illogwa Creek Gravity Survey
1st Vertical Derivative of Complete Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors





Red Dots = Surveyed stations

Gravity Datum - ISOGAL84
Grid Cell Size - 20m
Scan Distance - 150m
Histogram Equalisation
Northeast Sunshaded

Scale 1:24750

250 0 250 500 750 1000 1250 1500
(meters)

GDA94 / Map Grid of Australia zone 53

Gempart (NT) Pty Ltd

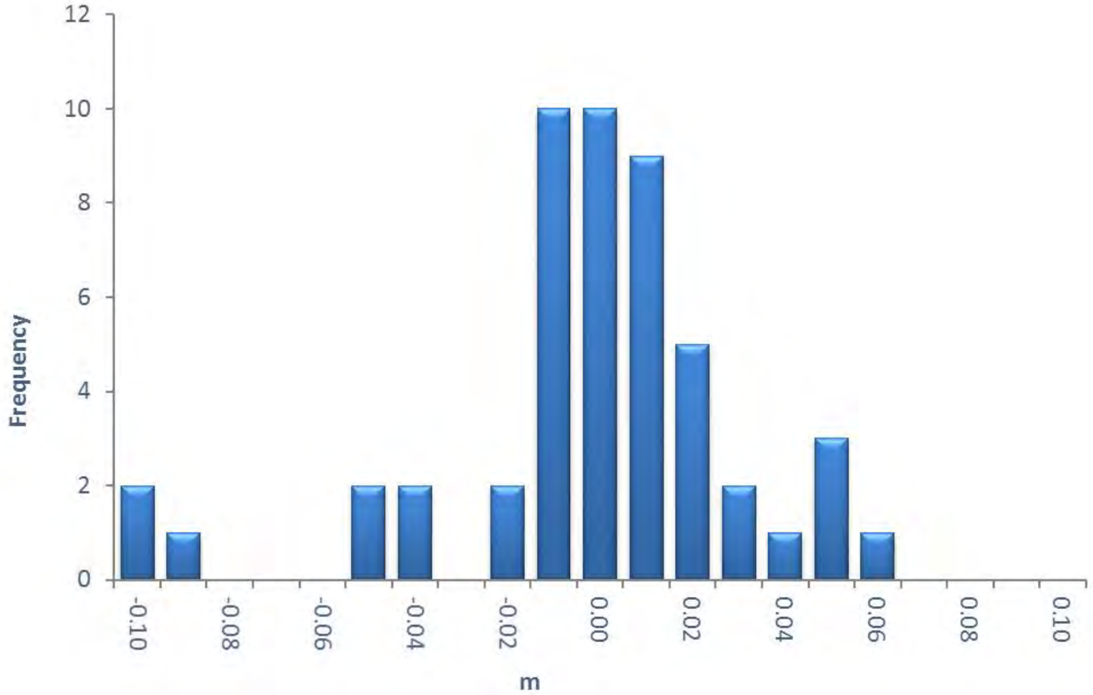
18020 Illogwa Creek Gravity Survey
1st Vertical Derivative of Complete Infinite Slab Bouguer Anomaly
Density = 2.67 gm/cc

Survey by Daishsat Geodetic Surveyors

Appendix B

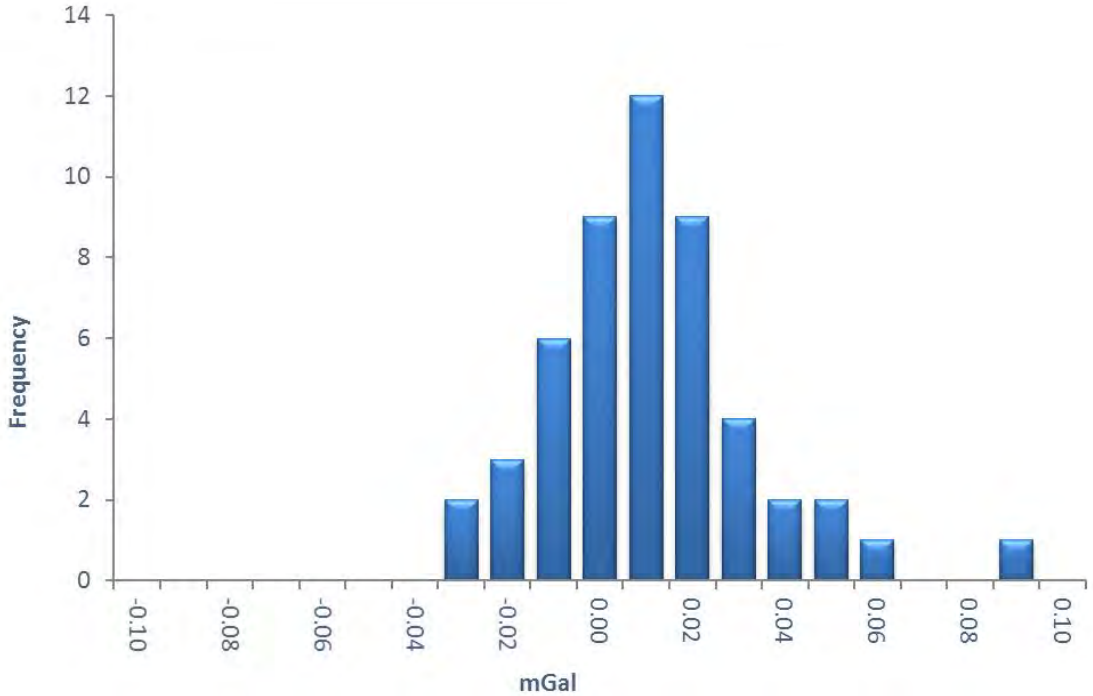
Repeat tabulation and analysis

Histogram of height repeats



Height standard deviation (SD) of repeats: 0.058 m

Histogram of gravity repeats



Gravity standard deviation (SD) of repeats: 0.022 mGal

Appendix C

Survey information

18020 GEMPART (NT) Pty Ltd - Illogwa Creek	
Survey Details	
Survey date	31/10/18 - 6/11/2018
Surveyors / Personnel	Hayden Harris / Frank Duffy
Processors	Harley Jones / Ben Wyschnja
Techniques employed	Post processed DATV gravity
GPS receiver types used	Leica GRX1230
Number of new points acquired	1,060
Number of repeats on new points	51 (4.8 %)
Station / line spacing	200m x 200m, infill areas at 100m and 50m
Height observation accuracy (SD)	0.058 m
Gravity observation accuracy (SD)	0.022 mGal
GPS / Gravity bases used	Daishsat Base 1538

Gravity Meters			
Meter Serial	**Meter Letter**	**Scale Factor**	**Date & State of Calibration**
CG5 - 80340364	J	1.000599	10/10/2018 SA
CG5 - 80440373	N	1.000351	10/10/2018 SA

Appendix D

Base station locations and information

GPS/Gravity 1538 - Illogwa Creek

FINAL AUSPOS CO-ORDINATES

MGA94 / AHD		GDA94 / GRS80	
EASTING (m)	558617.47	LATITUDE (DMS)	23° 44' 17.34442" S
NORTHING (m)	7374644.83	LONGITUDE (DMS)	135° 34' 30.53729" E
ZONE (UTM, South)	53	ELL HT (m)	358.19
ORTHO HT (AHD, m)	336.12		
N (AUSGEOID09, m)	22.07		

CONTROL DETAILS

Observed Gravity ISOGAL84 (mGal)		Observed Gravity AAGD07 (mGal)	
Calculated ObsG	978761.850	Calculated ObsG	978761.772

Gravity Control	GPS Control
Gravity – Daishsat using a B-A-B loop to existing Daishsat base 1287 using 2 meters. Expected accuracy better than 0.010mGal.	**GPS** – Daishsat using multiple static sessions and the AUSPOS online GPS processing system. Expected accuracy of station coordinates better than 0.005m.

MISCELLANEOUS DETAILS

Est. Date:	30/10/2018	Established By:	Hayden Harris	Survey:	18020

DESCRIPTION AND ACCESS

This base station consists of a small star picket protruding from the ground and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The base is approximatley 170km east of Alice Springs on Numery Station. From the Numery Station Homestead, zero the odometer (0.0km) and head north east. After 200m, head down the middle track which is signposted 'Illogwa Bore'. At 2.4km, pass through a gate and continue. At 9.7km, at Perseverance Bore, pass through another gate and stay on the track north of the cattle yards. At 16.4km, stay on the right side and at 19.4km, take the right side fork in the road. At 26.2km, take the left fork in the road and continue on where at 33.0km, there is a turn off on the right side of the track signposted as 'Karen's Junction'. Follow this track for 5.8km (38.8km) and Base 1538 will be approximatley 30m on the left (northern) side of the track.

Field Photo Of Base

Appendix E

Data USB & field headers

(USB storage attached to back cover)

18020 Data Column Headers		
Field Header	**Field Description**	**Units**
PROJECT	Contractor Project Number	
OPERATOR	Contractor Company Name	
SURVEY_NAME	Survey Name	
STATION	Unique Station ID	
LINE	Survey Line number (if applicable, -99 for null values)	
RECORD_TYPE	Record observation type (Base, Field, Repeat, Existing_Repeat)	
METER_MODEL	Model of Gravity Meter	
METER_SN	Serial Number of Gravity Meter	
EAST_MGA94_m	Easting (MGA Grid, GRS80, GDA94)	m
NORTH_MGA94_m	Northing (MGA Grid, GRS80, GDA94)	m
ZONE	UTM Zone Number	
LAT_GDA94_DD	Coordinate Latitude (Geodetic, GRS80, GDA94)	DD
LONG_GDA94_DD	Coordinate Longitude (Geodetic, GRS80, GDA94)	DD
HEIGHT_AHD09_m	Orthometric Height - Australian Height Datum AHD (AUSGEOID09)	m
HEIGHT_GRS80_m	Ellipsoid Height (Geodetic, GRS80, GDA94)	m
N_AUSGEOID09_m	Geoid Ellipsoid separation N (AUSGEOID09)	m
DATE	Observation Date (DD/MM/YYYY)	
TIME	Observation Time (HH:MM:SS)	
DIAL_mGal	Gravity Dial Reading	mGal
SCALE	Scale Factor Applied to Dial Reading	
ETC_mGal	Earth Tide Correction (Longman)	mGal
OBSG84_mGal	Observed Gravity (ISOGAL84)	mGal
OBSG07_GU	Observed Gravity (AAGD07)	GU
TG1967_mGal	Theoretical Gravity (1967 variant)	mGal
TG80_mGal	Theoretical Gravity (1980 variant)	mGal
ISFAC_mGal	Infinite Slab Free Air Correction using Orthometric Height (AHD AUSGEOID09)	mGal
ISFAA_mGal	Infinite Slab Free Air Anomaly using Orthometric Height (AHD AUSGEOID09)	mGal
ISBC_267_mGal	Infinite Slab Bouguer Correction (2.67 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ISBC_240_mGal	Infinite Slab Bouguer Correction (2.40 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ISBC_220_mGal	Infinite Slab Bouguer Correction (2.20 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ISBA_267_mGal	Infinite Slab Bouguer Anomaly (2.67 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ISBA_240_mGal	Infinite Slab Bouguer Anomaly (2.40 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ISBA_220_mGal	Infinite Slab Bouguer Anomaly (2.20 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
ATMC_GU	Spherical Cap Atmospheric Correction using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
EFAC_GU	Spherical Cap Free Air Correction using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
EFAA_GU	Spherical Cap Free Air Anomaly using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBC_267_GU	Spherical Cap Bouguer Correction (2.67 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBC_240_GU	Spherical Cap Bouguer Correction (2.40 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBC_220_GU	Spherical Cap Bouguer Correction (2.20 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBA_267_GU	Spherical Cap Bouguer Anomaly (2.67 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBA_240_GU	Spherical Cap Bouguer Anomaly (2.40 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
SCBA_220_GU	Spherical Cap Bouguer Anomaly (2.20 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
TC_METHOD	Terrain Correction software used	
TC_DEM	Digital Elevation Model (DEM) type used (default of SRTM is Geoscience Australia's 1sec SRTM data)	
TC_INNER_mGal	Inner Terrain Correction (2.67 t/m^3)	mGal
QF_INNER	Quality Factor Inner	
TC_OUTER_mGal	Outer Terrain Correction (2.67 t/m^3)	mGal
QF_OUTER	Quality Factor Outer	
TC_TOTAL_mGal	Total Terrain Correction (2.67 t/m^3)	mGal
CISBA_267_mGal	Complete Infinite Slab Bouguer Anomaly (2.67 t/m^3) using Orthometric Height (AHD AUSGEOID09)	mGal
CSCBA_267_GU	Complete Spherical Cap Bouguer Anomaly (2.67 t/m^3) using Ellipsoid Height (Geodetic, GRS80, GDA94)	GU
DIFF_EAST_m	Repeat Error for MGA Easting Observation	m
DIFF_NORTH_m	Repeat Error for MGA Northing Observation	m
DIFF_GDA94_m	Repeat Error for Ellipsoid Height (GDA94)	m
DIFF_OBSG84_mGal	Repeat Error for Observed Gravity (ISOGAL84)	mGal
CLOSURE_mGal	Loop Closure	mGal
BASE_GRV	Gravity Base Station Number	
BASE_GPS	GPS Base Station Number	