Atlas Geophysics Memorandum M2015074

EP 144, EP 153, & EP 154 Gravity Surveys

Hancock Prospecting PTY LTD

Memo completed by:

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APPENDICES

1.0 Project Brief

Project 2015074 involved the acquisition and processing of **4,083** new gravity stations over 3 separate areas in the north of the Northern Territory. Areas EP153 & EP154 are located approximately 150 kilometres to the south east of Katherine, while area EP144 is located approximately 400 kilometres further to the south east, close to the Queensland border. (See Figure 1.)

Atlas Geophysics completed the acquisition of the dataset using helicopter-borne gravity methods. Acquisition commenced on the 28th of September 2015 and was completed on the 31st of October 2015, with final data delivered shortly thereafter.

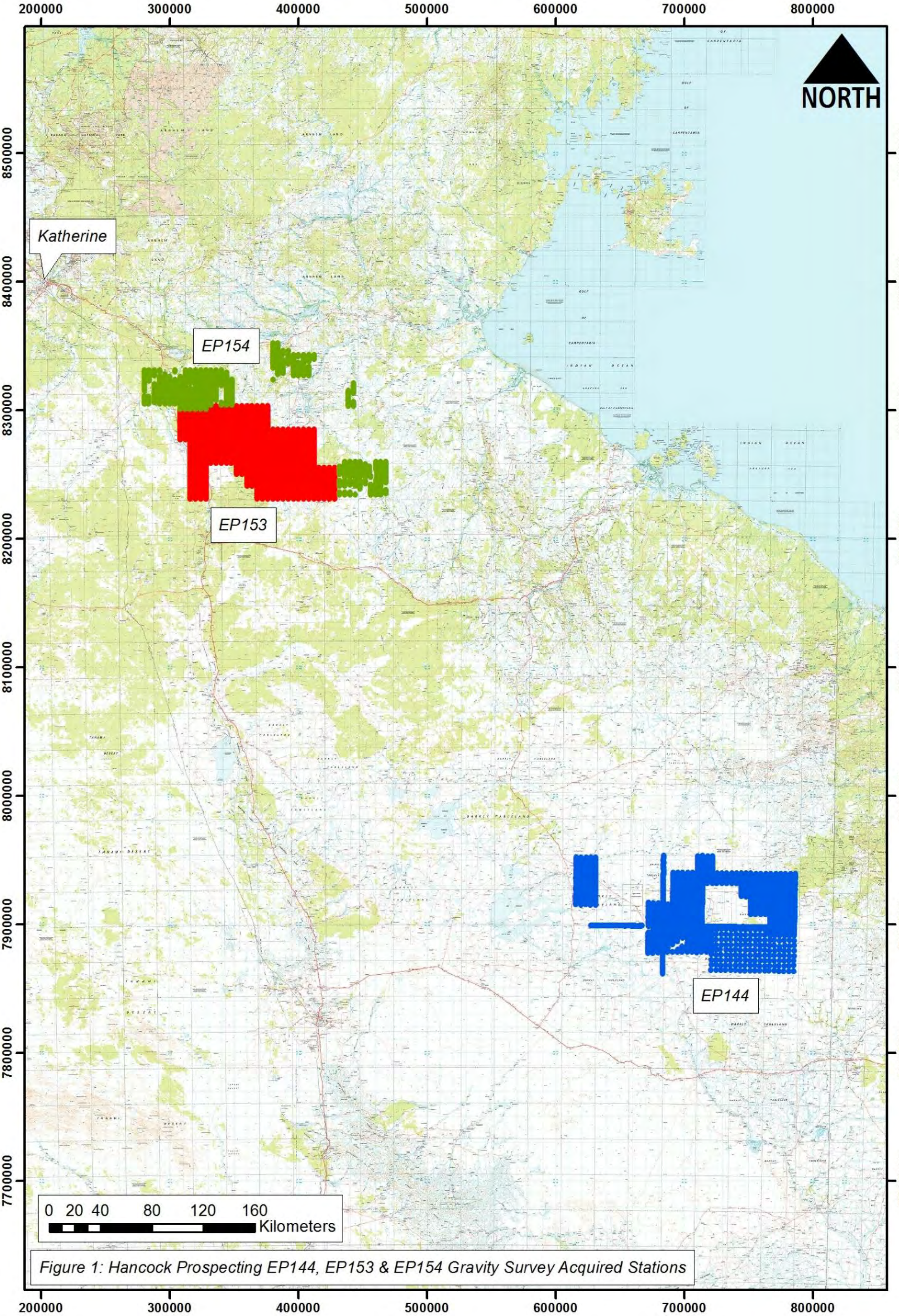


Figure 1: Hancock Prospecting EP144, EP153 & EP154 Gravity Survey Acquired Stations

2.0 Equipment and Instrumentation

The following instrumentation was used for acquisition of the gravity data:

- One CG-5 Autograv Gravity Meter (Serial Number; 40241 SF 0.999283)
- One Leica GS15 GNSS base receiver
- One NavCom 3050 GNSS receiver
- Two Leica System 1200 GNSS receivers

Ancillary equipment included:

- Two HP Laptop computers for data download and processing
- Garmin autonomous GPS receivers for navigation
- Iridium satellite phones for long distance communications
- Personal Protective Equipment for all personnel
- Batteries, battery chargers, UPS System
- Survey consumables
- Tools, engineering and maintenance equipment for vehicle servicing
- First aid and survival kits
- Tyres and recovery equipment

3.0 Calibration and Control

The gravity meter used for the survey had been recently calibrated on the Guildford Cemetery – Helena Valley Primary School calibration range (2010990117 - 2010990217) in Western Australia. The calibration process has validated the gravity meters' scale factor to ensure reduction of the survey data produces correct Observed Gravities from measured dial reading values.

Two control stations were used to control all gravity observations throughout the survey; 201507400001 "Alexandria Downs Station" and 201507400002 "Larrimah". These stations are tied to the Australian Absolute gravity Datum 2007 (AAGD07) via multiple ABABA loops to the Australian Fundamental Gravity Network (AFGN) via existing Atlas Geophysics Gravity Station 201507100001 "Carrara", and AFGN station 1964910133 "Daly Waters". Expected accuracy of the gravity ties are better than 0.01mGal.

Control Station 201507400001 "Alexandria Station" was also used to control positional observations throughout the EP144 survey. GNSS control station 201507400003 "Larrimah GNSS Base" was established in Larrimah to control GNSS observation for the EP153 and EP154 areas. GNSS control was established at all control stations Geoscience Australia's AUSPOS processing system to produce first-order geodetic coordinates accurate to better than 10mm for the x, y and z observables. Three days of static GPS data have been submitted for each station to ensure accuracy and reliability of the solution. Details of the control process have been summarised in a table included in Appendix C.

4.0 GNSS-Gravity Acquisition

Gravity data were acquired concurrently with positional GNSS data using a single Scintrex CG-5 gravity meter per crew. Data were acquired in a single shift of 10 hours duration, with each shift consisting of a single loop controlled by observations at the gravity control station. Each loop contained a minimum of two repeated readings so that an interlocking network of closed loops was formed. For quality control purposes **2.45%** repeats were gained in total for the survey area. Repeat readings were evenly distributed on a time-basis throughout each of the gravity loops.

GNSS data were acquired with the rover receivers operating in Post Processed Kinematic (PPK) mode with the GNSS receiver mounted to the tail of the helicopter. Static data were logged at the control station for submission to AUSPOS for delivery of final coordinates.

5.0 GNSS Processing and QC

The acquired GNSS raw data were processed nightly in the field using Novatel Waypoint GrafNav v8.60 post-processing software. The resulting data (in Atlas Geophysics PPK standard format) were then imported into Atlas Geophysics Reduction and Interpretation Software (AGRIS) for QC and use in the reduction of the gravity data.

Projection from GNSS derived WGS84/GDA94 coordinates to Map Grid of Australia (MGA) coordinates was performed in GrafNav. For most practical applications where a horizontal accuracy of only a metre or greater is required, GDA94 coordinates can be considered the same as WGS84. MGA coordinates were obtained by projecting the GNSS-derived WGS84 coordinates onto MGA Zones 53S using a Universal Transverse Mercator (UTM) projection. Elevations above the Australian Height Datum (AHD) were modelled using GrafNav software and the AUSGEOID09 geoid model.

A module built into AGRIS allows the user to import the positional data from NovaTel's GrafNav software package, and examine quality factors such as station repeatability between multiple control stations, coordinate velocity, dilution of precision, coordinate quality factor and standard error for each gravity station location. The procedure is carried out before merging the positional data with gravity data for final reduction to Bouguer anomaly. Comprehensive statistics, repeatability analysis and histogram plotting are also performed.

QC procedures were applied to the GNSS data on a daily basis and any gravity stations not conforming to the quoted specifications were repeated by the company at no cost to the client.

6.0 Gravity Processing and QC

The acquired gravity data were processed using the company's in-house gravity pre-processing and reduction software, AGRIS. This software allows for full data pre-processing, reduction to Bouguer Anomaly, repeatability and statistical analysis, as well as full quality control of the output dataset.

Once downloaded from the gravity meter, the data are analysed for consistency and preliminary QC is then performed to confirm that observations meet specification for standard deviation, reading rejection, temperature and tilt values. Once the data are verified, the software averages the multiple readings and performs a merge with the GPS data (which it has also previously verified) and performs a linear drift correction and earth tide correction. Any gravity stations not conforming to the quoted specifications were repeated by the company at no cost to the client.

The following corrections were applied to the dataset to produce Spherical Cap Bouguer Anomalies on the GRS80 ellipsoid and AAGD07 gravity datum. For legacy reasons, Geoidal Bouguer Anomalies on the Australian Height Datum (AHD) and ISOGAL84 gravity datum have also been calculated. The formulae below produce data in μms^{-2} or gravity units. To convert to mGal, divide by a factor of 10.

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

$$r_c = 10 \cdot (r \cdot S(r))$$

where,

r_c corrected reading in gravity units
r gravity meter reading in dial units
$S(r)$ scale factor (dial units/milliGal)

Earth Tide Correction: The earth is subject to variations in gravity due to the gravitational attraction of the Sun and the Moon. These background variations can be corrected for using a predictive formula which utilises the gravity observation position and time of observation. The Scintrex CG5 gravity meter automatically calculates ETC but uses only an approximate position for the gravity observation so is not entirely accurate. For this reason, the Scintrex ETC is subtracted from the reading and a new correction calculated within AGRIS software.

$$r_t = r_c + g_{tide}$$

where,

r_t tide corrected reading in gravity units
r_c scale factor corrected reading in gravity units
g_{tide} Earth Tide Correction (ETC) in gravity units

Instrument Drift Correction: Since all gravity meters are mechanical they are all prone to instrument drift. Drift can be caused by mechanical stresses and strains in the spring mechanism as the meter is moved, knocked, reset, subjected to temperature extremes, subjected to vibration, unclamped etc. The most common cause of instrument drift is due to extension of the sensor spring with changes in temperature (obeying Hooke's law). To calculate and correct for daily instrument drift, the difference between the gravity control station readings (closure error) is used to assume the drift and a linear correction is applied.

$$ID = \frac{r_{cs2} - r_{cs1}}{t_{cs2} - t_{cs1}}$$

where,

ID Instrument Drift in gu/hour
r_{cs2} control station 2nd reading in gravity units
r_{cs1} control station 1st reading in gravity units
t_{cs2} control station 2 time
t_{cs1} control station 1 time

Observed Gravity: The preceding corrections are applied to the raw gravity reading to calculate the earth's absolute gravitational attraction at each gravity station. The corrections produced Observed Gravities on the AAGD07 and ISOGAL84 datums.

$$G_o = g_{cs1} + (r_t - r_{cs1}) - (t - t_{cs1}) \cdot ID$$

where,

G_o Observed Gravity in gravity units (ISOGAL84 or AAGD07)
g_{cs1} control station 1 known Observed Gravity in gravity units
r_t tide corrected reading in gravity units
r_{cs1} control station 1 reading in gravity units
t reading time
t_{cs1} control station 1 time
ID instrument drift in gravity units/hour

Theoretical Gravity 1980: The theoretical (or normal) gravity value at each gravity station is calculated based on the assumption that the Earth is a homogeneous ellipsoid. The closed form of the 1980 International Gravity Formula is used to approximate the theoretical gravity at each station location and essentially produce a latitude correction. Gravity values vary with latitude as the earth is not a perfect sphere and the polar radius is much smaller than the equatorial radius. The effect of centrifugal acceleration is also different at the poles versus the equator.

$$G_{t80} = 9780326.7715((1 + 0.001931851353(sin^2 l)/(SQRT(1 - 0.0066943800229(sin^2 l)))$$

where,

G_{t80} Theoretical Gravity 1980 in gravity units
l GDA94 latitude at the gravity station in decimal degrees

Theoretical Gravity 1967: The theoretical (or normal) gravity value at each gravity station is calculated based on the assumption that the Earth is a homogeneous ellipsoid. The 1967 variant of the International Gravity Formula is used to approximate the theoretical gravity at each station location and essentially produce a latitude correction. Gravity values vary with latitude as the earth is not a perfect sphere and the polar radius is much smaller than the equatorial radius. The effect of centrifugal acceleration is also different at the poles versus the equator.

$$G_{t67} = (9780318.456 \cdot (1 + 0.005278895 \cdot sin^2(l) + 0.000023462 \cdot sin^4(l)))$$

where,
G_{t67} Theoretical Gravity 1967 in gravity units
l GDA94 latitude at the gravity station in decimal degrees

Atmospheric Correction: The gravity effect of the atmosphere above the ellipsoid can be calculated with an atmospheric model and is subtracted from the theoretical gravity.

$$AC = 8.74 - 0.00099 \cdot h + 0.0000000356 \cdot h^2$$

where,
AC Atmospheric Correction in gravity units
h elevation above the GRS80 ellipsoid in metres

Ellipsoidal Free Air Correction: Since the gravity field varies inversely with the square of distance, it is necessary to correct for elevation changes from the reference ellipsoid (GRS80). Gravitational attraction decreases as the elevation above the reference ellipsoid increases.

$$EFAC = -(3.087691 - 0.004398\, sin^2 l) \cdot h + 7.2125 \cdot 10^{-7} \cdot h^2$$

where,
$EFAC$ Ellipsoidal Free Air Correction in gravity units
l GDA94 latitude at the gravity station in decimal degrees
h elevation above the GRS80 ellipsoid in metres

Geoidal Free Air Correction: Since the gravity field varies inversely with the square of distance, it is necessary to correct for elevation changes from the reference geoid (AHD). Gravitational attraction decreases as the elevation above the reference geoid increases.

$$GFAC = (3.08768 - 0.00440 sin^2(l)) \cdot h - 0.000001442 \cdot h^2$$

where,
$GFAC$ Free Air Correction in gravity units
l GDA94 latitude at the gravity station in decimal degrees
h elevation above the reference geoid (AHD) in metres

Spherical Cap Bouguer Correction: If a gravity observation is made above the reference ellipsoid, the effect of rock material between the observation and the ellipsoid must be taken into account. The mass of rock makes a positive contribution to the gravity value. The correction is calculated using the closed form equation for the gravity effect of a spherical cap of radius 166.7km, based on a spherical Earth with a mean radius of 6,371.0087714km, height relative the ellipsoid and rock densities of 2.67, 2.40 and 2.20 tm^{-3} (gm/cc).

$$SCBC = 2\pi G\rho((1 + \mu) \cdot h - \lambda R)$$

where,

$SCBC$ Spherical Cap Bouguer Correction in gravity units

G gravitational constant = $6.67428 \cdot 10^{-11} m^3 kg^{-1} s^{-2}$

ρ rock density (2.67, 2.40 and 2.20 tm^{-3})

h elevation above the GRS80 ellipsoid in metres

R $(R_o + h)$ the radius of the earth at the station

R_o mean radius of the earth = 6,371.0087714 km (on the GRS80 ellipsoid)

μ & λ are dimensionless coefficients defined by:

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

where,

η h/R

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

where,

d $3 \cdot cos^2\alpha - 2$

f $cos\alpha$

k $sin^2\alpha$

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

δ (R_o/R)

m $-3 \cdot k \cdot f$

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

α S/R_o with S = Bullard B Surface radius = 166.735 km

Geoidal Bouguer Correction: If a gravity observation is made above the reference geoid, the effect of rock material between the observation and the ellipsoid must be taken into account. The mass of rock makes a positive contribution to the gravity value. The slab of rock makes a positive contribution to the gravity value. Rock densities of 2.67, 2.40 and 2.20 t/m^{-3} (gm/cc) were used in the correction.

$$GBC = 0.4191 \cdot \rho \cdot h$$

where,

GBC Geoidal Bouguer Correction in gravity units

ρ rock density (2.67, 2.40 and 2.20 tm^{-3})

h elevation above the reference geoid (AHD) in m

Terrain Correction: The terrain correction accounts for variations in gravity values caused by variations in topography near the observation point. The 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. The terrain correction is positive regardless of whether the local topography consists of a mountain or a valley. Terrain corrections were not applied on this project.

Ellipsoidal Free Air Anomaly: The Ellipsoidal Free Air Anomaly is the difference between the observed gravity and theoretical gravity that has been computed for latitude and corrected for the elevation of the gravity station above or below the reference ellipsoid.

$$EFAA = G_{oAAGD07} - (G_{t80} - AC) - EFAC$$

where,

$EFAA$ Ellipsoidal Free Air Anomaly in gravity units
G_o Observed Gravity on the AAGD07 datum in gravity units
G_{t80} Theoretical Gravity 1980 in gravity units
AC Atmospheric Correction in gravity units
$EFAC$ Ellipsoidal Free Air Correction in gravity units

Geoidal Free Air Anomaly: The Geoidal Free Air Anomaly is the difference between the observed gravity and theoretical gravity that has been computed for latitude and corrected for the elevation of the gravity station above or below the reference geoid.

$$GFAA = G_{oISOGAL84} - G_{t67} + GFAC$$

where,

$GFAA$ Free Air Anomaly in gravity units
G_o Observed Gravity on the ISOGAL84 datum in gravity units
G_{t67} Theoretical Gravity 1967 in gravity units
$GFAC$ Geoidal Free Air Correction in gravity units

Spherical Cap Bouguer Anomaly: The Spherical Cap Bouguer Anomaly is computed from the Ellipsoidal Free Air Anomaly above by removing the attraction of the spherical cap calculated by the Spherical Cap Bouguer Correction.

$$SCBA = EFAA - SCBC$$

where,

$SCBA$ Spherical Cap Bouguer Anomaly in gravity units
$EFAA$ Ellipsoidal Free Air Anomaly in gravity units
$SCBC$ Bouguer Correction in gravity units

Geoidal Bouguer Anomaly: The Geoidal Bouguer Anomaly is computed from the Geoidal Free Air Anomaly above by removing the attraction of the slab calculated by the Geoidal Bouguer Correction.

$$GBA = GFAA - GBC$$

where,

GBA Geoidal Bouguer Anomaly in gravity units
$GFAA$ Geoidal Free Air Anomaly in gravity units
GBC Geoidal Bouguer Correction in gravity units

Complete Bouguer Anomaly: This is obtained by adding the terrain correction to the Bouguer Anomaly (Spherical Cap or Geoidal). The Complete Bouguer Anomaly is the most interpretable value derived from a gravity survey as changes in the anomaly can be directly attributed to lateral density contrasts within the geology below the observation point.

$$CBA = BA + TC$$

where,

CBA Complete Bouguer Anomaly in gravity units
BA Bouguer Anomaly in gravity units
TC Terrain Correction in gravity units

7.0 Results

The gravity survey was completed in 23 total days of acquisition. An average acquisition rate of **178** stations per day of production was achieved over the duration of the project. The acquisition of the gravity stations progressed well with some delays due to rough terrain, extreme weather conditions and helicopter maintenance issues. A copy of the full production report is contained on the USB Flash Drive.

Final data have met and exceeded quoted project specifications. Repeatability of the data was good, with the standard deviation of the elevation repeats at **0.063m** for the EP144 area and **0.042m** for the EP153 & EP154 areas. Standard deviation of the gravity repeats is at **0.030mGal** for EP144 and **0.021mGal** for the EP153 & EP154 areas. The production report contains summary statistics and histograms for repeatability.

8.0 Data Formats and Deliverables

Final reduced ASCII data for the project have been delivered in standard Atlas format. Table 2 overleaf details the format of the final gravity database supplied. All fields are comma delimited.

Appendix B contains plots of final station locations, images of GNSS Derived Elevation (GRS80), Spherical Cap Bouguer Anomaly and first vertical derivative of Spherical Cap Bouguer Anomaly.

Raw GNSS and gravity data in their respective native formats have been included on the USB Flash Drive as Appendix D. Table 1 below summarises the deliverables.

Final Delivered Data	Format	USB Data	Hardcopy
Gravity Database	Comma Space Delimited .csv	•	
Gravity Database	Geosoft database	•	
Gravity Database	Point located data ASEG-GDF2	•	
Raw Positional Data	AGRIS format, comma delimited	•	
Raw Gravity Data	Scintrex CG-5 format	•	
Final Grids	ER Mapper Grids .ers	•	
Final Images	GIS compatible Geotiff .tif	•	•
Acquisition Memo	PDF .pdf	•	•

Table 1: Final Deliverables

Field Header	Field Description	Format	Units
PROJECT	Atlas Geophysics Project Number	A9	None
STATION	Unique Station ID	I8	None
STATIONCODE	Unique Station Code	A13	None
LINE	Line ID	I8	None
TYPE	Observation Type : Base, Field or Repeat	A8	None
MGAEAST	Coordinate Easting MGA94/GDA94	F11.3	M
MGANORTH	Coordinate Northing MGA94/GDA94	F12.3	M
ZONE	MGA Zone Number	F8.0	NA
GDA94LAT	Coordinate Latitude GDA94	F15.10	DD
GDA94LONG	Coordinate Longitude GDA94	F15.10	DD
ORTHOHTM	Coordinate Elevation Orthometric	F9.3	M
GRS80HTM	Coordinate Elevation Ellipsoidal	F9.3	M
NAG09	Geoid Separation	F8.3	M
AMG84EAST	Coordinate Easting AMG84	F11.3	M
AMG84NORTH	Coordinate Northing AMG84	F12.3	M
DATE	Observation Date	I8	None
TIME	Observation Time	I8	None
DIALMGAL	Gravity Dial Reading	F9.3	mGal
ETCMGAL	Earth Tide Correction (Longman)	F8.3	mGal
SCALE	Scale Factor Applied to Dial Reading	F9.6	None
OBSG84MGAL	Observed Gravity ISOGAL84	F11.3	mGal
OBSG84GU	Observed Gravity ISOGAL84	F11.2	Gu
OBSGAAGD07GU	Observed Gravity AAGD07	F13.2	Gu
OBSGAAGD007MGAL	Observed Gravity AAGD07	F16.3	mGal
DRIFTMGAL	Drift Applied to Dial Readings	F10.3	mGal
TGRAV67GU	Theoretical Gravity 1967	F11.2	Gu
TGRAV67MGAL	Theoretical Gravity 1967	F12.3	mGal
TGRAV80GU	Theoretical Gravity 1980	F11.2	Gu
GFACGU	Geoidal Free Air Correction	F8.2	Gu
GFACMGAL	Geoidal Free Air Correction	F9.3	mGal
GFAAGU	Geoidal Free Air Anomaly	F8.2	Gu
GFAAMGAL	Geoidal Free Air Anomaly	F9.3	mGal
GBC267GU	Geoidal Bouguer Correction 2.67 tm^-3	F9.2	Gu
GBC240GU	Geoidal Bouguer Correction 2.40 tm^-3	F9.2	Gu
GBC220GU	Geoidal Bouguer Correction 2.20 tm^-3	F9.2	Gu
GBC267MGAL	Geoidal Bouguer Correction 2.67 tm^-3	F11.3	mGal
GBC240MGAL	Geoidal Bouguer Correction 2.40 tm^-3	F11.3	mGal
GBC220MGAL	Geoidal Bouguer Correction 2.20 tm^-3	F11.3	mGal
GBA267GU	Geoidal Bouguer Anomaly 2.67 tm^-3	F9.2	gu
GBA240GU	Geoidal Bouguer Anomaly 2.40 tm^-3	F9.2	gu
GBA220GU	Geoidal Bouguer Anomaly 2.20 tm^-3	F9.2	gu
GBA267MGAL	Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	mGal
GBA240MGAL	Geoidal Bouguer Anomaly 2.40 tm^-3	F11.3	mGal
GBA220MGAL	Geoidal Bouguer Anomaly 2.20 tm^-3	F11.3	mGal
TGRAV80ACGU	Theoretical Gravity 1980 Atmospheric Corrected	F11.2	gu
EFACGU	Ellipsoidal Free Air Correction	F9.2	gu
EFAAGU	Ellipsoidal Free Air Anomaly	F8.2	gu
SCBC267GU	Spherical Cap Bouguer Correction 2.67 tm^-3	F10.2	gu
SCBC240GU	Spherical Cap Bouguer Correction 2.40 tm^-3	F10.2	gu
SCBC220GU	Spherical Cap Bouguer Correction 2.20 tm^-3	F10.2	gu
SCBA267GU	Spherical Cap Bouguer Anomaly 2.67 tm^-3	F10.2	gu
SCBA240GU	Spherical Cap Bouguer Anomaly 2.40 tm^-3	F10.2	gu
SCBA220GU	Spherical Cap Bouguer Anomaly 2.20 tm^-3	F10.2	gu
SCBA267MGAL	Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.3	mGal
SCBA240MGAL	Spherical Cap Bouguer Anomaly 2.40 tm^-3	F12.3	mGal
SCBA220MGAL	Spherical Cap Bouguer Anomaly 2.20 tm^-3	F12.3	mGal
TCINNERGU	Inner Terrain Correction	F8.2	gu
TCINNERMGAL	Inner Terrain Correction	F8.3	mGal
QFINNER	Quality Factor Inner TC	I2	None
TCOUTERGU	Outer Terrain Correction	F8.2	gu
TCOUTERMGAL	Outer Terrain Correction	F8.3	mGal
QFOUTER	Quality Factor Outer TC	F2	None
TCTOTALGU	Total Terrain Correction	F8.2	gu
TCTOTALMGAL	Total Terrain Correction	F8.3	mGal
CGBA267GU	Complete Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	gu
CGBA267MGAL	Complete Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	mGal
CSCBA267GU	Complete Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.2	gu
CSCBA267MGAL	Complete Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.2	mGal
DIFFEASTM	Repeat Error for Easting Observation	F8.3	m
DIFFNORTHM	Repeat Error for Northing Observation	F8.3	m
DIFFHTM	Repeat Error for Elevation Observation	F8.3	m
DIFFOBSGMGAL	Repeat Error for Observed Gravity	F8.3	mGal
DIFFOBSGGU	Repeat Error for Observed Gravity	F8.2	gu
METERSN	Serial Number of Gravity Instrument	I8	None
CLOSUREGU	Loop Closure in gu	F8.2	gu
CLOSUREMGAL	Loop Closure in mGal	F8.3	mGal
GRVBASE	Gravity Base	A11	None
GPSBASE	GPS Base	A11	None

Table 2: Final Gravity Database Format

9.0 Project Safety

Prior to survey commencement, a Hazard Identification and Risk Assessment (HIRA) was carried out for all new tasks not covered under Atlas Geophysics Standard Operating Procedures (SOP's) or the company's Health Safety Environment (HSE) field manual.

Weekly toolbox meetings were held to discuss project safety and address any staff member concerns.

Further HSE information is contained in the production reports included in the final data deliverables.

APPENDIX A
Control Station Descriptions

201507400001 – Alexandria Downs

GDA 94		MGA Z53		AMG Z53	
Latitude	-19° 03' 20.8352"	*Easting*	679,842.594	*Easting*	679,714
Longitude	136° 42' 32.7226"	*Northing*	7,892,123.841	*Northing*	7,891,953
Ellipsoidal Height	273.069	*Orthometric Height*	234.230	*Orthometric Height*	234.230

OBSERVED GRAVITY

Established on 29/09/2015

gu AAGD07	9784830.37
mGal ISOGAL84	978483.115

Occupation Method/Location Details

At this control station, the GPS control point consists of a steel picket driven into the ground with approximately 15cm protruding. The gravity control point consists of a small concrete slab set into the ground, opposite the GPS control point. The control station is witnessed by an Atlas Geophysics survey plaque attached to a 1.5 metre steel picket placed within 0.5m of the both control points.

Gravity Control was established via ABABA loops to the Atlas Geophysics Station 201507100001 “Carrara”. The gravity tie was completed with the project gravity meter on 06/10/2015. Expected accuracy is better than 0.01mGals.

GNSS Control was established using AUSPOS. Three separate 10 hour sessions were submitted to AUSPOS’s online processing systems where returned coordinates were accurate to better than 0.01m.

The station is located at the south eastern corner (known as ‘Contractor’s Corner’) of the Alexandria Downs station, which is located approximately 70kms north of the Barkly Highway, in eastern Northern territory.

Photograph of Control Station 20150740001 and surrounds

201507400002– Larrimah

GDA 94		MGA Z53		AMG Z53	
Latitude	-15° 34' 24.8700"	*Easting*	308,525	*Easting*	308,396
Longitude	133° 12' 51.7284"	*Northing*	8,277,430	*Northing*	8,277,262
Ellipsoidal Height	N/A	*Orthometric Height*	N/A	*Orthometric Height*	N/A

OBSERVED GRAVITY	Established on 13/10/2015
gu AAGD07	9783446.15
mGal ISOGAL84	978344.693

Occupation Method/Location Details

At this control station, the GPS control point consists of a steel picket driven into the ground with approximately 15cm protruding. The gravity control point consists of a small concrete slab set into the ground, opposite the GPS control point. The control station is witnessed by an Atlas Geophysics survey plaque attached to a 1.5 metre steel picket placed within 0.5m of the both control points.

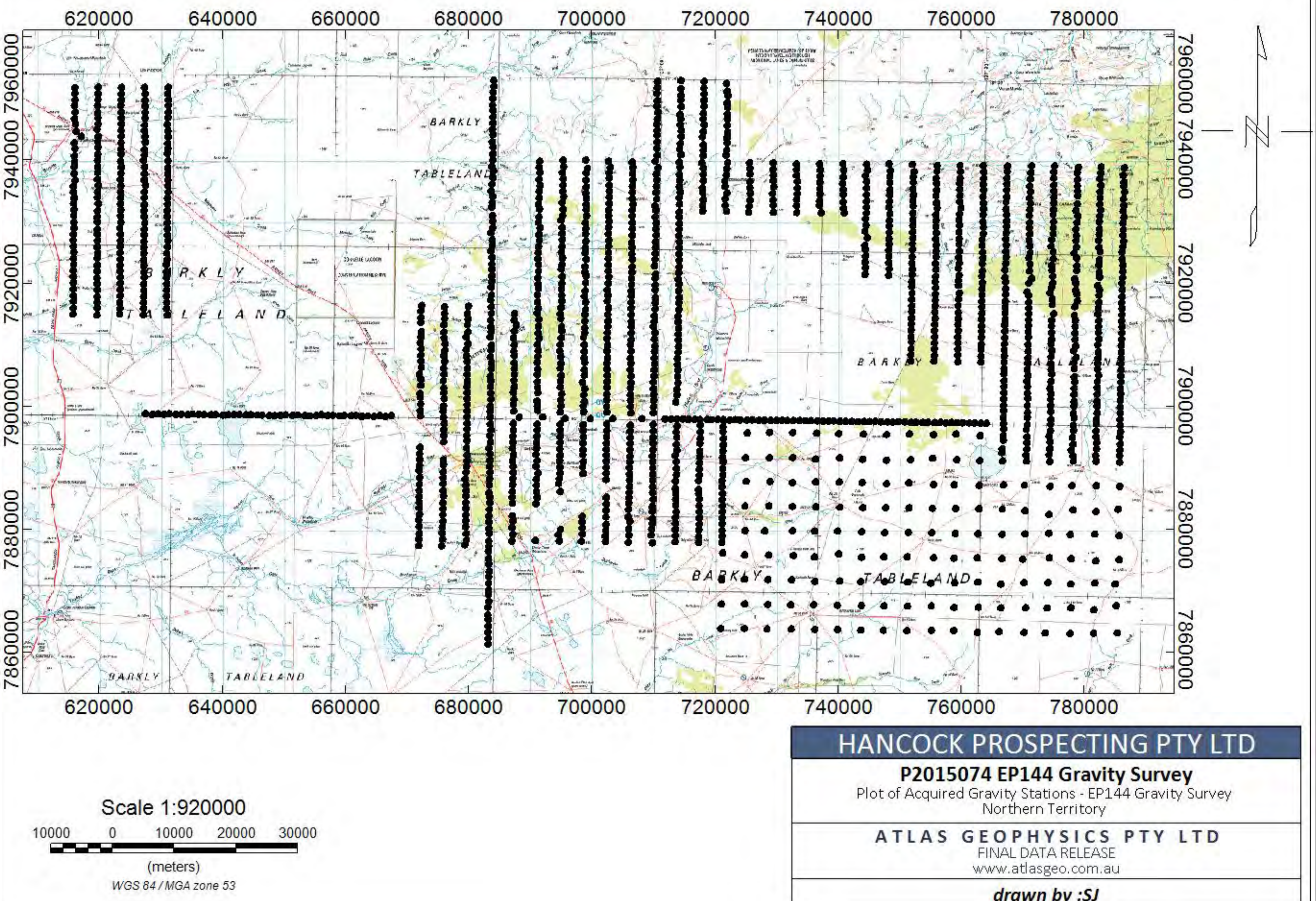
Gravity Control was established via ABABA loops to the Atlas Geophysics Station 201304600001, and AFGN station 1964910133. The gravity tie was completed with the project gravity meter on 31/10/2015. Expected accuracy is better than 0.01mGals.

GNSS Control was not established at this point.

The station is at the north western corner of Larrimah Wayside Inn, just off the Stuart Highway.

Photograph of Control Station 20150740002 and surrounds

APPENDIX B
Plots and Imagery



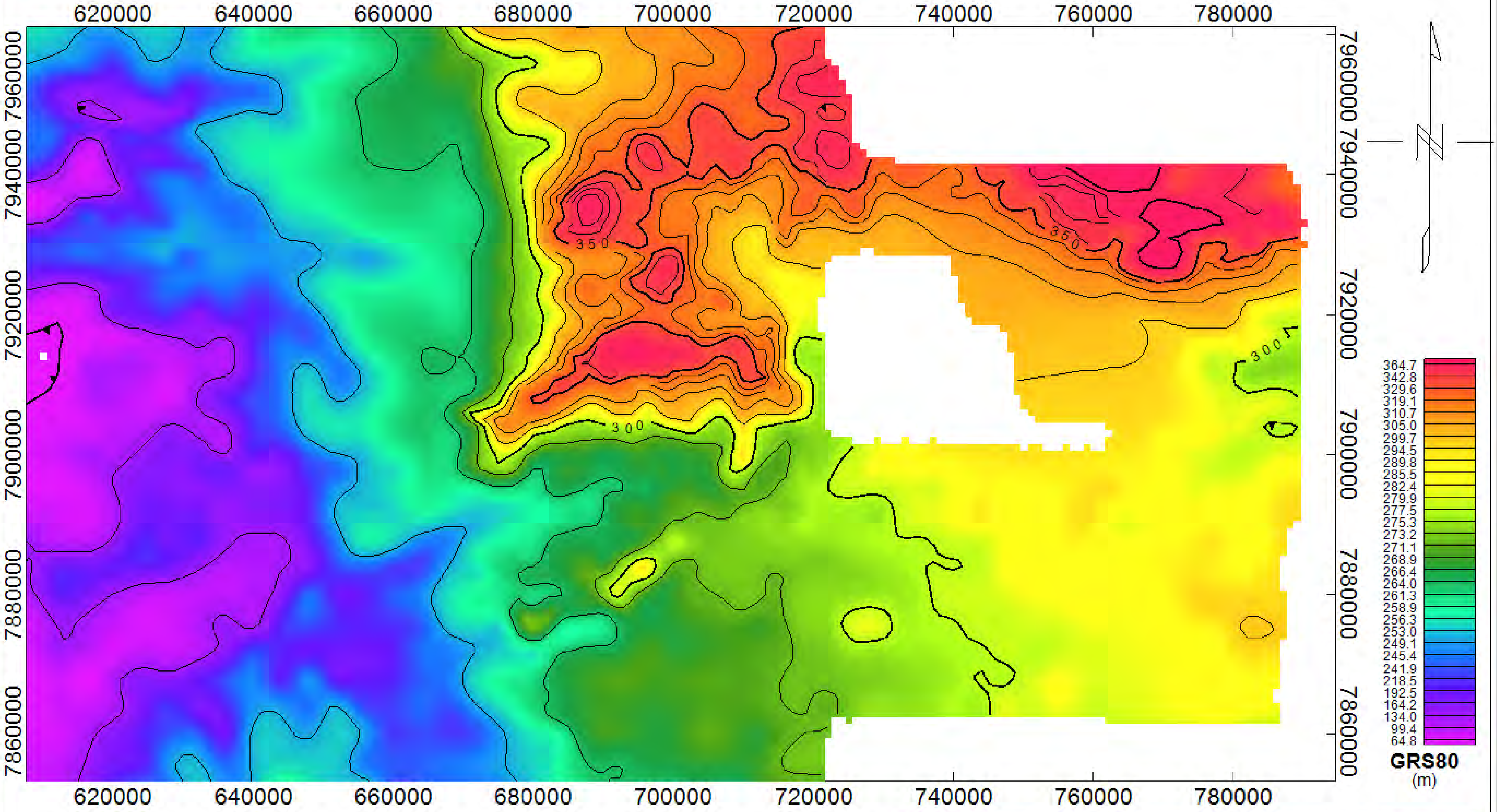
HANCOCK PROSPECTING PTY LTD

P2015074 EP144 Gravity Survey

Plot of Acquired Gravity Stations - EP144 Gravity Survey
Northern Territory

ATLAS GEOPHYSICS PTY LTD
FINAL DATA RELEASE
www.atlasgeo.com.au

drawn by :SJ



Scale 1:920000

10000 0 10000 20000 30000

(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP144 Gravity Survey

Pseudocoloured Image of GNSS Derived Elevation (GRS80)
Shade = None, Contours = 10.0m, Histo = Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA RELEASE
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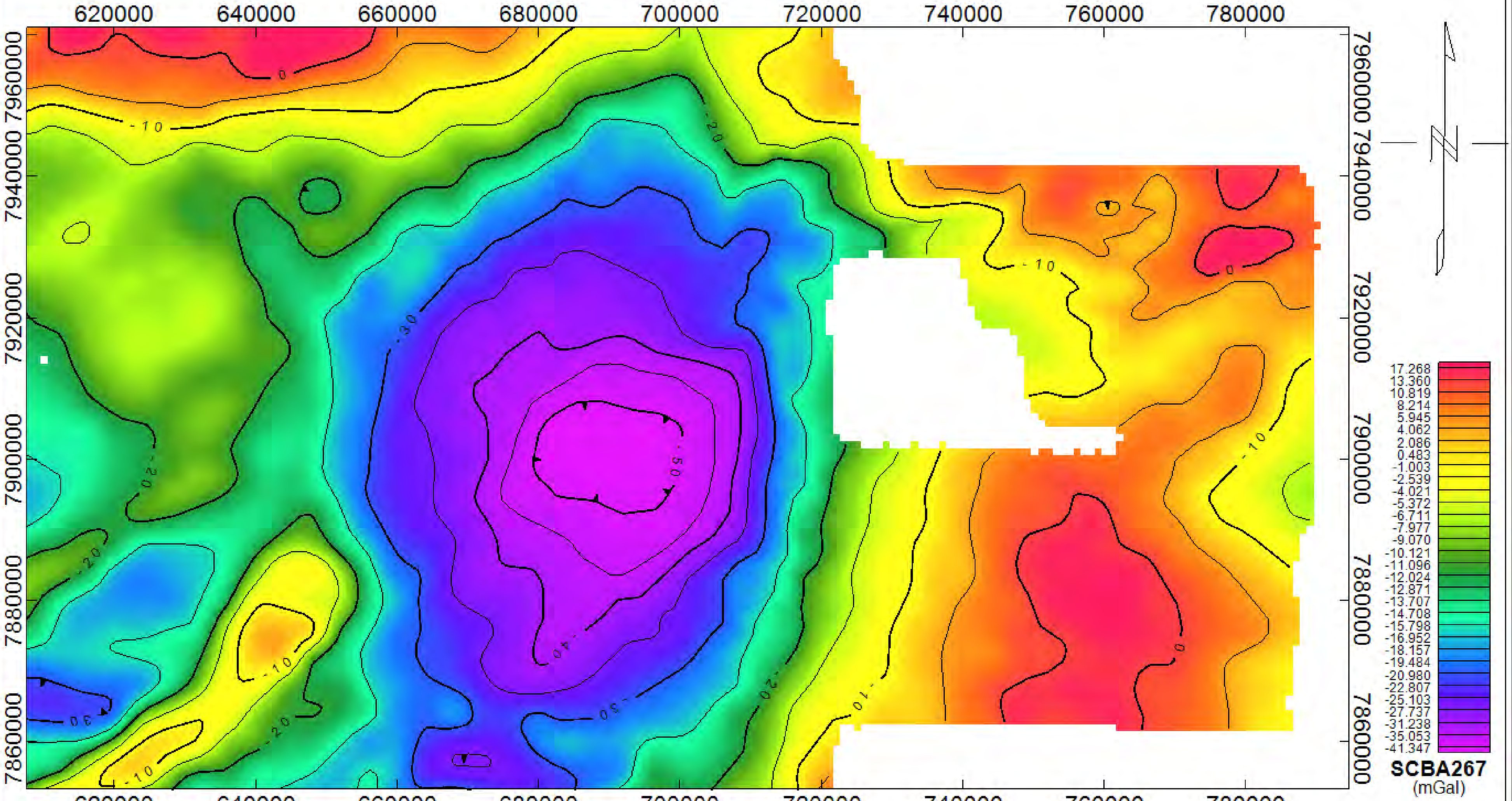

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(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP144 Gravity Survey

Pseudocoloured Image of SC Bouguer Anomaly (2.67gm/cc)
Shade = None, Contours = 5.0mGal, Histo = Equalised

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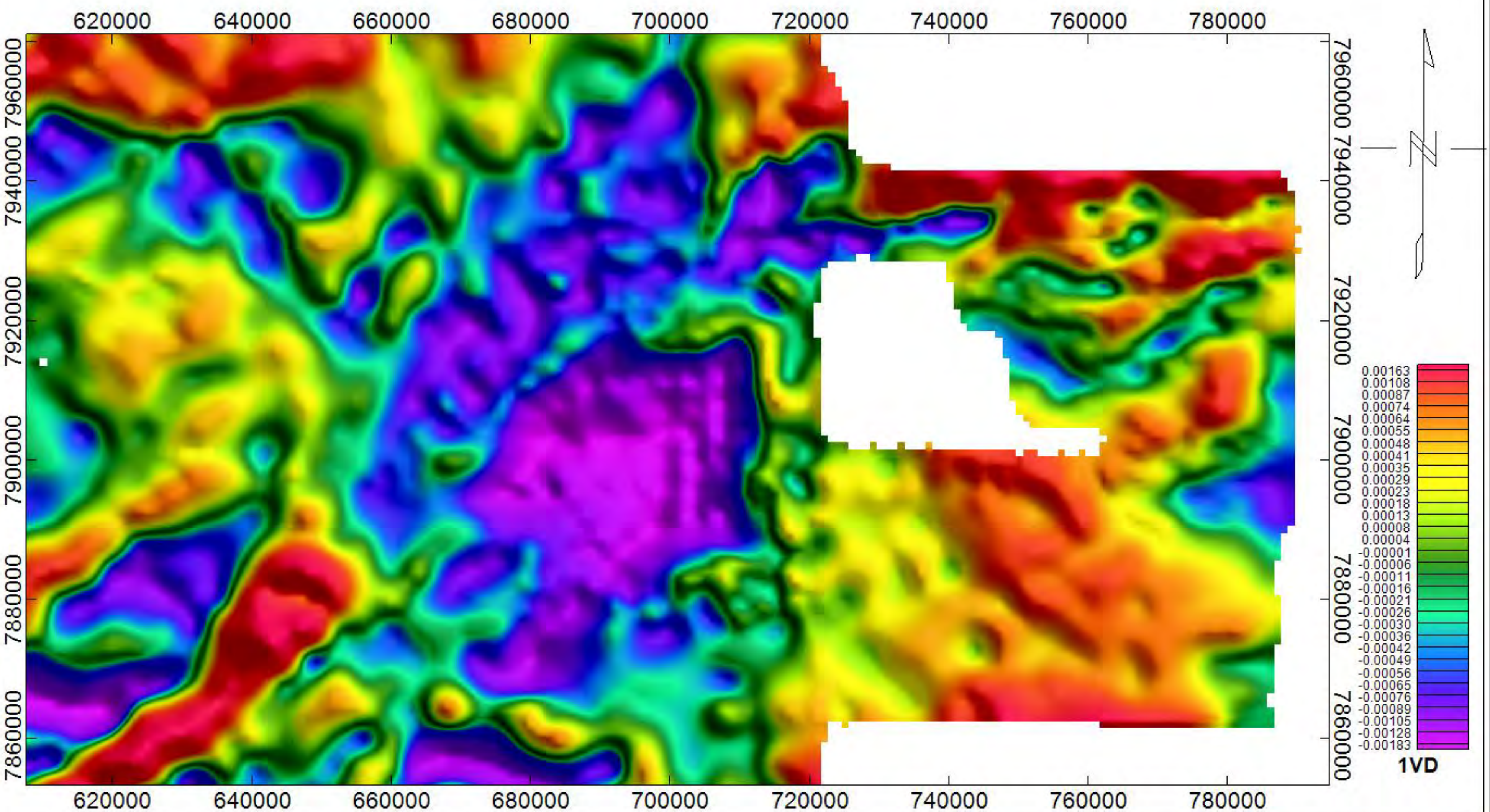

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(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP144 Gravity Survey

Pseudocoloured Image of 1VD of SC Bouguer Anomaly (2.67gm/cc)
Shade = None, Contours = None, Histo = Equalised

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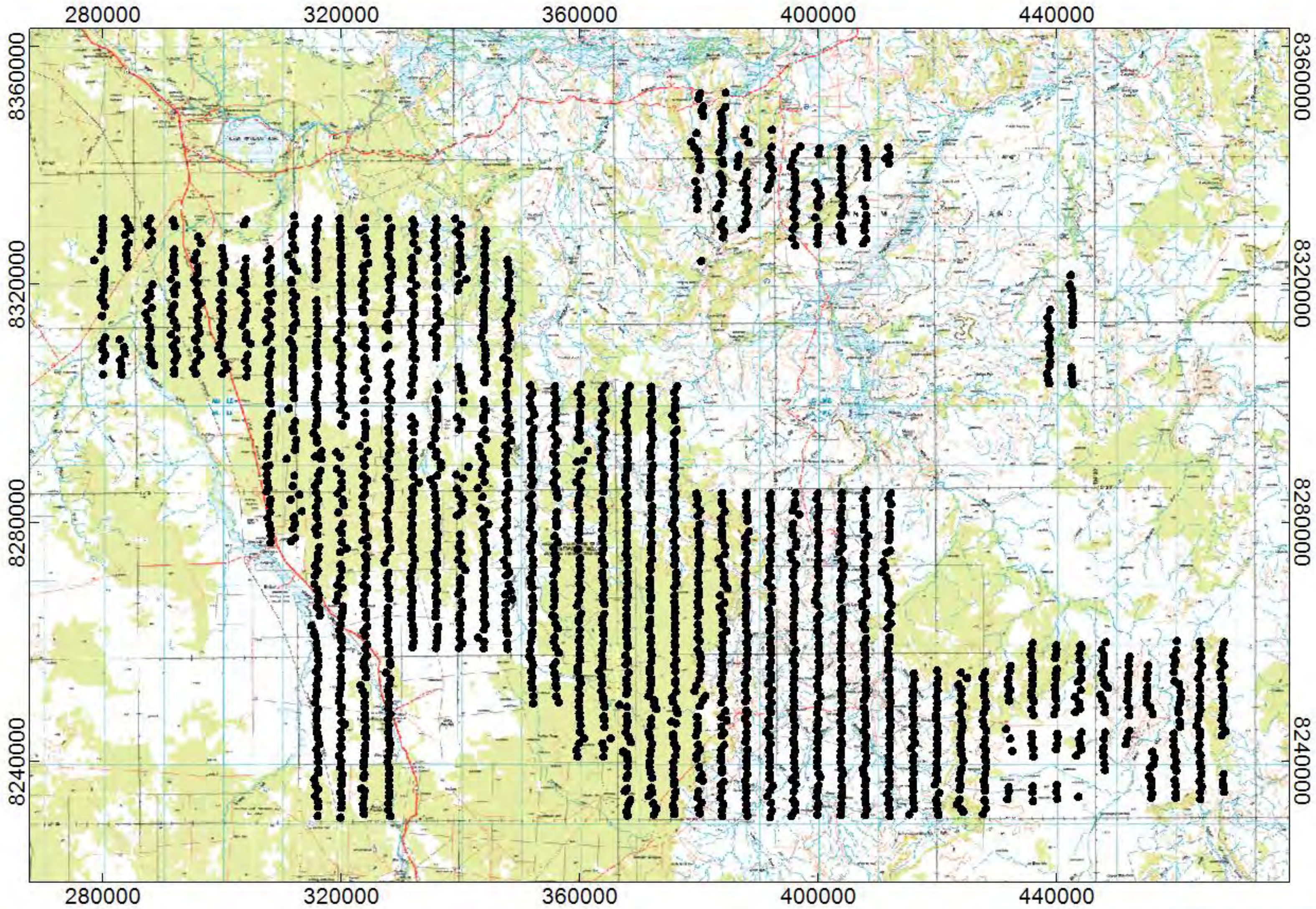

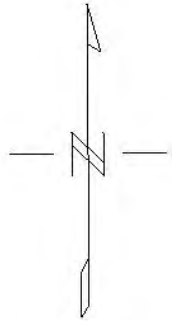

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(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP153 / EP154 Gravity Survey

Plot of Acquired Gravity Stations
EP153 EP154 Northern Territory

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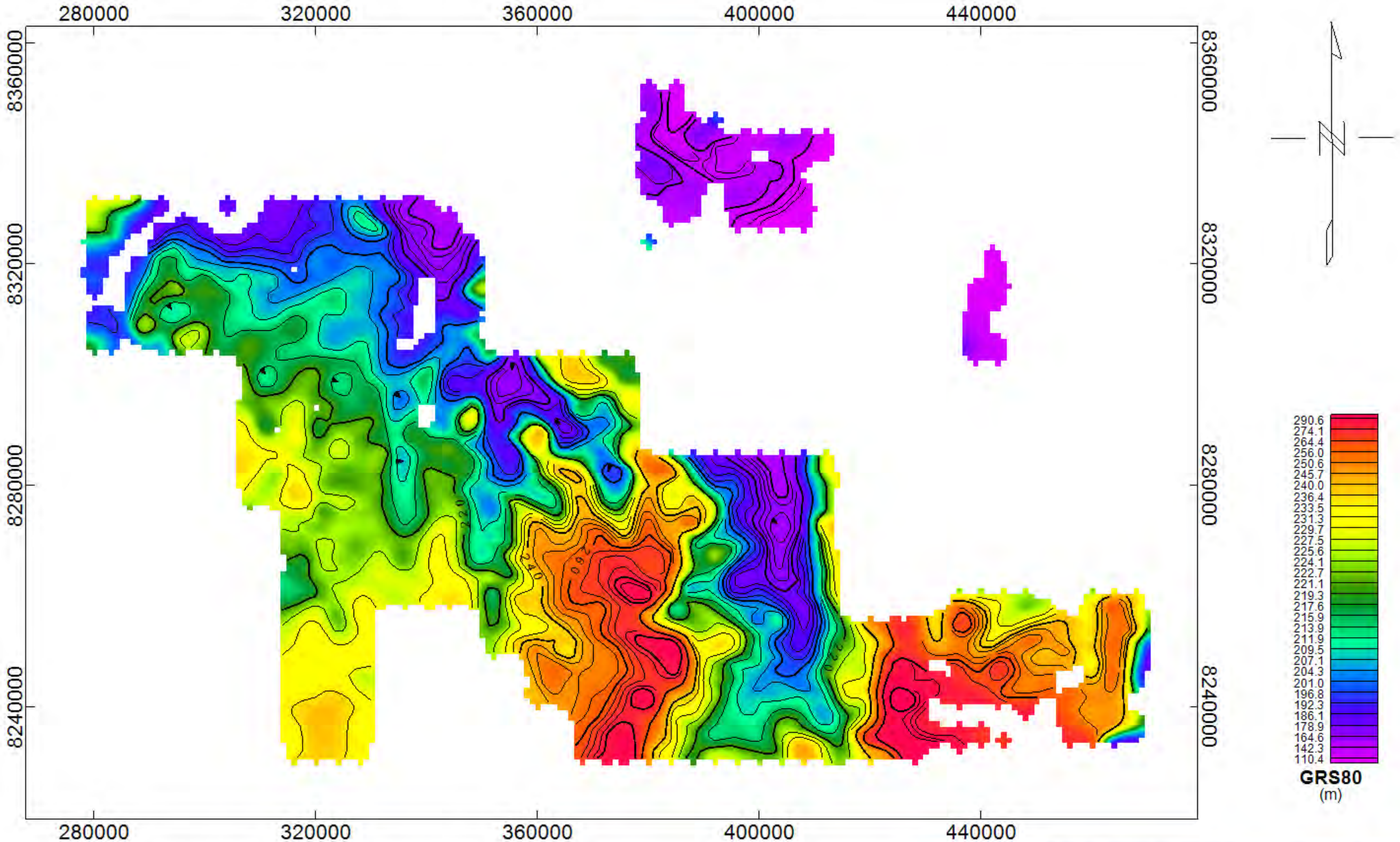

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(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP153 & EP154 Gravity Surveys

Pseudocoloured Image of GNSS Derived Elevation (GRS80)
Shade = None, Contours = 5.0m, Histo = Equalised

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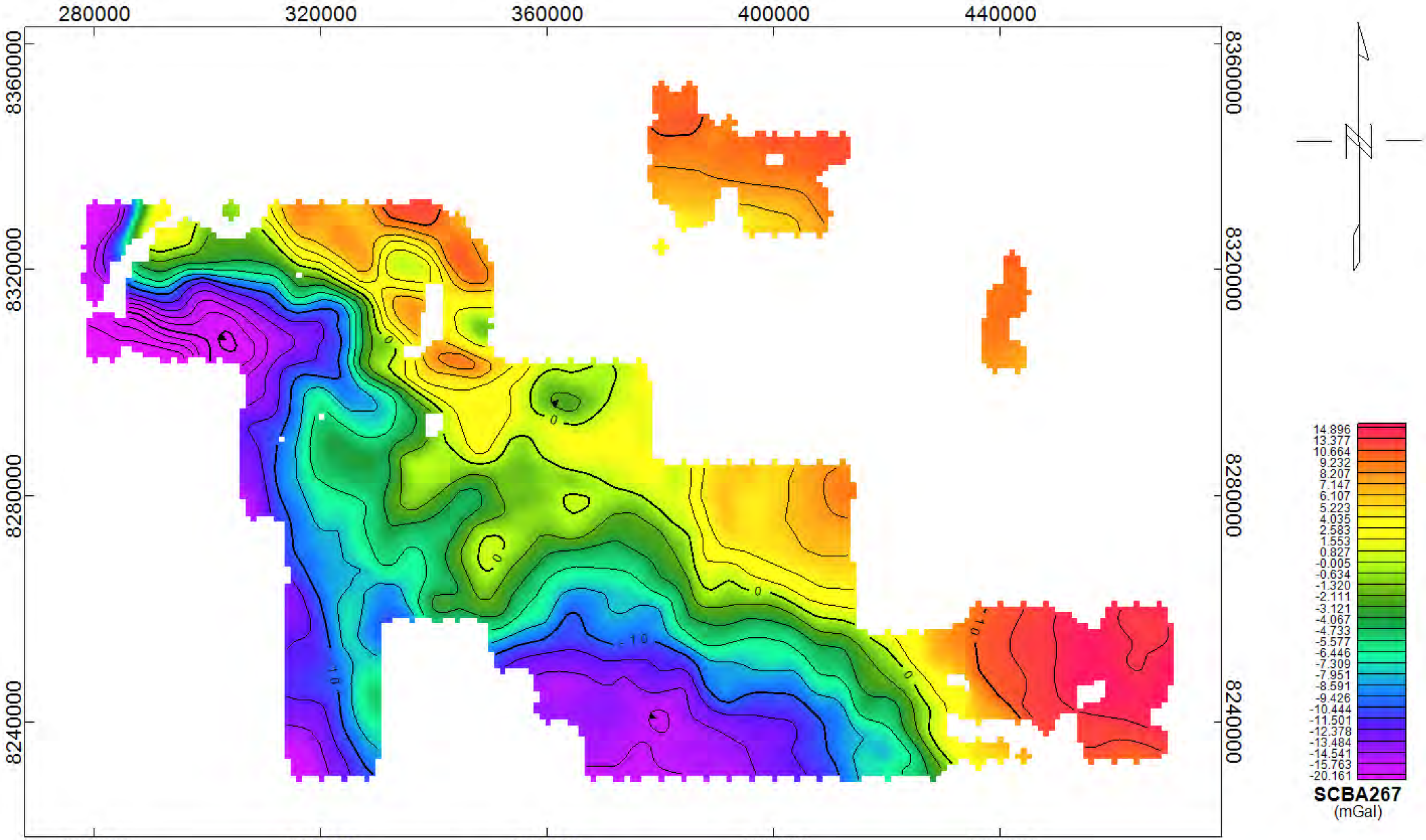

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(meters)

WGS 84 / MGA zone 53

HANCOCK PROSPECTING PTY LTD

P2015074 EP153 & EP154 Gravity Surveys

Pseudocoloured Image of SC Bouguer Anomaly (2.67gm/cc)
Shade = None, Contours = 2.0mGal, Histo = Equalised

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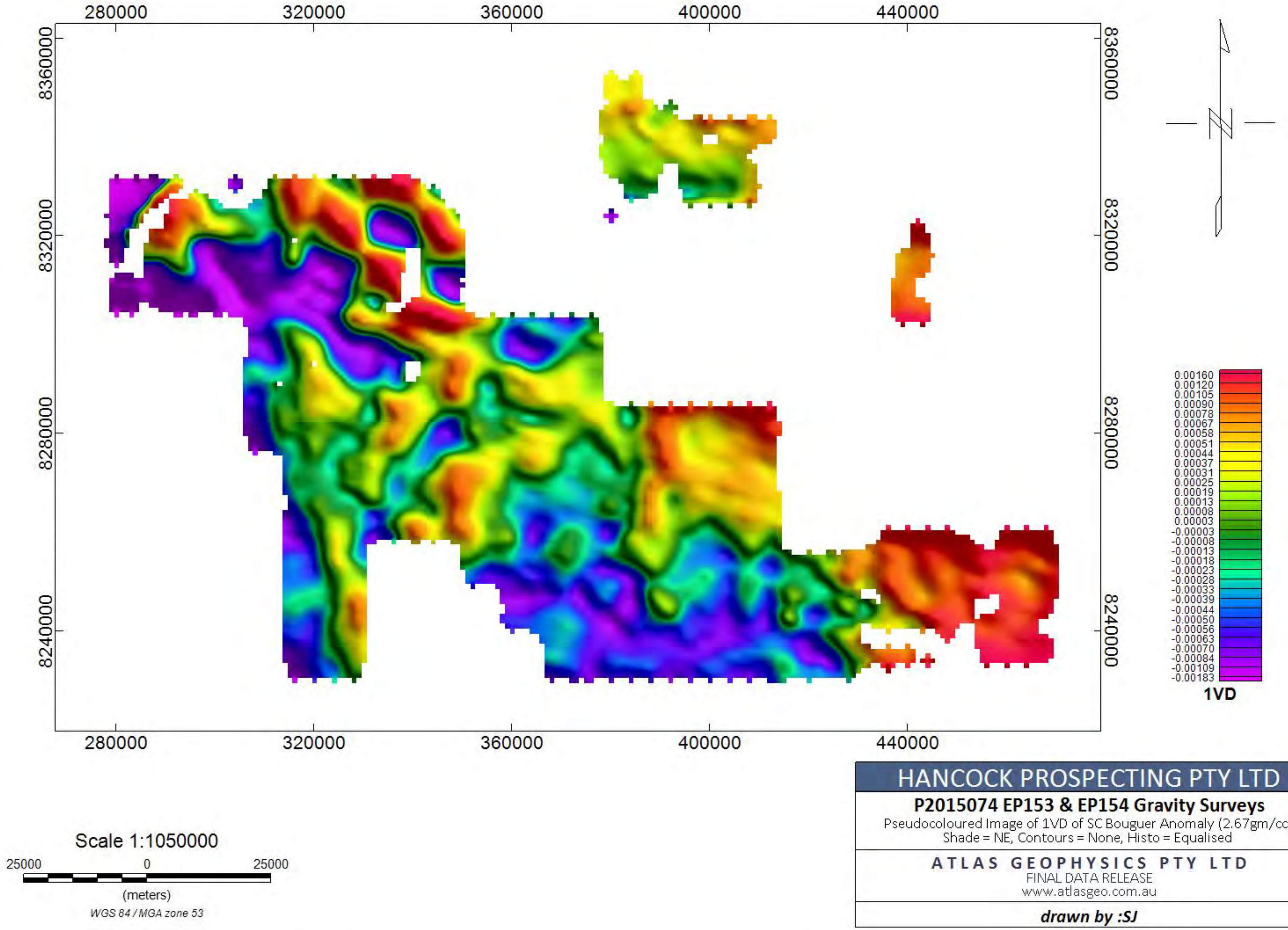

HANCOCK PROSPECTING PTY LTD

P2015074 EP153 & EP154 Gravity Surveys

Pseudocoloured Image of 1VD of SC Bouguer Anomaly (2.67gm/cc)
Shade = NE, Contours = None, Histo = Equalised

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APPENDIX C
GNSS Control Information

201507400001 Alexandria Downs Station
0001 -19 03 20.83517 136 42 32.72259 273.072 234.233 GDA94
0001 -19 03 20.83516 136 42 32.72253 273.067 234.228 GDA94
0001 -19 03 20.83519 136 42 32.72259 273.069 234.230 GDA94

GDA94AVE
-19 3 20.8352
136 42 32.7226

-19.05578756
136.70908961

GRS80HT
273.069

AHDHT
234.230

N
38.839

MGA53
679842.594
7892123.841

AMG53
679714.311
7891953.601

201507400003 Larrimah GNSS Base
0002 -15 34 22.47537 133 12 52.33237 230.400 186.692 GDA94
0002 -15 34 22.47536 133 12 52.33238 230.403 186.695 GDA94
0002 -15 34 22.47532 133 12 52.33239 230.408 186.700 GDA94
0002 -15 34 22.47535 133 12 52.33232 230.423 186.715 GDA94

GDA94AVE
-15 34 22.4754
133 12 52.3324

-15.57290983
133.21453678

GRS80HT
230.409

AHDHT
186.701

N
43.708

MGA53
308543.282
8277504.982

AMG53
308413.548
8277336.262