Atlas Geophysics Memorandum M2017117

BFZ Gravity Survey

CSIRO

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APPENDICES

1.0 Project Brief

Project P2017117 involved the acquisition and processing of **7,473** new gravity stations over an area spanning from the coast of the Northern Territory north of Borroloola, 290 km south in to the Barkly Tablelands (Figure 1). Acquisition was completed on behalf of CSIRO, funded by the Northern Territory Geological Survey (NTGS) a part of the Creating Opportunities for Resources Exploration (CORE) initiative.

Atlas Geophysics completed the acquisition of the dataset with one, helicopter-borne gravity crew.

For the most part, stations were acquired using a 2km x 2km spacing (infilling previously acquired 4km x 4km) with selected traverses at acquired at 500m spacing. A small area was acquired at 1km x 1km for a private company. A number of stations where landing was difficult/unsafe were either offset or omitted.

Acquisition commenced on the 28th of September 2017 and was completed on the 26th of November 2017, with final data delivered shortly thereafter.

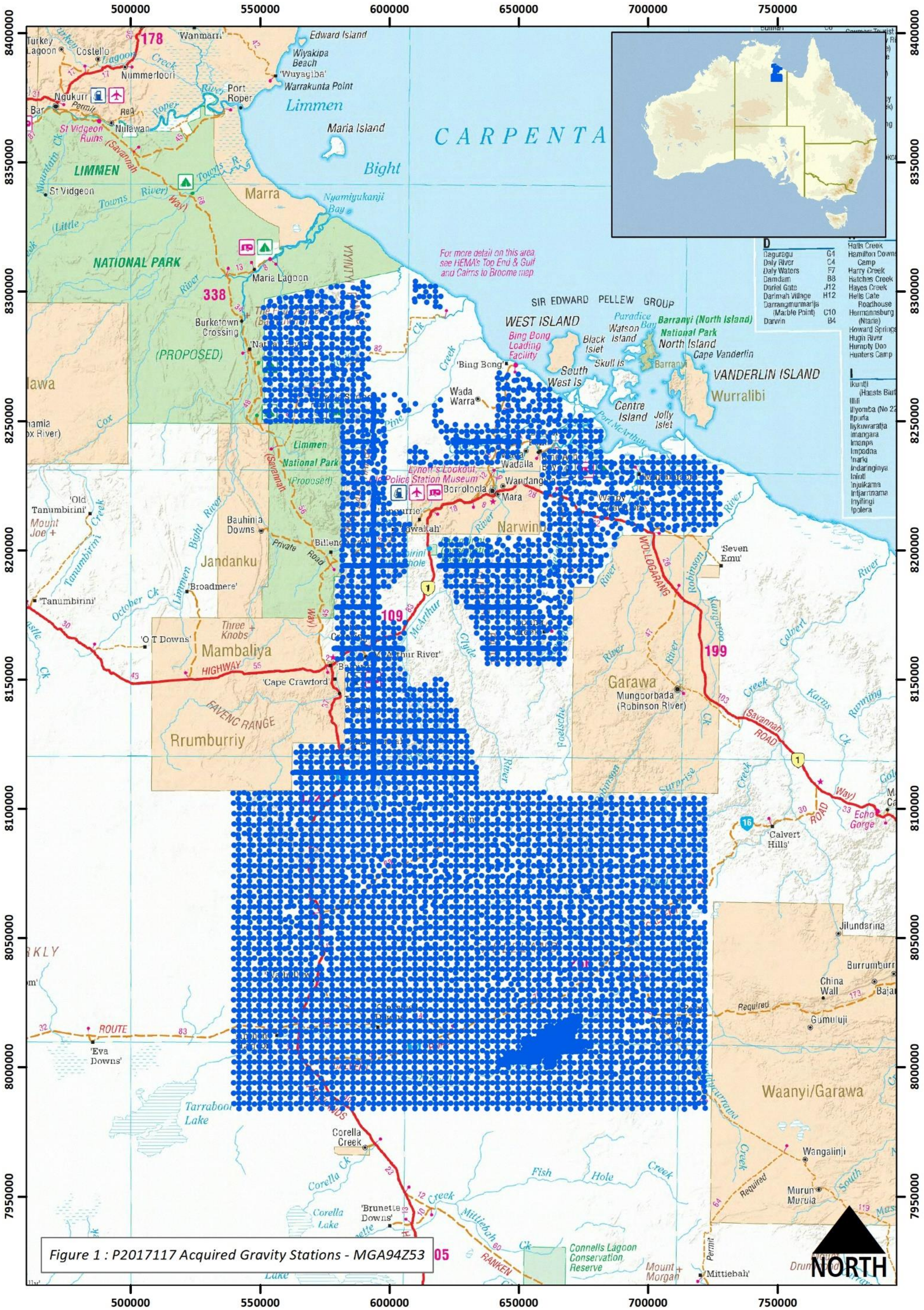


Figure 1 : P2017117 Acquired Gravity Stations - MGA94Z53
NORTH
CARPENTA
Limmen
Bight
Maria Island
SIR EDWARD PELLEW GROUP
WEST ISLAND
VANDERLIN ISLAND
North Island
LIMMEN
NATIONAL PARK
Borroloola
Garawa
Waanyi/Garawa
Mambaliya
Rrumburriy
Jandanku
Tarrabool Lake
Corella Creek
Connells Lagoon Conservation Reserve

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 1.000000)
- Two Navcom SF3040 GNSS Base Receivers.
- Two Navcom ANT3001R GNSS Rover Receivers
- One Leica System 1200 GNSS Backup Receiver

Ancillary equipment included:

- Two HP Laptop computer for data download and processing
- Garmin autonomous GPS receivers for navigation
- Garmin inReach personal satellite tracking units
- Iridium satellite phones for long distance communications
- Personal Protective Equipment for all personnel
- Batteries & battery chargers
- Survey consumables
- Tools, engineering and maintenance equipment for vehicle servicing
- First aid and survival kits
- Spare 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 validated the gravity meters scale factors to ensure reduction of the survey data produces correct Observed Gravities from measured dial reading values.

One existing and one new GNSS-gravity control stations were used to control all field observations throughout the survey: Existing base GRVGPS0068 “Borroloola Airstrip” was used when the crews were surveying around Borroloola while control station 201711700001 “Walhallow Airstrip”, was established and used when the crew completed the southern half of the survey out of Walhallow Station. 201711700001 was tied to the AAGD07 datum via ties to Australian Fundamental Gravity Network (AFGN) station 1964919066 and GRVGPS0068.

GNSS control was established and re-affirmed at the control stations using 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 GNSS 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 GNSS data using a Scintrex CG-5 gravity meter. 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. A total of **277** repeat readings representing **3.04%** of the survey were acquired for quality control purposes. Repeat readings were evenly distributed, where possible, on a time-basis throughout each of the gravity loops.

GNSS data were acquired with the rover receivers operating in post-process kinematic (PPK) mode with the GNSS sensor mounted on the body of the helicopter. Static data were logged at the GNSS control stations with a base receiver operating in post-process static (PPS) mode with the GNSS sensor mounted on a fixed 1.75m pole.

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.

GrafNav was used to transform the GNSS-derived WGS84 coordinates to GDA94 coordinates for each gravity station location. MGA coordinates were then derived by projecting the GDA94 geodetic coordinates with a Universal Transverse Mercator (UTM) transform using the appropriate zone. It should be noted that WGS84 and GDA94 coordinates (x, y, and z) are no longer roughly equivalent, with a difference in horizontal coordinates of greater than 1.0m and a difference in elevation of 90-100mm. GrafNav produced GDA94 ellipsoidal heights for each gravity station location; and elevations above the Australian Height Datum (AHD) were modelled using the AUSGEOID09 geoid model, with separations (N values) added to GDA94 ellipsoidal heights.

The resulting GrafNav data (output in Atlas Geophysics PPK standard format) were then imported into Atlas Geophysics Reduction and Interpretation Software (AGRIS) for QC and used in the reduction of the gravity data. A module built into AGRIS allows the user to examine data 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 were analysed for consistency and preliminary QC was performed to confirm that observations meet specification for standard deviation, reading rejection, temperature and tilt values. Once the data were verified the software averaged the multiple gravity readings and performed a merge with the previously QC-passed GNSS data. The software then applies 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 further applied to the dataset to produce Spherical Cap Bouguer Anomalies on the GDA94 transform of 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 (GU). 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.

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

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 GDA94 transformed 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 (GDA94 transformed 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 GDA94 transformed 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.

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

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 = $6.67428\cdot10^{-11}$m^{3}kg^{-1}s^{-2}
ρ rock density (2.67, 2.40 and 2.20 tm^{-3})
h elevation above the GDA94 transformed 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 GDA94 transformed 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

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

7.0 Gravity Results

The gravity survey was completed over **49** days of acquisition. An average acquisition rate of around **150-160** stations per day of production was achieved for the survey. The survey progressed well with small delays due to helicopter maintenance and moving the logistics base. A copy of the full production reports are 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 **0.041m** and the standard deviation of the gravity repeats at **0.029mGal**. 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 ASEG-GDF2 and standard Atlas format. Table 2 overleaf details the format of the final gravity database supplied. All fields are comma delimited.

Appendix B contains a plot of final station locations for each area and merged images of GNSS Derived Elevation (GDA94 transformed GRS80), Spherical Cap Bouguer Anomaly, and first vertical derivative of Spherical Cap Bouguer Anomaly which include historic data.

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	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
GDA94HT	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
OBSGAAGD07MGAL	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
GNSSBASE	GNSS 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.

APPENDIX A
Control Station Descriptions

GRVGPS0068 – Borroloola Airport Windsock

GEODETIC COORDS GDA94		GRID COORDINATES MGA Z53	
Latitude (DD MM SS)	16° 04' 15.22009"S	*Easting*	639,444.453
Longitude (DD MM SS)	136° 18' 13.27198"E	*Northing*	8,222,783.426
Ellipsoidal Height	64.8804	*Orthometric Height (AUSGEOID09)*	16.307

OBSERVED GRAVITY		Established: 01/09/2009
AAGD07 gu	9784290.11	

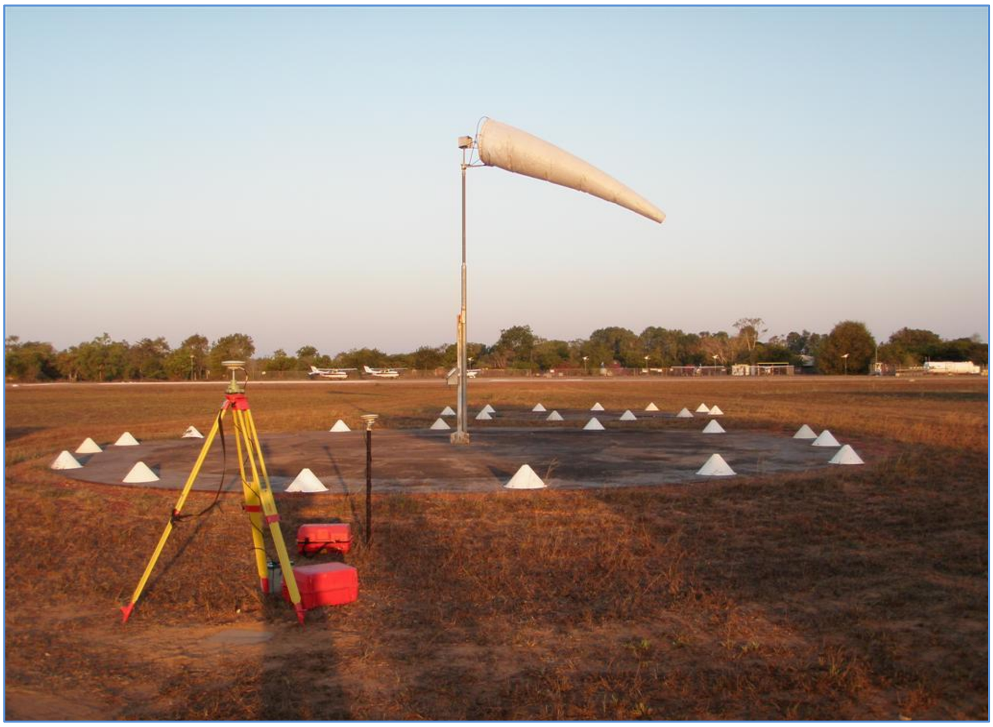
Occupation Method/Location Details

The GNSS control point consists of a dumpy steel picket driven into the ground to a height of 10cm above ground level. The gravity control point consists of a small concrete slab (30cm square) concreted into the ground, opposite the GNSS 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 both control points.

Gravity Control was established via multiple ABA and ABABA loops to AFGN gravity base station 1964919066 located at the Mallapunyah Springs A/S Windsock. Expected accuracy would be better than 0.01 mGal.

GNSS Control was re-affirmed using AUSPOS. Three separate 10 hour sessions were submitted to AUSPOS's online processing system where returned coordinates were accurate to better than 0.01m.

This control station is located approximately 3m west of the markers surrounding the windsock at Borroloola airport. The windsock is located near to the helipad, 70m west from the shoulder of the airstrip (northern end) and directly opposite the apron. The airport is located south of the town and operators should seek permission from the airport manager before accessing the station.



Photograph of Control Station GRVGPS0068 and surrounds

201711700001 – Walhallow Airstrip

GEODETIC COORDS GDA94		GRID COORDINATES MGA Z53	
Latitude (DD MM SS)	17° 46' 50.45394"S	*Easting*	570,048.666
Longitude (DD MM SS)	135° 39' 39.13160"E	*Northing*	8,033,955.345
Ellipsoidal Height	269.399	*Orthometric Height (AUSGEOID09)*	227.541

OBSERVED GRAVITY		Established: 16/10/2017
AAGD07 gu	9784444.66	

Occupation Method/Location Details

The GNSS control point consists of a dumpy steel star picket driven into the ground to a height of 10cm above ground level. The control station is witnessed by a star picket with a plaque. The GNSS and gravity location are within 0.5m of the picket.

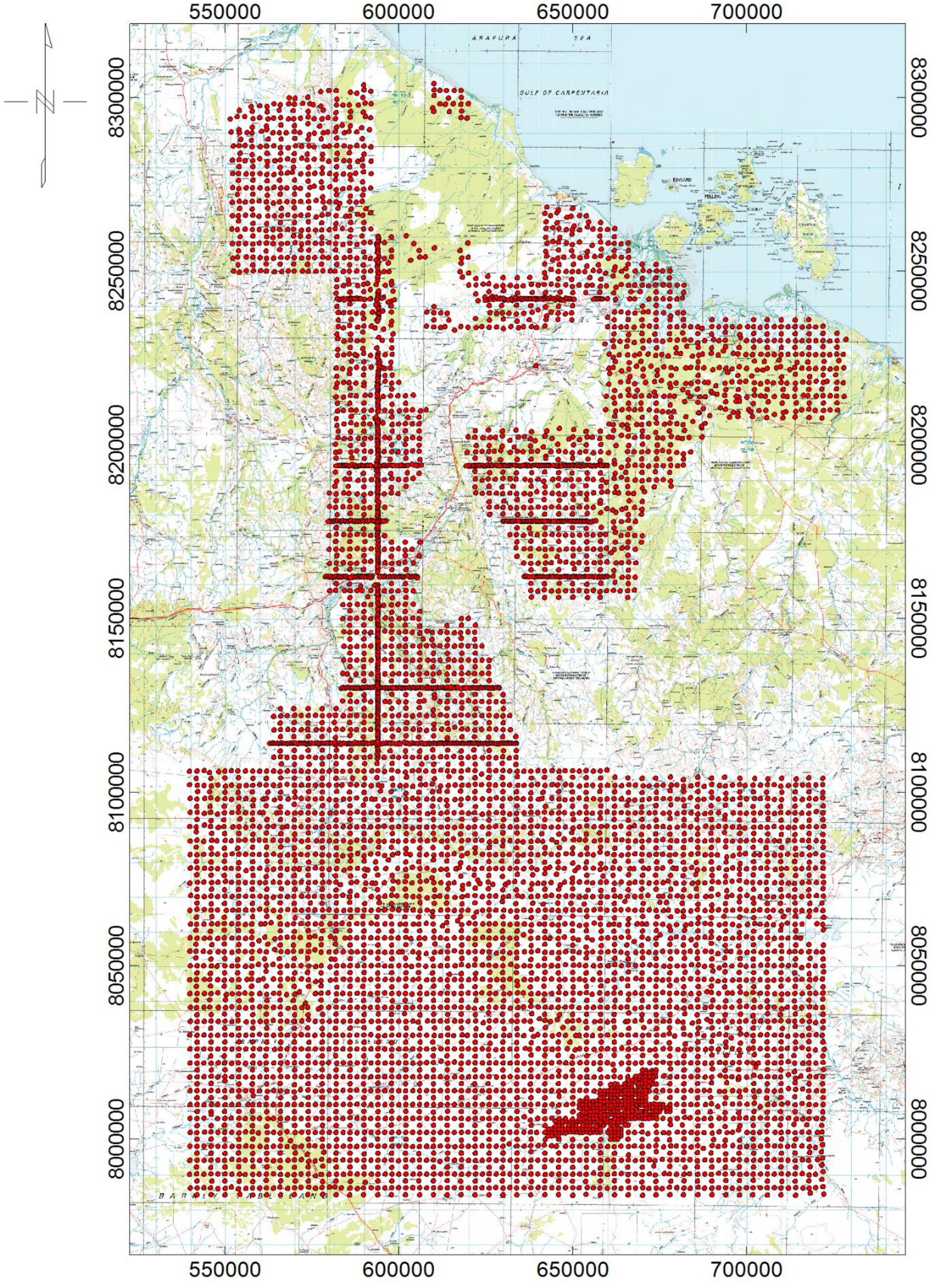
Gravity Control was established via multiple ABA tie loops with the project meter to AFGN control station 1964919066 “Mallapunyah Springs” & Atlas Geophysics station GRVGPS0068 “Borroloola Airport Windsock”. Expected accuracy would be better than 0.01 mGal.

GNSS Control was established using AUSPOS. Multiple, 10 hour sessions were submitted to Geoscience Australia’s online processing system, AUSPOS. Returned coordinates were accurate to better than 0.01m.

The control station is located on the southern side of the Walhallow Station Air Strip, near the sheds.

Photograph of Control Station 201711700001 and surrounds

APPENDIX B
Plots and Imagery



Scale 1:1717700

25000 0 25000

(meters)

GDA94 / MGA zone 53

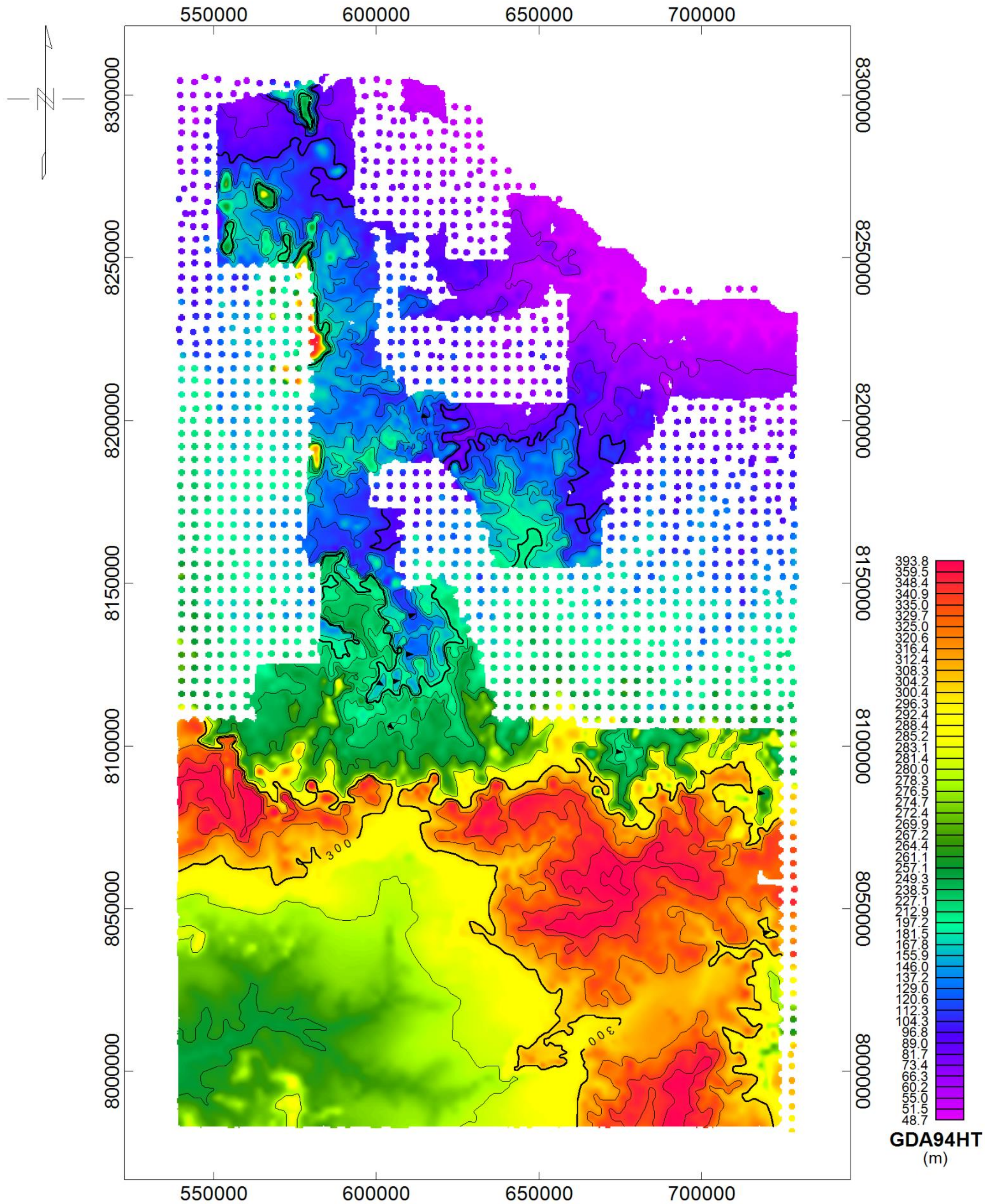
CSIRO

P2016117 BFZ GRAVITY SURVEY

Plot of Gained Stations
2km x 2km Infill, 1km x 1km infill and 500m Traverses

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

drawn by : RNA



CSIRO

P2016117 BFZ GRAVITY SURVEY

Pseudocoloured Image of GNSS Derived Elevation (GDA94HT)
Shade = None, Contours = 20.0m, Histo = Equalised

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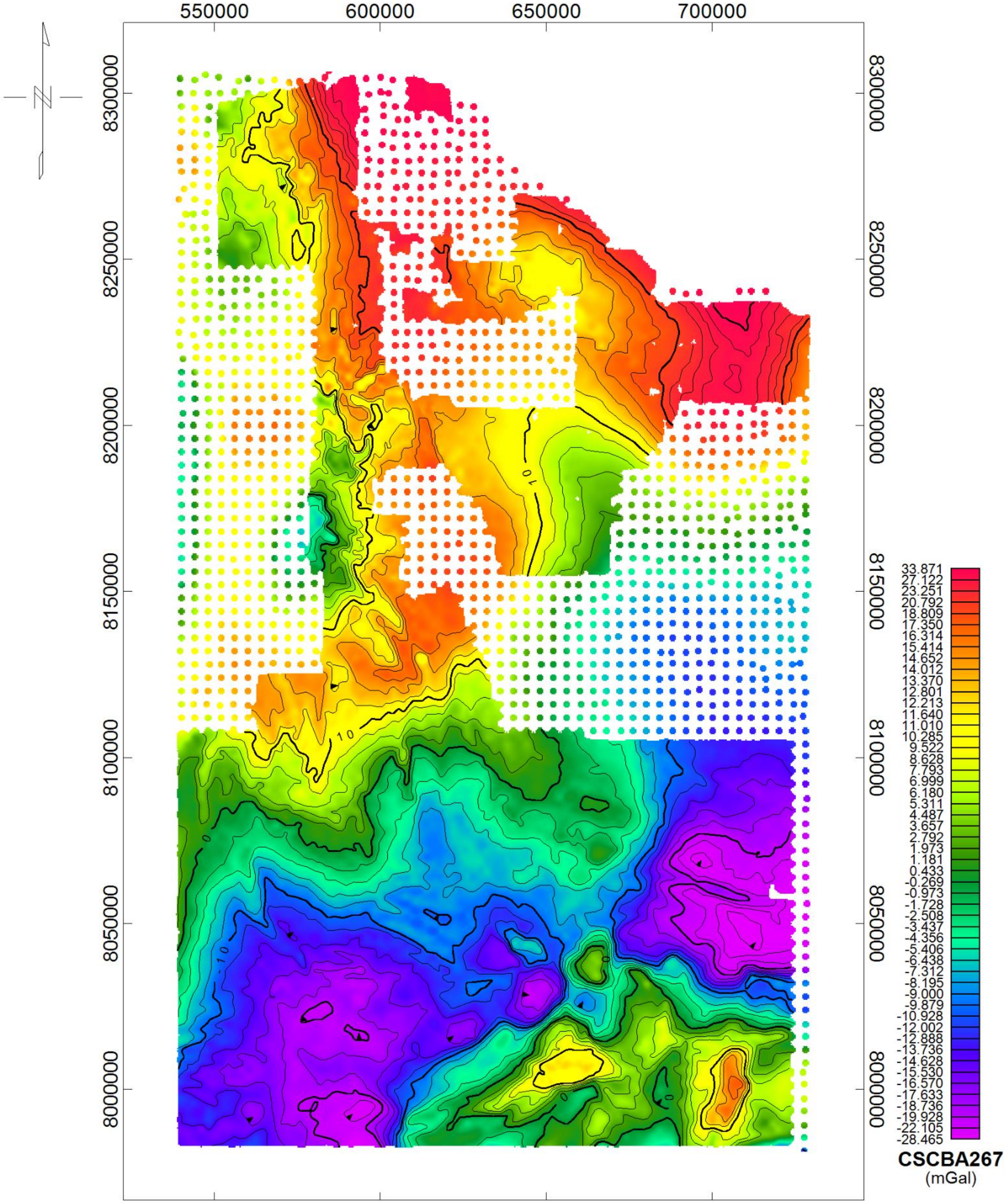
drawn by : RNA



Scale 1:1717700

25000 0 25000

(meters)

GDA94 / MGA zone 53

CSIRO

P2016117 BFZ GRAVITY SURVEY

Pseudocoloured Image of Complete SC Bouguer Anomaly (2.67gm/cc)

Shade = None, Contours = 2.0mGal, Histo = Equalised

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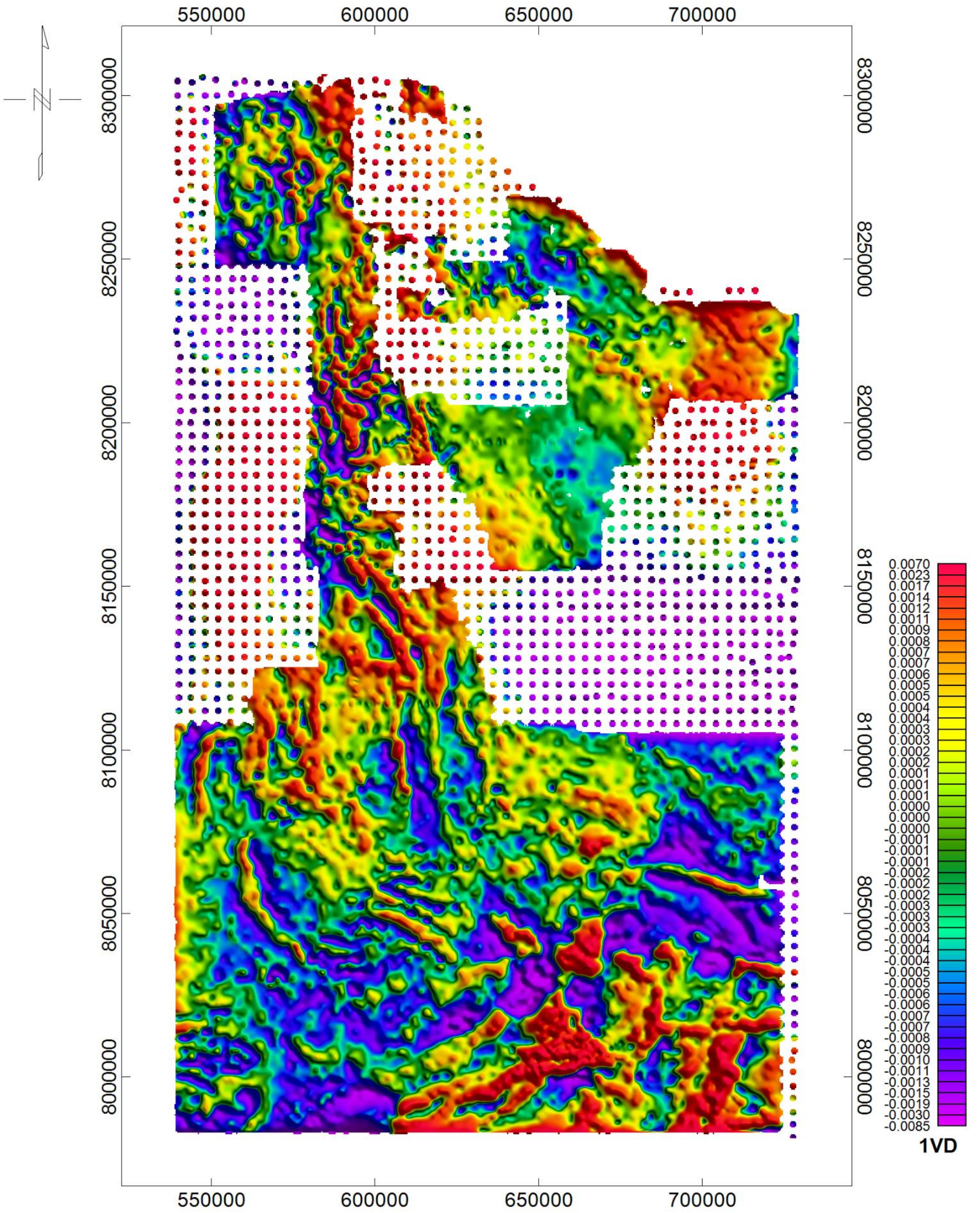

Scale 1:1717700

25000 0 25000

(meters)

GDA94 / MGA zone 53

CSIRO

P2016117 BFZ GRAVITY SURVEY

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

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drawn by : RNA

APPENDIX C
GNSS Control Information

201711700001 Walhallow Airstrip
0001 -17 46 50.45392 135 39 39.13154 269.397 227.331 GDA94
0001 -17 46 50.45394 135 39 39.13167 269.400 227.333 GDA94

GDA94AVE
-17 46 50.45394
135 39 39.13160

-17.78068165
135.66086989

GDA94HT
269.399

AHDHT
227.332

N
42.067

MGA53
570048.666
8033955.345

AMG53
569920.072
8033785.645

201711700100 Borroloola Back Up GNSS Base
0100 -16 04 15.29184 136 18 13.19647 64.911 16.184 GDA94
0100 -16 04 15.29184 136 18 13.19643 64.910 16.182 GDA94
0100 -16 04 15.29193 136 18 13.19642 64.915 16.188 GDA94

GDA94AVE
-16 04 15.29188
136 18 13.19645

-16.07091441
136.30366568

GDA94HT
64.912

AHDHT
16.185

N
48.727

MGA53
639442.195
8222781.234

AMG53
639313.961
8222612.272

201711700109 Walhallow Field Base 109
0109 -16 36 03.68930 135 52 56.94266 117.076 70.645 GDA94

GDA94AVE
-16 36 3.68932
135 52 56.94265

-16.60102481
135.88248407

GDA94HT
117.076

AHDHT
70.645

N
46.431

MGA53
594134.082
8164373.602

AMG53
594005.626
8164204.411

GRVGPS0068 Borroloola Air Strip
0068 -16 04 15.22003 136 18 13.27195 64.878 16.150 GDA94
0001 -16 04 15.22003 136 18 13.27195 64.878 16.150 GDA94
0068 -16 04 15.22019 136 18 13.27200 64.885 16.158 GDA94

GDA94AVE
-16 04 15.22009
136 18 13.27198

-16.07089447
136.30368666

GDA94HT
64.880

AHDHT
16.153

N
48.727

MGA53
639444.453
8222783.426

AMG53
639316.220
8222614.464