AUSTRALIAN NATIONAL GRAVITY DATA

ACKNOWLEDGMENT

Geoscience Australia would like to acknowledge the enormously valuable contribution made by all state and territory Geological Surveys, private companies, educational institutions and other research organisations in helping to produce and maintain a National Gravity Database of over 1 400 000 stations. The data contributed by these organisations make up a large component of the Australian National Gravity Database. Their inclusion considerably enhances the value of the Australian National Gravity Database to the geoscientific community.

DATA FORMAT

The gravity data are supplied in either an ASCII file or INTREPID database format and consist of open file data from the Australian National Gravity Database of over 1,400,000 gravity station records.

All onshore gravity station records have the survey number, station number, latitude, longitude, ellipsoid ground elevation, geoid ground elevation, geoid-ellipsoid separation (N-Value), observed gravity, ellipsoid gravity meter height, geoid gravity meter height, Free Air Anomaly and Bouguer Anomaly fields filled. Some gravity stations have an "informal name", indicating bench mark number, isogal station, etc. Where terrain corrections have been calculated, they have been included in the gravity station record but **NOT APPLIED** to the Bouguer anomaly. If known the density used in the terrain correction is listed immediately following the terrain correction value and method. All onshore Bouguer anomalies are calculated using a density of 2.67 tonne/cubic metre.

All offshore gravity station records have the survey number, station number, latitude, longitude, water depth (located in the GNDELEV field), geoid-ellipsoid separation (N-Value), observed gravity, gravity meter height, Free Air Anomaly and Bouguer Anomaly fields filled. Some gravity stations have an "informal name" field filled in.

GRAVITY DATA FIELD DESCRIPTION

Selected Field	Delivered Field	Description	Units	Datum	Null Value
Survey_Number	**SURVEYID**	Project number unique to each survey			N/A
Observation_Number	**OBSNO**	Oracle defined unique number			N/A
Station_Number	**STATIONNO**	Station number (includes surveyid)			N/A
Station_Name	**STATIONNAME**	Name of station			null
Station_Type	**STATIONTYPE**	Type of station eg absolute, base, control, ground, helicopter etc			N/A
Longitude	**DLONG**	Longitude	decimal degrees	GDA94	N/A
Latitude	**DLAT**	Latitude (negative) for southern hemisphere	decimal degrees	GDA94	N/A
Location_Units	**LOCUNITS**	Location units (degrees, decimal degrees)			N/A
Geodetic_Datum	**GEODETIC_DATUM**	Position datum		GDA94	N/A
Method_of_Location	**LOCMETH**	Method used to position the station eg digitised from map, GPS, etc			null
Accuracy_of_Location	**LOCACC**	Estimate of accuracy of the position	metres		N/A
Units_of_Location_Accuracy	**LOCCACCUOM**	Units of the estimated accuracy of the position	metres		N/A
Method_of_Location_Accuracy	**LOCACCMETHOD**	Method used to determine the accuracy of the position	1 to 7		N/A
Geoid_Ground_Elevation	**GNDELEV**	Elevation of ground at the station referenced to the Geoid	metres	AHD	N/A
Units_of_Geoid_Gnd_Elev	**GNDELEVUNITS**	Units of the ground elevation	metres	AHD	N/A
Geoid_Gnd_Elev_Datum	**GNDELEVDATUM**	Ground elevation datum		AHD	N/A

Method_of_Geoid_Gnd_Elev	**GNDELEVMETH**	Method used to define ground elevation eg barometer, map, GPS etc			null
Geoid_Gnd_Elev_Type	**GNDELEVTYPE**	Ground elevation description eg land, marine, underground etc			N/A
Accuracy_of_Geoid_Gnd_Elev	**GNDELEVACC**	Estimate of accuracy of the ground elevation.	metres		N/A
Units_of_Geoid_Gnd_Elev_Acc	**GNDELEVACCUOM**	Units of the estimated accuracy of the ground elevation.	metres		N/A
Method_of_Geoid_Gnd_Elev_Acc	**GNDELEVACCMETHOD**	Method used to determine the accuracy of the ground elevation	1 to 7		N/A
Observed_Gravity	**GRAV**	Observed gravity value	μms^{-2}	AAGD07	N/A
Units_of_Observed_Gravity	**GRAVUNITS**	Units of the observed gravity	μms^{-2}	AAGD07	N/A
Observed_Gravity_Datum	**GRAVDATUM**	Observed gravity datum		AAGD07	N/A
Gravity_Meter_Make	**GRAVMETH**	Gravity meter used eg LaCoste Romberg, Scintrex etc			null
Accuracy_of_Observed_Gravity	**GRAVACC**	Estimate of accuracy of the observed gravity	μms^{-2}		N/A
Units_of_Observed_Grav_Acc	**GRAVACCUOM**	Units of the estimated accuracy of the observed gravity	μms^{-2}		N/A
Method_of_Observed_Grav_Acc	**GRAVACCMETHOD**	Method used to determine the accuracy of the observed gravity	1 to 7		N/A
Gravity_Meter_Serial_Number	**METERID**	Gravity meter serial number			null
Geoid_Gravity_Meter_Height	**METERHGT**	Geoid height of the gravity meter at observation point	metres	AHD	N/A
Units_of_Geoid_Meter_Hgt	**METERHGTUNITS**	Units of the gravity meter height referenced to the Geoid	metres		N/A

Method_of_Geoid_Meter_Hgt	**METERHGTMETH**	Method used to obtain height of gravity meter			null
Error_of_Geoid_Meter_Hgt	**METERHGTERR**	Estimate of accuracy of meter height	metres		N/A
Units_of_Geoid_Meter_Hgt_Error	**METERHGTERRUOM**	Units of the estimated accuracy of the gravity meter height	metres		N/A
Method_of_Geoid_MeterHgt_Error	**METERHGTERRMETHOD**	Method used to obtain accuracy of the meter height error	1 to 7		N/A
Terrain_Correction	**TC**	Terrain Correction	μms^{-2}		9999
Units_of_Terrain_Correction	**TCUNITS**	Units of the Terrain Correction	μms^{-2}		null
Method_of_Terrain_Correction	**TCMETH**	Method used to calculate Terrain Correction eg Hammer by hand, INTREPID software etc			null
Terr_Corr_Density_used	**TCDENSITY**	Density used in the Terrain Correction	tonne $metre^{-3}$		9999
Error_in_Terrain_Correction	**TCERR**	Terrain Correction accuracy estimate	μms^{-2}		9999
Units_of_Terr_Corr_Error	**TCERRUOM**	Units of the estimated accuracy of the Terrain Correction	μms^{-2}		null
Method_of_Terr_Corr_Error	**TCERRMETHOD**	Method used to calculate the accuracy of the TC error	1 to 7		9999
Observation_Date	**OBSDATE**	Date observation was made		DATE	31-DEC-9999
Processing_Date	**CALCDATE**	Date gravity data were processed		DATE	31-DEC-9999
Estimate_of_Stn_Reliability	**RELIAB**	Estimate of the overall reliability of the reading (0 unreliable, 9 high reliability)	0 to 9		9999
Comments	**COMMENTS**	Comments made when observing the station			comment is null

Ellipsoid_Ground_Height	**ELLIPSOIDHGT**	Elevation of ground at the station referenced to the Ellipsoid	metres	GRS80	N/A
Units_of_Ellipsoid_Ground_Hgt	**ELLIPSOIDHGTUNITS**	Units of the ellipsoid height	metres		N/A
Ellipsoid_Gnd_Hgt_Datum	**ELLIPSOIDHGTDATUM**	Ellipsoid height datum		GRS80	N/A
Method_of_Ellipsoid_Gnd_Hgt	**ELLIPSOIDHGTMETH**	Method used to define ellipsoid height eg GPS, post processing software, AHD + NVALUE etc			null
Accuracy_of_Ellipsoid_Gnd_Hgt	**ELLIPSOIDHGTACC**	Estimate of accuracy of the ellipsoid height	metres		N/A
Units_of_Ellipsoid_Gnd_Hgt_Acc	**ELLIPSOIDHGTACCUOM**	Units of the estimated accuracy of the ellipsoid height.	metres		N/A
Method_of_Ellipsoid_GndHgt_Acc	**ELLIPSOIDHGTACCMETHOD**	Method used to determine the accuracy of the ellipsoid height	1 to 7		N/A
Ellipsoid_Hgt_of_Gravity_Meter	**ELLIPSOIDMETERHGT**	Ellipsoid height of the gravity meter at observation point	metres	GRS80	N/A
Units_of_Ellipsoid_Meter_Hgt	**ELLIPSOIDMETERHGTUNITS**	Units of the gravity meter ellipsoid height	metres		N/A
Method_of_Ellipsoid_Meter_Hgt	**ELLIPSOIDMETERHGTMETH**	Method used to obtain ellipsoid height of gravity meter		GRS80	N/A
Error_of_Ellipsoid_Meter_Hgt	**ELLIPSOIDMETERHGTERR**	Estimate of the accuracy of gravity meter ellipsoid height	metres		null
Units_of_Ellips_Meter_Hgt_Err	**ELLIPSOIDMETERHGTERRUOM**	Units of the estimated accuracy of the gravity meter ellipsoid height	metres		N/A
Method_of_Ellips_Meter_Hgt_Err	**ELLIPSOIDMETERHGTERRMETHOD**	Method used to obtain accuracy of the gravity meter ellipsoid height error	1 to 7		N/A
Geoid_Ellipsoid_Separation	**NVALUE**	Geoid-ellipsoid	metres	AUSGEOID98	N/A

		separation at the observation point.			
Units_of_G_E_Separation	**NVALUEUNITS**	Units of the geoid-ellipsoid separation.	metres		N/A
Geoid_used_in_G_E_Separation	**NVALUEGEOID**	The geoid used to obtain N-Value.		AUSGEOID98	N/A
Ellips_used_in_G_E_Separation	**NVALUEELLIPSOID**	The ellipsoid used to obtain N-Value.		GRS80	null
Method_used_in_G_E_Separation	**NVALUEMETH**	Method used to define N-Value eg GPS, post survey software (WINTER) etc			null
Accuracy_of_G_E_Separation	**NVALUEACC**	Estimate of accuracy of the N-Value	metres		N/A
Units_of_G_E_Separation_Acc	**NVALUEACCUOM**	Units of the estimated accuracy of the N-Value	metres		N/A
Method_of_G_E_Separation_Acc	**NVALUEACCMETHOD**	Method used to obtain accuracy of the N-Value.	1 to 7		N/A
Ellipsoid_Freeair_Anomaly	**FREEAIR**	Free Air Anomaly value (see below) using ellipsoidal height for calculations	μms^{-2}	AAGD07	N/A
Spherical_Cap_Bouguer_Anomaly	**BOUGUER**	Bouguer Anomaly at 2.67 tonne $metre^{-3}$ (see below) using ellipsoidal height for calculations	μms^{-2}	AAGD07	N/A
Geoidal_Freeair_Anomaly	**GEOIDAL_FREEAIR**	Free Air Anomaly value (see below) using geoidal elevation for calculations	μms^{-2}	AAGD07	N/A
Infinite_Slab_Bouguer_Anomaly	**GEOIDAL_BOUGUER**	Bouguer Anomaly at 2.67 tonne $metre^{-3}$ (see below) using geoidal elevation for calculations	μms^{-2}	AAGD07	N/A
Gridding_Flag	**GRIDFLAG**	Flag indicates whether a gravity observation has been included in the creation of gravity grids	N/A	N/A	N/A

		by Geoscience Australia. A zero value indicates the observation has not been used and a value of one indicates it has been.			

DATA QUALITY – LINEAGE

The Australian National Gravity Database contains over 1,400,000 point data values in the area extending from 8°S to 48°S and 108°E to 162°E. All data are provided in GDA94 coordinates. The database is regularly updated as Geoscience Australia acquires additional gravity data.

The parameters of the point located data are:

Station spacing:	various from 10 m to 11 km
Projection:	Geodetic in latitude and longitude
Null value:	"null", "9999" or "31-DEC-9999"

DATA QUALITY – POSITIONAL ACCURACY

Highly variable, depending on the age of the individual surveys that comprise this data set.
Prior to 1995 (approximately), data were collected using various techniques to determine position such as:

- manual scaling from base maps (100's m error);
- digitising from base maps derived from air photo station plots (100's m error); or
- optical surveying methods (metre accuracy).

Post 1995 most surveys were acquired using differential GPS with sub metre accuracy.

Vertical accuracy is highly variable too, depending on the age of the survey.
Prior to the use of differential GPS station heights were determined by:

- estimating heights from a topographic map (10's metre error);
- using barometric techniques (metre errors); or
- optical surveying techniques (sub metre accuracy).

Differential GPS gives centimetre accuracy.

DATA QUALITY – ATTRIBUTE ACCURACY

Highly variable depending on the age of the individual surveys that comprise this dataset.
Modern surveys use LaCoste Romberg or Scintrex gravity meters which have an accuracy of 0.01 μms^{-2} (micrometres per second squared).
Earlier surveys used older style quartz spring meters with a lower accuracy (approximately 1.0μms^{-2}).

DATA QUALITY – ERROR AND ACCURACY METHODS

The value given in the fields; LOCACCMETHOD, GNDELEVACCMETHOD, METERHGTERRMETHOD, GRAVACCMETHOD, TCERRMETHOD, ELLIPSOIDHGTACCMETHOD, ELLIPSOIDMETERHGTERRMETHOD and NVALUEACCMETHOD indicates the method used to determine the accuracy or error of the location value, ground elevation value, meter height value, observed gravity value, terrain correction value, ellipsoid height value, ellipsoid meter height value or N-Value.

METHOD NO DESCRIPTION

1………………Accuracy value taken as reported in Operations/Acquisition Report or reported metadata.
2………………Accuracy value taken as reported in Recomputation Report after reprocessing at a later date.
3………………Assigned accuracy value based on reported method/equipment used to measure the quantity.
4………………Assigned accuracy value based on assumed method/equipment used to measure the quantity.
5………………Assigned accuracy value based on survey era.
6………………Assigned accuracy value based on analysis of the external network adjustment errors.
7………………Accuracy value previously entered into Oracle pre Sept 2004.

DATA QUALITY – OVERALL DATA VALIDITY

RELIAB NO is the value assigned to a gravity observation indicating the level of confidence in the station's overall accuracy. The higher the value the greater the level of confidence in its accuracy.

RELIAB NO	DESCRIPTION
0	Unreliable data which should not be used pending remedial action.
1	Insufficient information to accurately classify but still regarded as reliable data.
2	Poorly controlled data which should be used cautiously.
3	Data with weak gravity, position and elevation control.
4	Data with moderate gravity, position and elevation control.
5	Documented gravity ties, levelled elevations and accurately scaled positions.
6	A point occupied once with well defined position and elevation.
7	Multiple occupations at a point with well defined position and elevation.
8	Multiple measurements at a point with accurate position and elevation.
9	Data measured numerous times with absolute, geodetic or first order precision.

DATUMS

The gravity data as supplied are based on the Australian Absolute Gravity Datum 2007 (AAGD07). This new datum supercedes the previous ISOGAL84 datum. To convert observed gravity values from ISOGAL84 to AAGD07, the following formula can be used:

$$g_{(AAGD07)} = g_{(ISOGAL84)} - 0.78\ \mu ms^{-2}$$

The gravity unit used is μms^{-2} (micrometres per second squared). The height data are given in metres above the ellipsoid. Station positions are given in the geodetic datum GDA94.

GRAVITY DATA PROCESSING

The processing of the gravity data used the following formulae:

(i) normal (theoretical) gravity used the closed form of the 1980 international gravity formula (Moritz, 1980). This is

$$\gamma = \gamma_e((1 + k\sin^2\theta)/\sqrt{(1- e^2\sin^2\theta)})$$

where:

γ = normal or theoretical gravity (G_n);
γ_e = 9 780 326.7715 micrometres/sec/sec = normal gravity at the equator;
k = 0.001 931 851 353 = derived constant;
e^2 = 0.006 694 380 022 90 = first eccentricity;
θ = geodetic latitude in degrees.

This becomes:

$$G_n=\gamma =9780326.7715((1+0.001931851353(\sin^2\theta)/(SQRT(1-0.0066943800229(\sin^2\theta))) \text{ in } \mu ms^{-2}$$

(ii) an atmospheric correction was applied to the normal (theoretical) gravity to correct for the gravity effect of the atmosphere. This correction is **SUBTRACTED** from the theoretical gravity value calculated from the equation above.
The atmospheric gravity effect is approximated using the following equation (Wenzel, 1985):

$$atmos\_corr = \delta g_{atm} = 8.74 - 0.00099*h + 0.0000000356*h^2$$

Where h = ellipsoid height in metres and the units for atmospheric correction are in micrometres/sec/sec.

(iii) free air correction using the ellipsoid height and a second order approximation equation (Heiskanen and Mortiz, 1969):

$$\delta g_h = (-2\gamma_e/a)*[1 + f + m + (-3*f + ((5/2)*m))*\sin^2\phi]*h + (3\gamma_e/a^2)*h^2$$

where, for the GRS80 ellipsoid, these parameters have the following values or definitions:

γ = normal gravity for a point on the reference ellipsoid at latitude ϕ;
γ_h = normal gravity for a point at a height, h in metres above the ellipsoid;
a = 6,378,137 metres = the semi major axis;
b = 6,356,752.3141 metres = the semi minor axis;
f = 0.003 3528 106 81 18= the flattening;
γ_e = 9.780 3267715 metres/sec/sec = normal gravity at the equator;
GM = 3,986,005*10^8 m^3/sec/sec = is a geocentric gravitational constant;
ω = 7,292,115*10^{-11} radians/sec = angular velocity;
m = $\omega^2 a^2 b/GM$ = 0.003 449 786 003 08; and
h = height of gravity meter above the ellipsoid in metres.

This equation can be expressed as:

$$\text{Free Air correction (FAC)} = -(3.087691 - 0.004398 \sin^2\phi)*h + 7.2125*10^{-7}*h^2 \;;$$

The Free air Anomaly is given by;

Free Air Anomaly (FAA) = $G_{obs} - (G_n - \delta g_{atm})$ - FAC in μms^{-2}

Where
G_{obs} = observed gravity &
δg_{atm} = atmospheric correction

(iv) Bouguer correction calculated using the closed form equation for the gravity effect of a spherical cap of radius 166.7 km (La Fehr 1991) based on a spherical Earth with a mean radius of 6,371.0087714 km, height relative to the ellipsoid, and a density of 2.67 t/m^3 (for solid earth).

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

where
π is pi;
G is the gravitational constant; = 6.67428 x 10^{-11} $m^3kg^{-1}s^{-2}$ (Mohr and Taylor 2001);
ρ is density in t/m^3 typically 2.67t/m^3;
h is the ellipsoid height in metres of the station.;
R = (R_o + h) the radius of the earth at the station and

R_o is the mean radius of the earth = 6,371.008 771 4 km GRS 80 value from Moritz;
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.
$k = \sin^2\alpha$;
$p = -6*\cos^2\alpha\sin(\alpha/2) + 4*\sin^3(\alpha/2)$;
$\delta = R_o/R$;
$m = -3*\sin^2\alpha\cos\alpha = -3*k*f$; Please Note this "m" is NOT the same as the parameter "m" in Free Air Correction above.
$n = 2*[\sin(\alpha/2) - \sin^2(\alpha/2)]$; and
$\alpha = S/R_o$, with S = Bullard B Surface radius = 166.735 km.

The Bouguer Anomaly is given by:

Bouguer_Anomaly (BA) = FAA - BC in μms^{-2}

CONSTANTS USED IN THE NEW FORMULAE IN THE AUSTRALIAN NATIONAL GRAVITY DATABASE

Name	**Use**	**Value**	**Source**
γ_e - normal gravity at equator	Theoretical Gravity Formula and Free Air Correction	9,780,326.7715 micrometres sec^{-2}	Moritz, 1980;
k - derived constant	Theoretical Gravity Formula	0.001 931 851 353	Moritz, 1980;
e^2 – first eccentricity	Theoretical Gravity Formula	0.006 694 380 022 90	Moritz, 1980;
a – the semi major axis	Free Air Correction	6,378,137 metres	Moritz, 1980;
b – the semi minor axis	Free Air Correction	6,356,752.3141 metres	Moritz, 1980;
f – the flattening	Free Air Correction	0.003 352 810 681 18	Moritz, 1980;
GM – a geocentric gravitational constant	Free Air Correction	3,986,005 x 10^8 m^3sec^{-2}	Moritz, 1980;
ω – angular velocity	Free Air Correction	7,292,115 x 10^{-11}	Moritz, 1980;

		radians/sec	
m - constant	Free Air Correction	0.003 449 786 003 08	Moritz, 1980;
G – gravitational constant	Bouguer Correction	6.67428 x 10^{-11} $m^3kg^{-1}sec^{-2}$	Mohr and Taylor, 2001 revised in March 2007; See web page reference for 2007 CODATA value.
R_0 – the mean radius of the earth	Bouguer Correction	6,371.0087714 km	Moritz, 1980;
S – Bullard B Surface Radius	Bouguer Correction	166.735 km	LaFehr 1991

Free Air Anomalies and Bouguer Anomalies are also provided using geoid heights and an infinite slab Bouguer correction. They are designated as Geoidal Free Air Anomaly and Geoidal Bouguer Anomaly respectively.
These anomalies are calculated with the formulae in use in GADDS prior to 5 February 2008 when the AAGD07 gravity datum was implemented. These formulae are:

(i) normal gravity based on the 1967 international gravity formula:
$Gn = 9780318.456*(1 + 0.005278895 \sin^2\phi + 0.000023462 \sin^4\phi)$

where ϕ represents degrees of latitude;

(ii) free air correction using the full formula expressed as a vertical gradient. For IGSN71(GRS67) the formula is as follows (Robbins, 1981) and (Flis, Butt, Hawke, 1998):
$\delta g_h / \delta h = -2g_o/a[1 + f + m + (-3f + (5m)/2)\sin^2\phi] + (6g_o/a^2)*H_m$

where g_o = equatorial gravity on the ellipsoid
= 9780318.456 μms^{-2}
f = flattening coefficient = 1/298.25
a = semi–major axis radius of the ellipsoid
= 6378160 m
m = centrifugal force at equator/g_o
= 0.0034498014
ϕ = latitude
H_m = **height of gravity meter** above geoid

This can be expressed as:

Free Air correction (FAC) = (3.08768 – 0.00440 $\sin^2\phi$)* H_m – 0.000001442* H_m^2 μms^{-2} per metre; Therefore,

Free Air Anomaly (FAA) = Obsgrav – Gn + FAC

The Geoidal Bouguer correction is calculated using the infinite slab formula as follows:

Geoidal Bouguer_Correction = 0.4191 *H*density

where

H = ground elevation (geoid height) in metres
Density = crustal density, typically 2.67t/m^3

The Geoidal Bouguer Anomaly is given by:

Geoidal Bouguer_Anomaly = Geoidal FreeAir_Anomaly – Geoidal Bouguer_corr in μms^{-2}

Users should be aware that Geoidal Free Air and Bouguer Anomalies calculated using geoid heights and the infinite slab model will NOT be the same as those obtained prior to 5 February 2008. The data are now referenced to the new gravity datum AAGD07. Data downloaded prior to 5 February 2008 were in the ISOGAL84 gravity datum.

REFERENCES

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GRAVITY DATA ERRORS

Most of the gross errors have been removed from the database. However, errors may still be present in the data. If any such errors are found, please FAX or e-mail the details to:

The Gravity Database Administrator:
Mr Phillip Wynne,
Continental Geophysics Project,
Geoscience Australia.

FAX: 02 6249 9917
E-mail: phill.wynne@ga.gov.au

These errors will be investigated and any corrections will be applied to the Australian National Gravity Database.

Phillip Wynne
Gravity Database Administrator
June 2009