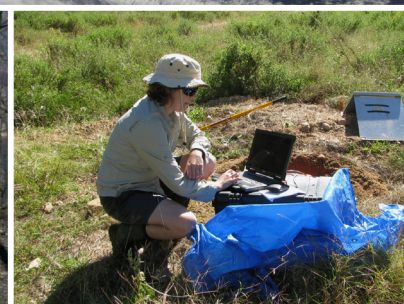
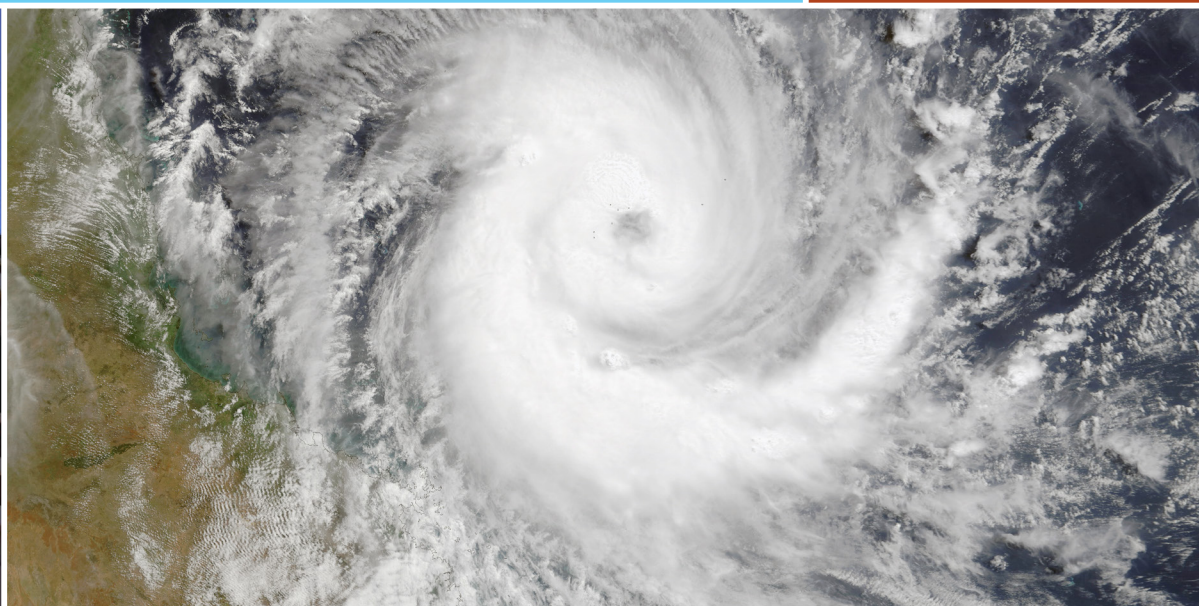




Australian Government
Geoscience Australia



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G. Hu, J. Dawson

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Minister for Industry: The Hon Ian Macfarlane MP
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Name of NATA approved facility

Geoscience Australia – National Geospatial Reference Systems Project
Corner Jerrabomberra Ave and Hindmarsh Drive
Symonston ACT 2609 Australia
Telephone: (02) 6249 9111 Facsimile: (02) 6249 9969
Email: geodesy@ga.gov.au

Client Detail

Justin Hjort
JTH Surveys Pty Ltd
29 McCool Street Moranbah, QLD, Australia, 4744
Telephone: (07) 4941 8376 Facsimile: (07) 4941 8607
Email: justinhjort@jthsurveys.com.au
Date of request: 15 June 2013

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Abbreviations

AFN	Australian Fiducial Network
ARGN	Australian Regional GNSS Network
CORS	Continuously Operating Reference Station(s)
GDA94	Geocentric Datum Australia 1994
GNSS	Global Navigation Satellite System(s)
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
ITRF92	International Terrestrial Reference Frame 1992
ITRF2008	International Terrestrial Reference Frame 2008

Introduction

An application dated 15 June 2013 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the JTH Surveys Pty Ltd in Queensland, for verification of GDA94 position on their owned or managed station monument. This report documents the processing and analysis of GPS data observed by the JTH Surveys Pty Ltd during a 7-day period from 13 May 2013 to 19 May 2013 (day of year 133 to 139) for the station MILL to satisfy the position verification requirements.

Measurand

Station position, at the time of measurement and stated instrumentation, of a GPS monument with respect to the Geocentric Datum of Australia (GDA94) referred to the GRS80 ellipsoid being in the ITRF92 reference frame at the epoch 1994.0.

Measurand Traceability

Measurement traceability was ensured by comparing the computed solution against the recognised value standard for position of the Australian Fiducial Network stations. Additionally, the computed solution was checked against the ITRF based solutions computed by the IGS and the individual global analysis centres of the IGS. The validity and traceability of the entire GPS system was ensured via its link to the global Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) observing networks through the ITRF. The validity and traceability of our internal computation processes were ensured by undertaking standard benchmark analysis prior to this analysis.

Measurand Uncertainty

Position uncertainties were calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k , of 2.

Type A uncertainty sources were evaluated by adopting an *a priori* sigma of **0.001** metre for the precision (1 sigma) of the L1-frequency, one-way, phase observation, at zenith. The corresponding uncertainties of all parameters were determined, by standard error propagation theory, in the least-squares estimation process used in the GPS analysis. Since the formal (internal) precision estimates of GPS solutions are well known to be optimistic, a factor of **10** (i.e. variance scale factor of 100) was subsequently applied to the variance-covariance matrix of the computed GDA94 coordinates.

Type B uncertainty sources, which in practice contribute to position uncertainty, cannot be estimated from the statistical analysis of short-period (i.e. 7-day) observations; these include environmental effects, such as long-period station loading (deformation) processes. [Table 1](#) shows the major type B uncertainty sources for GPS analysis.

Table 1. Type B uncertainty sources (95% C.L.) for position, determined from GPS, and the total uncertainty, assuming the normal distribution of the uncertainty sources, high degrees of freedom and a coverage factor, k , of 2.

Uncertainty Source	Position Uncertainty Horizontal (mm)	Position Uncertainty Vertical (mm)
Antenna phase centre	3	10
Monument stability	1	1
Other sources including un-modelled crustal loading, satellite orbit variations, atmosphere, tectonics, signal multi-path	6	10

GPS Data

GPS RINEX data was supplied for spanning a 7-day period from 13 May 2013 to 19 May 2013 (day of year 133 to 139) for the station MILL. [Figure 1](#) shows the location of the station. [Table 2](#) lists the GPS receiver and antenna type at this site. An antenna height of 0.000 m to the Antenna Reference Point (ARP) has been adopted for the GPS data processing. The ARP is the reference point as defined by IGS and the RINEX specifications.

The AFN/ARGN/IGS network sites used in the GPS data processing are plotted in [Figure 1](#). [Table 2](#) lists the GPS receiver and antenna type used in the GPS data processing for each of the AFN/ARGN/IGS network sites. [Table 3](#) lists the GPS antenna heights used in the GPS data processing for the AFN/ARGN/IGS and the MILL stations.

GPS Data Irregularities

The data set updated on 10 July 2013 was adopted for the GPS data processing.

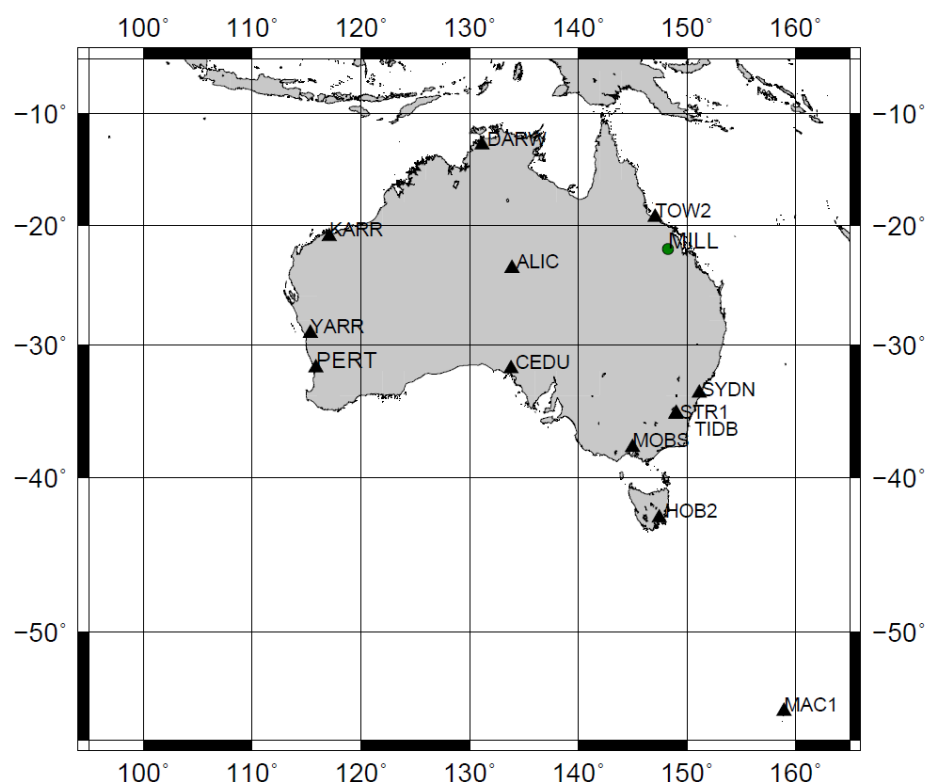


Figure 1: Station MILL (circle) at the Millennium Mine in Queensland and AFN/ARGN/IGS (black triangles) stations used in GPS data processing.

Table 2: GPS receiver and antenna types for the MILL station and the AFN/ARGN/IGS (bold station names) sites.

Station	GPS receiver type	GPS antenna serial number	IGS antenna type and dome type
MILL	TRIMBLE SPS855	5000113466	TRM57971.00 NONE
ALIC	LEICA GRX1200GGPRO	09370001	LEIAR25.R3 NONE
CEDU	TRIMBLE NETR8	194	AOAD/M_T AUST
DARW	GRX1200GGPRO	CR13354	ASH700936D_M NONE
HOB2	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
KARR	TRIMBLE NETR8	4938353444	TRM59800.00 NONE
MAC1	LEICA GRX1200+GNSS	308	AOAD/M_T AUST
MOBS	LEICA GRX1200GGPRO	CR20020709	ASH701945C_M NONE
PERT	TRIMBLE NETR9	5220354498	TRM59800.00 NONE
STR1	LEICA GRX1200GGPRO	CR620023911	ASH701945C_M NONE
SYDN	JPS E_GGD	CR519994908	ASH701945C_M NONE
TIDB	ASHTECH UZ-12	205	AOAD/M_T JPLA
TOW2	LEICA GRX1200GGPRO	09310016	LEIAR25.R3 NONE
YARR	LEICA GRX1200PRO	103314	LEIAT504 NONE

Table 3: GPS antenna heights to ARP used in GPS processing for the MILL station and minimally constrained AFN/ARGN/IGS (bold station names) stations.

Station	Domes number	Antenna height to ARP (m)	Station	Domes number	Antenna height to ARP (m)
MILL	-	0.0000	MOBS	50182M001	0.0000
ALIC	50137M001	0.0015	PERT	50133M001	0.0595
CEDU	50138M001	0.0060	STR1	50119M002	0.0040
DARW	50134M001	0.0025	SYDN	50124M003	0.0300
HOB2	50116M004	0.0000	TIDB	50103M108	0.0614
KARR	50139M001	0.0010	TOW2	50140M001	0.0033
MAC1	50135M001	0.0280	YARR	50107M006	0.0045

Method

Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position Issue 1.15.

In summary, daily solutions of the MILL station and AFN/ARGN/IGS/other site data were processed using Bernese GPS Processing Software version 5.0. The Bernese GPS Software conforms to the IERS2003 conventions. IGS final GPS satellite ephemerides and earth orientation parameters were used in the computations. The double difference carrier phase observables at 30-second epoch intervals were used for GPS data processing. Other measurement modelling and parameter estimation included:

- Receiver clock corrections.
- Absolute antenna elevation-dependent phase centre variation corrections.
- Solid earth tide displacements.
- Ocean tide loading displacements.
- Elevation cutoff of 10° for all observations.
- QIF integer ambiguity resolution strategy.
- Elevation dependent observation weighting.
- Troposphere zenith delays estimated at 1-hour intervals for all stations.
- Minimum constraint condition for daily network solution in terms of the ITRF2008 using subset of the IGS08 reference stations.

This solution was transformed to GDA94 using the transformation approach detailed in: ITRF to GDA94 coordinate transformation, John Dawson and Alex Woods, *Journal of Applied Geodesy* 4 (2010), no. 4, pp. 189-199, available online at <http://www.reference-global.com/loi/jag>.

Results

Table 4 lists the Root Mean Square (RMS) of the daily station coordinate values. Table 5 lists the station coordinates resulting from the combination of the daily ITRF solutions and their subsequent transformation to GDA94.

Table 4: Root Mean Square (RMS) of daily MILL station and minimally constrained AFN/ARGN/IGS (bold station names) station coordinates.

Station	North (mm)	East (mm)	Up (mm)	Station	North (mm)	East (mm)	Up (mm)
MILL	0.8	0.8	3.3	MOBS	0.8	0.5	3.2
ALIC	0.7	0.8	2.8	PERT	1.1	0.6	3.1
CEDU	0.5	0.8	3.7	STR1	1.0	1.9	4.6
DARW	1.6	1.3	4.0	SYDN	0.8	0.7	3.4
HOB2	0.8	1.2	5.0	TIDB	0.6	3.5	2.5
KARR	0.6	0.9	3.7	TOW2	1.0	1.0	2.0
MAC1	1.3	2.4	5.4	YARR	0.9	0.7	2.4

Table 5: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the MILL station. The uncertainties are calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k , of 2.

Station	Longitude (DMS east) Uncertainty (m)			Latitude (DMS south) Uncertainty (m)			Ellipsoidal height (m) Uncertainty (m)
MILL	148	15	37.43457	22	1	43.62853	294.1528
			±0.008			±0.008	±0.022

END OF REPORT