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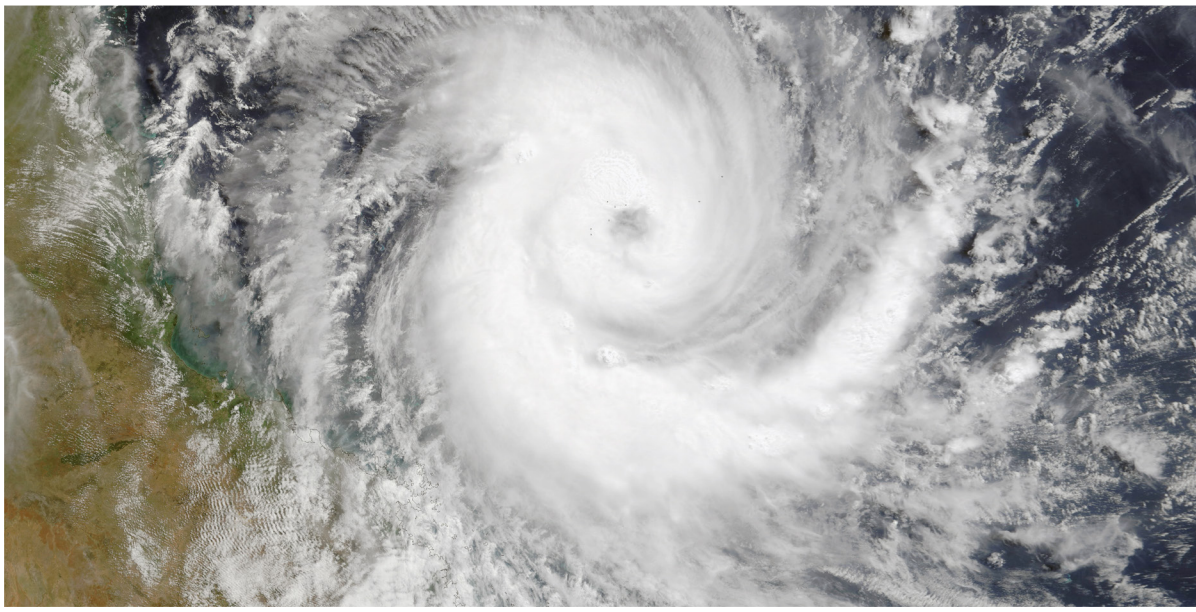

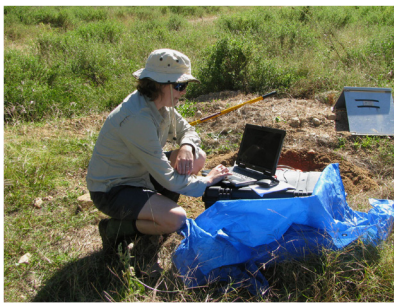

**Record** 2013/47 | **GeoCat** 78541

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G. Hu, J. Dawson

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GEOSCIENCE AUSTRALIA
RECORD 2013/47

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Accredited for compliance with ISO/IEC 17025. Accreditation No. 15002.

**Department of Industry**

Minister for Industry: The Hon Ian Macfarlane MP
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**ISSN 2201-702X (PDF)**

**ISBN 978-1-922201-85-0 (PDF)**

**GeoCat 78541**

**Bibliographic reference**: Hu, G. & Dawson, J. 2013. *Determination of GDA94 coordinates for eight stations of Ultimate Positioning Group Pty Ltd using the May 2013 GPS data set.* Record 2013/47. Geoscience Australia: Canberra.

# Contents

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Date of request: 30 May 2013

## Expiry of this Report

5 years after authorisation date.

## 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 30 May 2013 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from Ultimate Positioning Group Pty Ltd, for verification of GDA94 position on their owned or managed station monument. This report documents the processing and analysis of GPS data observed by Ultimate Positioning Group Pty Ltd during a 7-day period for eight stations 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 08 April 2013 to 14 April 2013 (day of year 098 to 104) for the stations COOM, KAWA, MAIN and TSRV; from 06 May 2013 to 12 May 2013 for the station STAN; from 22 May 2013 to 28 May 2013 for the stations HOBA, QUEE and TSMI. Figure 1 shows the location of the stations. 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 above stations 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 stations.

# GPS Data Irregularities

The station TSRV was excluded for the GPS data processing because the meta data issues could not be clarified.

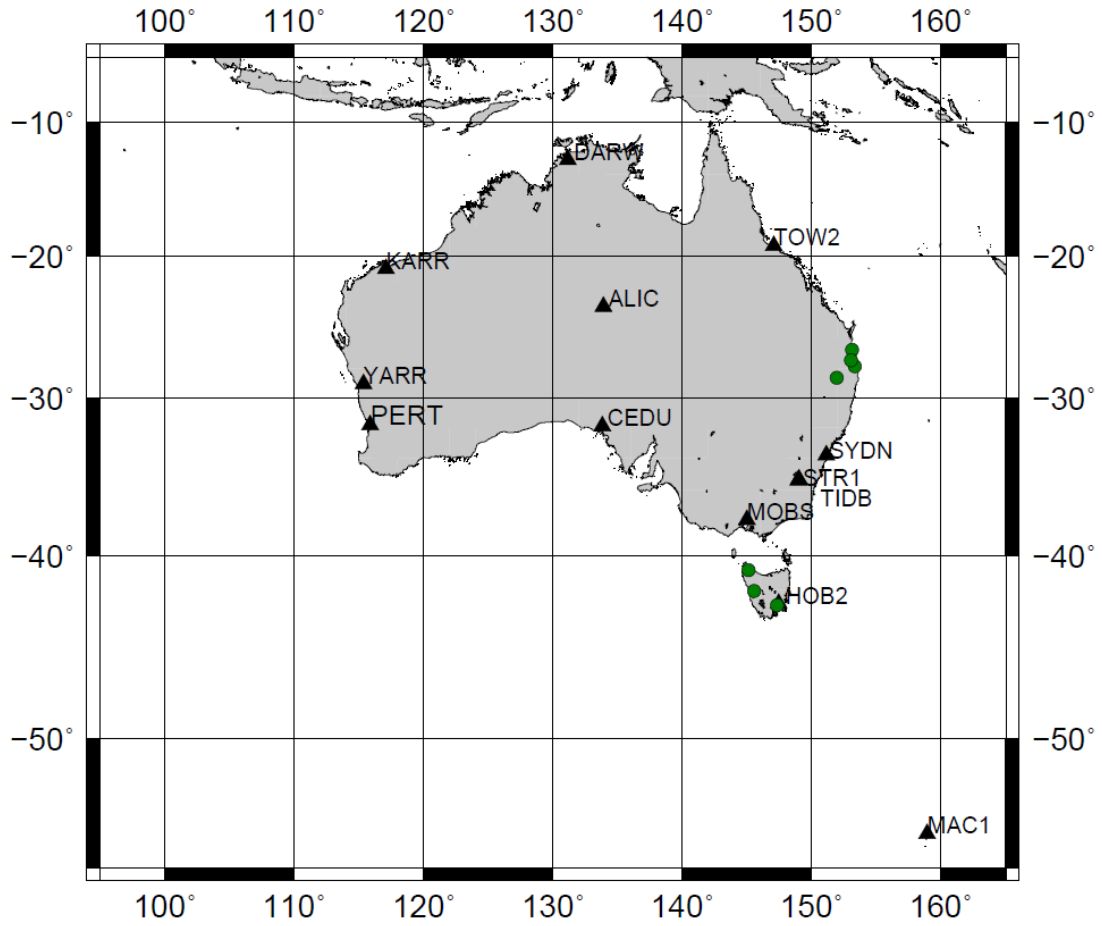


***Figure 1:*** *Stations of Ultimate Positioning Group Pty Ltd (circle) and AFN/ARGN/IGS (black triangles) stations used in GPS data processing.*

***Table 2:*** *GPS receiver and antenna types for the stations of Ultimate Positioning Group Pty Ltd and the AFN/ARGN/IGS (bold station names) sites.*

| Station | GPS receiver type | GPS antenna serial number | IGS antenna type and dome type |
|---|---|---|---|
| COOM | TRIMBLE SPS851 | 1441101006 | TRM55971.00 NONE |
| HOBA | TRIMBLE NETR5 | 30520192 | TRM55971.00 NONE |
| KAWA | TRIMBLE NETR5 | 30403899 | TRM55971.00 NONE |
| MAIN | TRIMBLE NETR5 | 30436649 | TRM55971.00 NONE |
| QUEE | TRIMBLE NETR8 | 1312118758 | TRM57971.00 NONE |
| STAN | TRIMBLE NETR5 | 1441047046 | TRM57971.00 NONE |
| TSMI | TRIMBLE NETR9 | 1441101134 | 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 |

| Station | GPS receiver type | GPS antenna serial number | IGS antenna type and dome type |
|---|---|---|---|
| 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 minimally constrained AFN/ARGN/IGS stations.*

| Station | Domes number | Antenna height to ARP (m) | Station | Domes number | Antenna height to ARP (m) |
|---|---|---|---|---|---|
| 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 |
| MOBS | 50182M001 | 0.0000 | | | |

# 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 stations of Ultimate Positioning Group Pty Ltd 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 stations of Ultimate Positioning Group Pty Ltd 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) |
|---|---|---|---|---|---|---|---|
| COOM | 1.0 | 0.9 | 5.8 | HOB2 | 1.1 | 1.7 | 2.5 |
| HOBA | 1.7 | 1.5 | 4.6 | KARR | 0.5 | 0.9 | 3.0 |
| KAWA | 1.1 | 1.7 | 7.7 | MAC1 | 1.2 | 1.2 | 3.8 |
| MAIN | 1.1 | 0.8 | 4.8 | MOBS | 0.7 | 0.5 | 2.3 |
| QUEE | 0.7 | 0.5 | 5.6 | PERT | 0.8 | 1.1 | 3.2 |
| STAN | 0.8 | 1.0 | 2.1 | STR1 | 0.6 | 0.7 | 3.7 |
| TSMI | 0.8 | 1.2 | 3.6 | SYDN | 1.0 | 0.5 | 4.1 |
| ALIC | 0.4 | 0.9 | 3.0 | TIDB | 0.9 | 1.2 | 2.3 |
| CEDU | 0.5 | 0.8 | 3.2 | TOW2 | 1.0 | 2.0 | 2.9 |
| DARW | 1.4 | 1.5 | 4.4 | YARR | 1.0 | 1.1 | 2.1 |

***Table 5:*** *Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the stations of Ultimate Positioning Group Pty Ltd. 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) |
|---|---|---|---|---|---|---|---|
| COOM | 153 | 18 | 56.25007 | 27 | 52 | 21.40852 | 49.8334 |
| | | | ±0.008 | | | ±0.008 | ±0.021 |
| HOBA | 147 | 19 | 41.20419 | 42 | 53 | 5.89940 | 58.3273 |
| | | | ±0.008 | | | ±0.008 | ±0.019 |
| KAWA | 153 | 07 | 19.39404 | 26 | 43 | 57.04956 | 62.7903 |
| | | | ±0.008 | | | ±0.008 | ±0.021 |
| MAIN | 153 | 02 | 29.55452 | 27 | 26 | 22.82330 | 55.8850 |
| | | | ±0.007 | | | ±0.008 | ±0.018 |
| QUEE | 145 | 33 | 52.52755 | 42 | 04 | 46.66779 | 240.6819 |
| | | | ±0.008 | | | ±0.009 | ±0.021 |

| Station | Longitude (DMS east) Uncertainty (m) | | | Latitude (DMS south) Uncertainty (m) | | | Ellipsoidal height (m) Uncertainty (m) |
|---|---|---|---|---|---|---|---|
| STAN | 151 | 56 | 3.65863 | 28 | 39 | 13.49732 | 841.9625 |
| | | | ±0.008 | | | ±0.008 | ±0.018 |
| TSMI | 145 | 07 | 56.60708 | 40 | 51 | 1.81137 | 43.0457 |
| | | | ±0.007 | | | ±0.008 | ±0.019 |

**END OF REPORT**