Determination of GDA94 coordinates for station CAVL at the Caval Ridge Mine of RPS Australia East Pty Ltd in Queensland using the November 2012 GPS data set

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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 20 November 2012 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the Caval Ridge Mine of RPS Australia East 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 Caval Ridge Mine during a 7-day period from 11 November to 17 November 2012 (day of year 316 to 322) for the station CAVL 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) |
| --- | --- | --- |
| Satellite orbits | 5 | 10 |
| Station deformation | 5 | 15 |
| Antenna phase centre | 3 | 3 |
| Monument stability | 5 | 10 |
| Reference Frame (ITRF) | 3 | 5 |
| Reference Frame (GDA94) | 30 | 50 |
| Total | 32 | 54 |

# GPS Data

GPS RINEX data was supplied for the station CAVL at the Caval Ridge Mine of RPS Australia East Pty Ltd in Queensland spanning a 7-day period from 11 November to 17 November 2012 (day of year 316 to 322). Figure 1 shows the location of the station. Table 2 lists the GPS receiver and antenna type at the site. The GPS receiver and antenna types, and a GPS antenna height of 0.000 m to the Antenna Reference Point (ARP) have been adopted for the GPS data processing. The ARP is the reference point as defined by IGS and the RINEX specifications.

The AFN 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 network sites. Table 3 lists the GPS antenna heights used in the GPS data processing for the AFN and the site CAVL.

# GPS Data Irregularities

It was noted that the RINEX header record for this site was 0.0001 m whereas the meta-data indicated 0.0000 m. This was discussed with the client and it was agreed to proceed with certification adopting the 0.0000 m value as true and correct.

The location of the CAVL station and the extended AFN network

Figure 1: Station CAVL (circle) at the Caval Ridge Mine of RPS Australia East Pty Ltd in Queensland and AFN (black triangles) stations used in GPS data processing.

Table 2: GPS receiver and antenna types for the station CAVL and the AFN sites.

| 4-char. ID | GPS receiver type | GPS antenna serial number | IGS antenna type and dome type |
| --- | --- | --- | --- |
| CAVL | TRIMBLE NETR9 | 4611118879 | TRM57971.00 NONE |
| ALIC | LEICA GRX1200GGPRO | 09370001 | LEIAR25.R3 NONE |
| CEDU | TRIMBLE NETR8 | 194 | AOAD/M\_T AUST |
| COCO | TRIMBLE NETR8 | 202 | AOAD/M\_T NONE |
| 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 |
| PARK | JPS E\_GGD | CR620011902 | 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 |
| XMIS | LEICA GRX1200GGPRO | CR6200503003 | ASH701945C\_M NONE |
| YARR | LEICA GRX1200PRO | 103314 | LEIAT504 NONE |

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

| Station 4-char. ID | Domes number | Antenna height to ARP (m) | Station 4-char. ID | Domes number | Antenna height to ARP (m) |
| --- | --- | --- | --- | --- | --- |
| CAVL | - | 0.0000 | PARK | 50108M001 | 0.0000 |
| ALIC | 50137M001 | 0.0015 | PERT | 50133M001 | 0.0595 |
| CEDU | 50138M001 | 0.0060 | STR1 | 50119M002 | 0.0040 |
| COCO | 50127M001 | 0.0040 | SYDN | 50124M003 | 0.0300 |
| DARW | 50134M001 | 0.0025 | TIDB | 50103M108 | 0.0614 |
| HOB2 | 50116M004 | 0.0000 | TOW2 | 50140M001 | 0.0033 |
| KARR | 50139M001 | 0.0010 | XMIS | 50183M001 | 0.0000 |
| 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 1.14.

In summary, daily solutions of the station CAVL 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 station CAVL and minimally constrained AFN (bold station names) station coordinates.

| Station | North  (mm) | East  (mm) | Up  (mm) | Station | North  (mm) | East  (mm) | Up  (mm) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CAVL | 1.7 | 2.6 | 6.3 | PARK | 0.8 | 1.1 | 2.4 |
| ALIC | 1.0 | 0.4 | 3.6 | PERT | 0.6 | 1.4 | 3.3 |
| CEDU | 0.6 | 1.0 | 3.7 | STR1 | 1.4 | 1.3 | 3.7 |
| COCO | 1.8 | 2.4 | 8.8 | SYDN | 0.9 | 1.1 | 2.8 |
| DARW | 2.1 | 2.5 | 8.0 | TIDB | 0.9 | 0.7 | 4.3 |
| HOB2 | 0.8 | 0.8 | 2.8 | TOW2 | 1.4 | 2.3 | 8.0 |
| KARR | 1.0 | 1.4 | 3.6 | XMIS | 2.0 | 3.2 | 7.8 |
| MAC1 | 1.8 | 2.0 | 4.9 | YARR | 0.8 | 1.2 | 2.9 |
| MOBS | 0.8 | 0.8 | 2.5 |  |  |  |  |

Table 5: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the station CAVL. 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. The uncertainties are 0.032 m, 0.032 m and 0.054 m for east, north and vertical components respectively for all stations.

| Station | Longitude (DMS east) | | | Latitude (DMS south) | | | Ellipsoidal height (M) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CAVL | 148 | 03 | 4.47437 | 22 | 08 | 53.80452 | 331.1596 |

End of report