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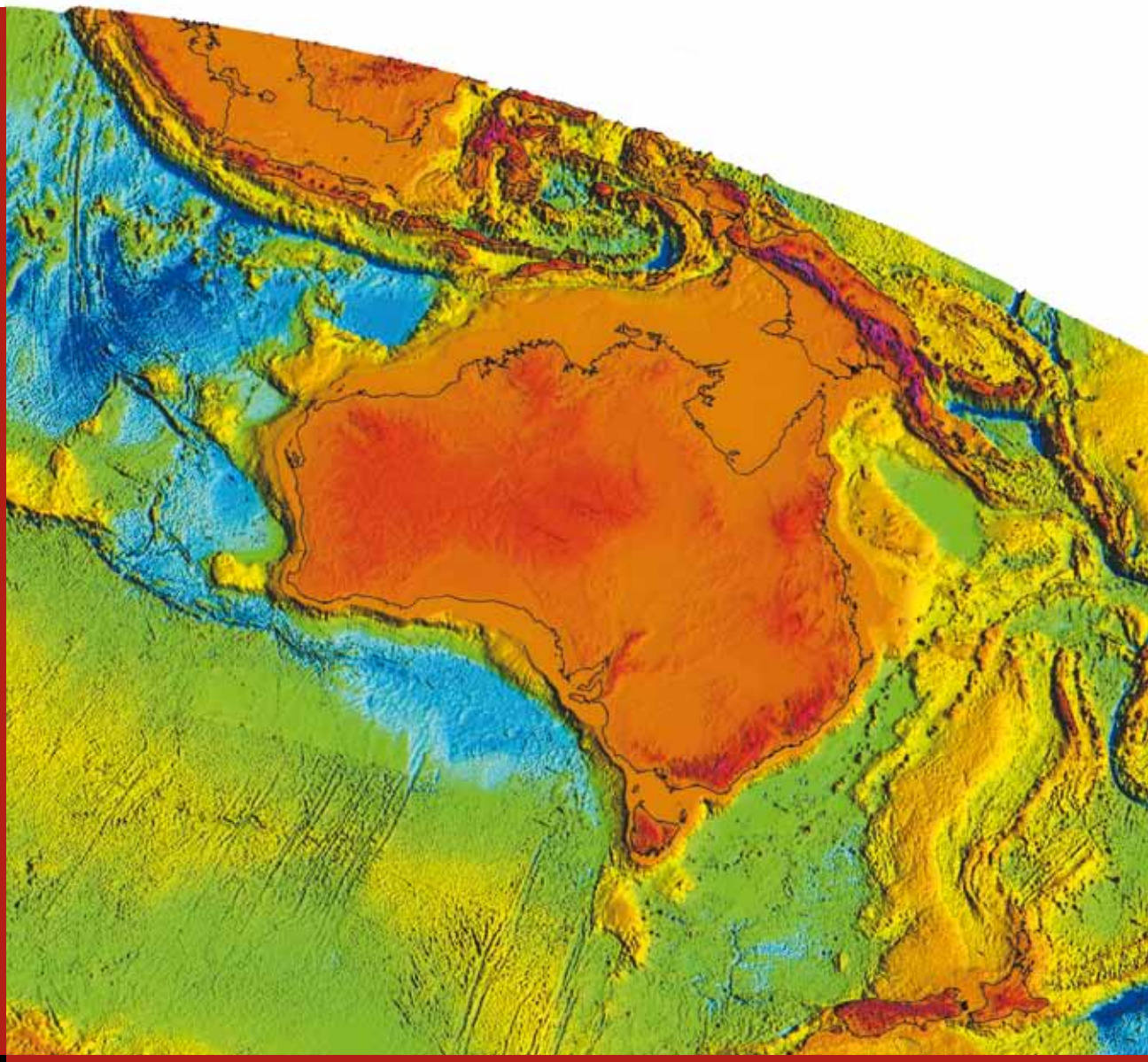

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by

G. Hu, J. Dawson

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Abbreviations:

AFN	Australian Fiducial Network
ARGN	Australian Regional GNSS Network.
CORS	Continuously Operating Reference Stations
GDA94	Geocentric Datum Australia 1994
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
ITRF92	International Terrestrial Reference Frame 1992
ITRF2005	International Terrestrial Reference Frame 2005

Introduction:

Applications dated 21 October 2009 and 03 February 2010 for verification of a reference standard of measurement under regulation 12 of the National Measurement Regulations 1999 were received from the Land and Property Management Authority, NSW for verification of GDA94 position on their CORSnet monuments. This report documents the processing and analysis of GPS data observed by the CORSnet-NSW GPS stations during a 7-day period from 27 September to 03 October 2009 (day of year 270 to 276) for 24 stations (ARMD, BALL, BATH, CHIP, COFF, CWN2, DBBO, GFTN, GLBN, GONG, MENA, MGRV, NEWC, NWRA, PMAC, SPWD, TARE, ULLA, UNSW, VLWD, WFAL, WGGA, WWLG and WYNG); DKSN station from 11 October to 17 October 2009 (day of year 284 to 290); three stations (LGOW, MUDG and ORNG) from 17 January to 23 January 2010 (day of year 17 to 23), and PKTL station from 27 December 2009 to 02 January 2010 (day of year 361 to 365 in 2009 and day of year 01 to 02 in 2010), 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 28 CORSnet-NSW stations spanning a 7-day period from 27 September to 03 October 2009 (day of year 270 to 276) for 24 stations (ARMD, BALL, BATH, CHIP, COFF, CWN2, DBBO, GFTN, GLBN, GONG, MENA, MGRV, NEWC, NWRA, PMAC, SPWD, TARE, ULLA, UNSW, VLWD, WFAL, WGGA, WWLG and WYNG); from 11 October to 17 October 2009 (day of year 284 to 290) for DKSN station; from 17 January to 23 January 2010 (day of year 17 to 23) for three stations (LGOW, MUDG and ORNG), and from 27 December 2009 to 02 January 2010 (day of year 361 to 365 in 2009 and day of year 01 to 02 in 2010) for PKTL station. Figure 1 shows the distribution of these stations. Table 2 lists the GPS antenna type at each site. The GPS receiver type as listed in the amended email dated 19 February 2010 submitted with the application for verification of position has been adopted for the GPS data processing. An antenna height of 0.000m to the Antenna Reference Point (ARP) has been adopted for all CORSnet-NSW stations, except at ARMD (0.076 m) and GONG (0.193 m). The ARP is the reference point as defined by IGS and the RINEX specifications.

Figure 2 shows the extended regional network of IGS, ARGN and AFN network sites used in the GPS data processing. Table 3 lists the GPS antenna type used in the GPS data processing for each of the IGS, ARGN and AFN network sites. Table 4 lists the GPS antenna heights used in the GPS data processing for all sites.

GPS Data Irregularities:

No irregularities were identified in the GPS data supplied in RINEX format from the CORSnet-NSW stations.

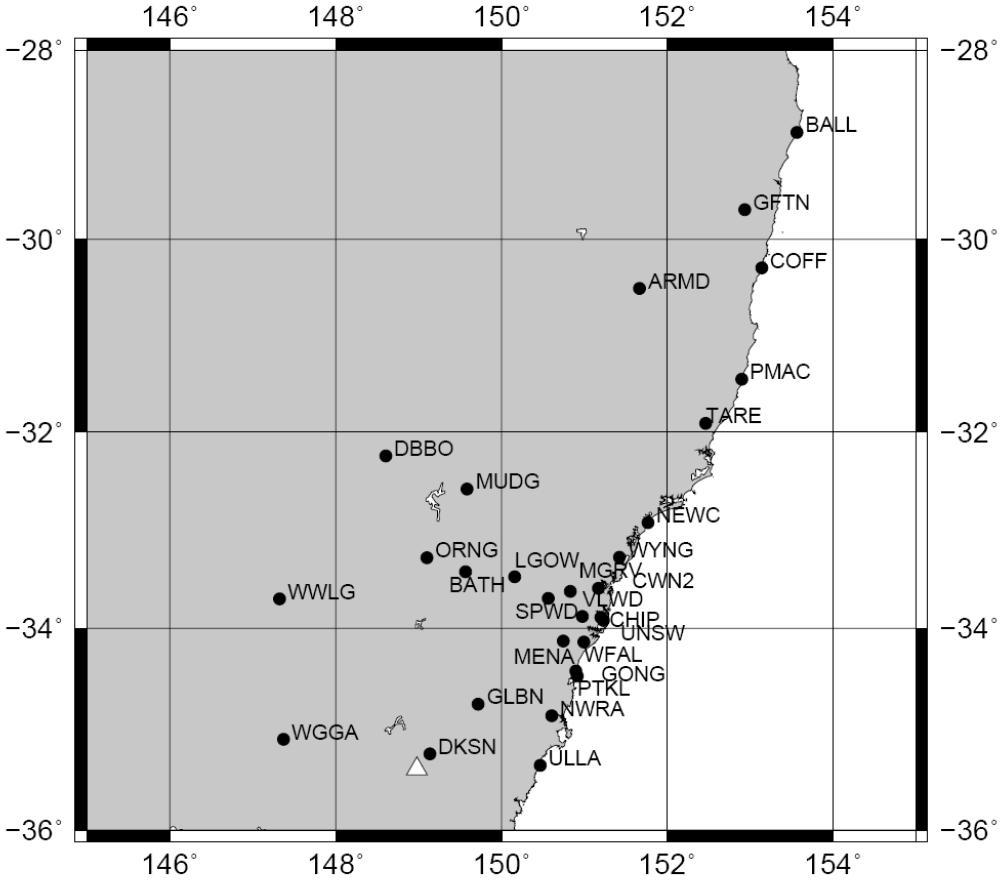

Figure 1: CORSnet-NSW stations used in GPS data processing.

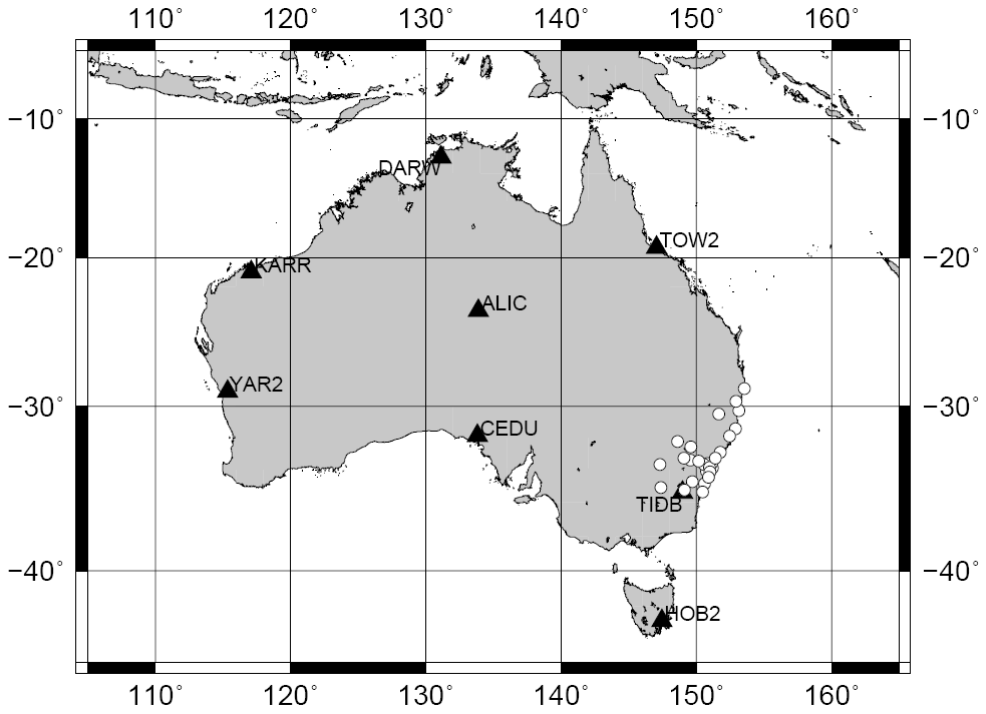

Figure 2: AFN/ARGN/IGS stations used in GPS data processing.

Table 2: CORSnet-NSW receiver and antenna types.

CORSnet-NSW base station	4-char. ID	GPS receiver type	GPS antenna SERIAL NUMBER	IGS antenna type AND DOME TYPE
Armidale	ARMD	LEICA GRX1200+GNSS	09240064	LEIAX1203+GNSS NONE
Ballina	BALL	LEICA GRX1200GGPRO	07490014	LEIAX1202GG NONE
Bathurst	BATH	LEICA GRX1200GGPRO	CR1998380112	ASH700936D_M SNOW
Chippendale	CHIP	LEICA GRX1200GGPRO	CR6200323020	ASH701945B_M SCIS
Coffs Harbour	COFF	LEICA GRX1200GGPRO	08340033	LEIAX1202GG NONE
Cowan 2	CWN2	TRIMBLE NETR5	CR6200323012	ASH701945E_M SCIS
Dubbo	DBBO	TPS NETG3	3830928	TPSCR.G3 TPSH
Dickson	DKSN	LEICA GRX1200+GNSS	09120016	LEIAR25 LEIT
Grafton	GFTN	TRIMBLE NETR5	30738847	TRM57971.00 NONE
Goulburn	GLBN	LEICA GRX1200GGPRO	CR6200232023	ASH701945E_M SCIS
Wollongong	GONG	TRIMBLE NETR5	30607527	TRM57971.00 NONE
Lithgow	LGOW	LEICA GRX1200+GNSS	09250080	LEIAX1203+GNSS NONE
Menangle	MENA	LEICA GRX1200GGPRO	CR6200323021	ASH701945E_M SCIS
Mulgrave	MGRV	LEICA GRX1200GGPRO	CR6200323001	ASH701945E_M SCIS
Mudgee	MUDG	LEICA GRX1200+GNSS	09250090	LEIAX1203+GNSS NONE
Newcastle	NEWC	TRIMBLE NETR5	CR6200323013	ASH701945E_M SCIS
Nowra	NWRA	LEICA GRX1200GGPRO	CR6200323011	ASH701945E_M SCIS
Orange	ORNG	LEICA GRX1200+GNSS	09250076	LEIAX1203+GNSS NONE
Port Macquarie	PMAC	LEICA GRX1200GGPRO	07520004	LEIAX1202GG NONE
TS 12067	PTKL	LEICA GRX1200GGPRO	200537	LEIAT504GG SCIS
Springwood	SPWD	TRIMBLE NETRS	CR6200323024	ASH701945E_M SCIS
Taree	TARE	LEICA GRX1200GGPRO	08340035	LEIAX1202GG NONE
Ulladulla	ULLA	LEICA GRX1200+GNSS	08470020	LEIAX1203+GNSS NONE
University of NSW	UNSW	LEICA MC500	448	LEIAT504 LEIS
Villawood	VLWD	TRIMBLE NETR5	CR6200323007	ASH701945E_M SCIS
Waterfall	WFAL	TRIMBLE NETR5	CR6200323022	ASH701945E_M SCIS
Wagga	WGGA	TRIMBLE NETR5	30765520	TRM57971.00 NONE
West Wyalong	WWLG	LEICA GRX1200GGPRO	200525	LEIAT504GG SCIS
Wyong	WYNG	LEICA GRX1200GGPRO	08340043	LEIAX1202GG NONE

Table 3: GPS receiver and antenna types for the AFN sites.

GPS Network	4-char. ID	GPS receiver type	GPS antenna SERIAL NUMBER	IGS antenna type AND DOME TYPE
IGS, ARGN,AFN	ALIC	LEICA GRX1200GGPRO	318	AOAD/M_T NONE
IGS, ARGN,AFN	CEDU	ASHTECH UZ-12	194	AOAD/M_T AUST
IGS, ARGN,AFN	DARW	LEICA GRX1200GGPRO	133	ASH700936D_M NONE
IGS, ARGN,AFN	HOB2	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
IGS, ARGN,AFN	KARR	ASHTECH UZ-12	320	AOAD/M_T AUST
IGS, ARGN,AFN	TIDB	ASHTECH Z-XII3	205	AOAD/M_T JPLA
IGS, ARGN,AFN	TOW2	LEICA GRX1200GGPRO	326	AOAD/M_T AUST
IGS, ARGN,AFN	YAR2	ASHTECH UZ-12	371	AOAD/M_T JPLA

Table 4: GPS antenna heights to ARP used in GPS processing and site DOMES numbers.

Site 4-char. ID	DOMES number	ANTENNA HEIGHT TO ARP (M)	site 4-char. ID	DOMES number	ANTENNA HEIGHT TO ARP (M)
ARMD	—	0.076	PTKL	—	0.000
BALL	—	0.000	SPWD	—	0.000
BATH	—	0.000	TARE	—	0.000
CHIP	—	0.000	ULLA	—	0.000
COFF	—	0.000	UNSW	—	0.000
CWN2	—	0.000	VLWD	—	0.000
DBBO	—	0.000	WFAL	—	0.000
DKSN	—	0.000	WGGA	—	0.000
GFTN	—	0.000	WWLG	—	0.000
GLBN	—	0.000	WYNG	—	0.000
GONG	—	0.193			
LGOW	—	0.000	ALIC	50137M001	0.007
MENA	—	0.000	CEDU	50138M001	0.006
MGRV	—	0.000	DARW	50134M001	0.0025
MUDG	—	0.000	HOB2	50116M004	0.000
NEWC	—	0.000	KARR	50139M001	0.002
NWRA	—	0.000	TIDB	50103M108	0.0614
ORNG	—	0.000	TOW2	50140M001	0.0035
PMAC	—	0.000	YAR2	50107M004	0.0814

Method:

Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position Issue 1.3.

In summary, daily solutions of the CORSnet-NSW 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 loading displacements.
- Elevation cutoff of 10° for all observations.
- QIF integer ambiguity resolution strategy.
- Elevation dependent observation weighting.
- Troposphere zenith delays estimated at 2-hour intervals for all stations.
- Minimum constraint condition for daily network solution in terms of the ITRF2005 using subset of the IGS05 reference stations.

Daily solutions were combined to provide a weekly solution. This solution was transformed to GDA94 using a seven parameter transformation.

Results:

Table 5 lists the Root Mean Square (RMS) of the daily station coordinate values. Table 6 lists the GDA94 station coordinates resulting from the combination together with the position recognised-value standard GDA94 coordinates held fixed in the adjustment.

Table 5: Root Mean Square (RMS) of daily CORSnet-NSW and minimally constrained AFN/ARGN/IGS station coordinates.

Station	East (mm)	North (mm)	Up (mm)	Station	East (mm)	North (mm)	Up (mm)
ALIC	0.4	1.5	6.3	GONG	1.6	0.4	6.0
CEDU	0.7	0.4	2.1	LGOW	0.6	1.1	4.3
DARW	2.1	1.3	4.5	MENA	1.0	0.6	3.3
HOB2	1.4	1.1	8.6	MGRV	1.0	0.6	3.8
KARR	0.6	0.5	4.9	MUDG	1.0	2.2	5.5
TIDB	1.0	2.6	3.6	NEWC	0.8	0.8	3.2
TOW2	1.1	1.0	6.3	NWRA	0.8	0.4	3.6
YAR2	0.6	0.7	3.8	ORNG	0.6	1.1	3.2
				PMAC	1.3	1.2	3.5
ARMD	0.7	0.7	5.0	PTKL	0.7	1.1	6.7
BALL	1.3	1.1	5.6	SPWD	1.2	1.5	4.7
BATH	0.7	0.9	5.9	TARE	1.2	0.6	4.5
CHIP	1.0	0.5	4.8	ULLA	2.4	0.5	3.2
COFF	0.9	1.2	5.2	UNSW	1.0	0.6	4.2
CWN2	1.1	0.8	5.6	VLWD	0.7	0.8	5.0
DBBO	0.8	1.3	4.4	WFAL	0.7	1.5	3.3
DKSN	1.5	0.9	3.1	WGGA	1.2	0.5	3.4
GFTN	0.8	0.9	2.8	WWLG	0.7	0.6	3.9
GLBN	0.9	0.9	4.4	WYNG	0.8	1.0	3.1

Table 6: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the CORSnet-NSW stations. 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	Latitude (DMS south)	Longitude (DMS east)	Ellipsoidal height (M)
ARMD	30 30 52.62719 0.0315	151 39 56.97386 0.0315	1034.7800 0.0544
BALL	28 52 21.62975 0.0315	153 33 50.72000 0.0315	44.5213 0.0544
BATH	33 25 46.90205 0.0315	149 34 1.95889 0.0315	756.6217 0.0544
CHIP	33 53 12.80931 0.0315	151 12 4.37256 0.0315	55.9005 0.0544
COFF	30 18 0.43823 0.0315	153 08 17.98140 0.0315	46.5766 0.0544
CWN2	33 35 37.33393 0.0315	151 10 17.59718 0.0315	218.0707 0.0544
DBBO	32 14 57.75176 0.0315	148 36 7.64050 0.0315	297.6588 0.0544
DKSN	35 15 2.71105 0.0315	149 8 8.62211 0.0315	613.8427 0.0544
GFTN	29 41 34.93218 0.0315	152 55 58.43948 0.0315	59.1902 0.0544
GLBN	34 45 20.50522 0.0315	149 43 3.76336 0.0315	678.7286 0.0544
GONG	34 25 38.01226 0.0315	150 53 55.82805 0.0315	75.6022 0.0544
LGOW	33 28 51.42943 0.0315	150 9 35.39270 0.0315	969.4072 0.0544
MENA	34 7 33.95972 0.0315	150 44 37.50930 0.0315	111.4312 0.0544
MGRV	33 37 35.49114 0.0315	150 49 51.54274 0.0315	45.2413 0.0544
MUDG	32 35 24.02353 0.0315	149 35 4.84596 0.0315	482.3993 0.0544
NEWC	32 55 46.51111 0.0315	151 45 54.82088 0.0315	52.9517 0.0544
NWRA	34 52 25.58378 0.0315	150 36 17.31232 0.0315	46.5776 0.0544
ORNG	33 17 6.72323 0.0315	149 5 52.87995 0.0315	906.9491 0.0544
PMAC	31 27 42.88798 0.0315	152 53 51.63217 0.0315	43.8810 0.0544
PTKL	34 28 31.99645 0.0315	150 54 49.30183 0.0315	34.5494 0.0544
SPWD	33 41 54.76981 0.0315	150 33 50.17160 0.0315	399.5114 0.0544
TARE	31 54 43.94988 0.0315	152 27 49.65684 0.0315	44.8738 0.0544
ULLA	35 21 43.10414 0.0315	150 27 55.22175 0.0315	63.0887 0.0544
UNSW	33 55 3.63447 0.0315	151 13 54.63333 0.0315	86.9773 0.0544
VLWD	33 52 50.30944 0.0315	150 58 37.79258 0.0315	42.6775 0.0544
WFAL	34 8 3.18108 0.0315	150 59 41.88787 0.0315	251.6560 0.0544
WGGA	35 6 25.87656 0.0315	147 22 9.46461 0.0315	215.9876 0.0544
WWLG	33 42 12.36727 0.0315	147 19 18.03049 0.0315	359.7549 0.0544
WYNG	33 16 57.18781 0.0315 0.0315	151 25 26.31935 0.0315	57.9367 0.0544

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