HONORARY SECRETARY'S REPORT

Summary of the Minutes of the ISNSW Board Meeting 1 September 2017

The President Michael Green opened the meeting at 1000 hrs.

APOLOGIES RECEIVED

Tony Proust (President-elect), Mathew Hynes (Hon Treasurer), Neil Kennedy, Ben Jackson.

Bill Hamer was welcomed to his first day on the Board as the Sydney North Group representative.

TREASURERS REPORT

The Honorary Treasurer Mathew Hynes had presented a tabled report in his absence. Details of the audit from last financial year revealed a modest profit of approximately $12000. This is an excellent result given that there was a budgeted loss for the financial year.

MEMBERSHIP REPORT

The Honorary Secretary Graeme Stewart presented the membership report. Congratulations to the following members:

- Luke Patrick Haavisto – Admission to Student Membership.
- Beau Fredericks – Transfer to Working Student Membership.
- Joshua Stephen Ventura – Admission to Graduate Membership.
- Evan (Eshan) Akar – Readmission to Corporate Membership.
- Richard Mutape – Readmission to Corporate Membership.
- Mark Warren Thompson – Advancement to Corporate Membership.
- Andre Di Filippo – Advancement to Corporate Membership.
- Brendan Thomas O'Farrell – Admission to Corporate Membership.

Application for Senior (Retired) Membership status were approved for Pankaj Bamola and Norman Bruhn.

Resignations were received from John Mittelheuser, Jayden Wadd, Ashley Jelley, Neil Doherty, Benjamin Gray and Ryan Jeffrey.

It is with regret to report the passing of John Dudley Bald (Joined 3 October 1966) from the Sutherland Group who died on 8 August 2017 and Gerard Voerman (Joined 6 May 1955) from the Central Western Group who died on the 21 August 2017.

EXECUTIVE OFFICERS REPORT TERINA SAWYER

Numerous matters were discussed including:

There are 450 people booked into the EISSI Awards night for the 16 September. The Institution Patron His Excellency General The Honourable David Hurley AC DSC (Ret'd) Governor of New South Wales, and his wife will be in attendance.

The annual Institution Golf Day will be held at the Pennant Hills Golf Club on the 10 November.

Australia Day Seminar 2018

To be held at the Four Seasons Hotel Sydney on 24 and 25 January 2018.

Other Business:

The Seniors Group is focusing on the unveiling of the George William Evans "Footsteps in Time" Commemorative Pillar in Bathurst due to take place in early 2018.

The history of Bathurst has a long association with surveyors commencing with the 1815 Flagstaff being the gazetted commencement point of the exploration and survey of inland New South Wales. Bathurst is also the location of the State`s mapping services. This association has been recognised by Bathurst Regional Council in the creation of the Surveyors Walk. The walk is about 1.5 km long, commencing at the site of the Evans Pillar in the Bicentennial River Park, then along Stanley Street and William Street to the Court House and the Evans Monument in the centre of town. Starting at the Evans Pillar, there are seven further heritage points along the route.

Bathurst Regional Council will be printing brochures for the Surveyors Walk and will make them available without cost to the Profession. The meeting closed at 1430 hrs

Graeme Stewart
Honorary Secretary ISNSW

Datum Modernisation: GDA2020, AUSGeoid2020 and ATRF Explained

The Geocentric Datum of Australia 1994 (GDA94) has been our national datum since its adoption in 2000. Significant improvements in positioning technology in the recent past have revealed that it is no longer capable of providing the required quality of datum for modern-day positioning applications. Consequently, Federal, State and Territory Governments have worked towards modernising Australia's datum for some time.

We are now on the cusp of these changes taking effect: The GDA2020 Technical Manual has been released, gazettal of the GDA2020 coordinates for the Australian Fiducial Network (AFN) is imminent, and related datum modernisation products are being finalised.

The Geocentric Datum of Australia 2020 (GDA2020) is a new, much improved Australian national datum that is expected to replace GDA94 by 1 January 2020 (Figure 1). It is to be used in conjunction with the new AUSGeoid2020 to connect to the Australian Height Datum (AHD). After 2020, GDA2020 will be complemented (and possibly one day replaced) by the time-dependent, earth-fixed Australian Terrestrial Reference Frame (ATRF).

This article provides some background on datums before explaining the terms GDA2020, AUSGeoid2020 and ATRF in general. It outlines the difference between plate-fixed and earth-fixed datums, and explains how important the change is for users intending to benefit from the improved geodetic infrastructure.

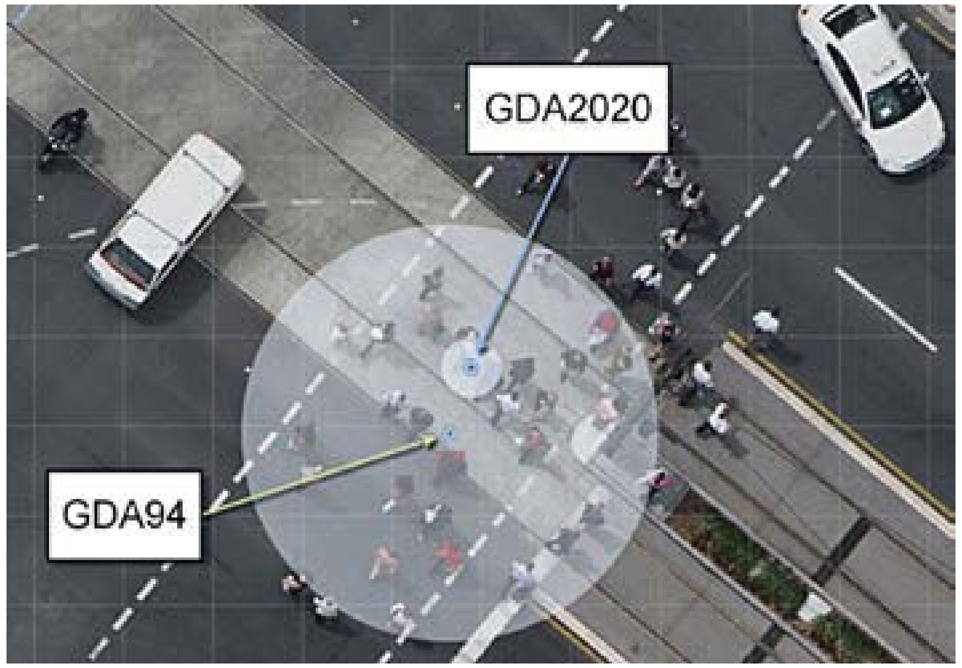

Figure 1: Artistic illustration of GDA94 and GDA2020 coordinates and their uncertainties (aerial image courtesy of AEROmetrex Pty. Ltd.).

COORDINATE REFERENCE SYSTEMS & DATUMS

A coordinate reference system is a methodology to define the specific location of a feature in space. Routinely, we use an ellipsoid to approximate the shape of the Earth. Positions on the ellipsoid are usually expressed in Cartesian coordinates (X, Y, Z) or curvilinear geographic coordinates

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(f, l, h), i.e. latitude, longitude and ellipsoidal height.

Since a coordinate reference system is an idealised abstraction, it can only be accessed in practice through its physical materialisation (or realisation) called reference frame or datum. The datum effectively defines the origin and orientation of the coordinate reference system at a certain instant in time (epoch), generally by adopting a set of station coordinates.

Nowadays, this is generally provided by a network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS). Over time, different techniques with varying levels of sophistication have been applied to approximate the shape of the Earth's surface, resulting in the adoption of many different datums.

A geocentric datum uses the Earth's centre of mass as its origin and is therefore compatible with GNSS-based positioning. The current ellipsoid of choice in Australia (and indeed for the International Terrestrial Reference Frame – ITRF) is the Geodetic Reference System 1980 (GRS80), a geocentric ellipsoid designed to approximate the Earth on a global scale.

PROJECTIONS & TRANSFORMATIONS

In practice, it is often required to express positions on a flat surface in the form of grid coordinates, i.e. in a 2-dimensional Cartesian coordinate system such as Easting and Northing. This is achieved by map projections according to a recognised set of mathematical rules, resulting in an ordered system of projected meridians (lines of constant longitude) and parallels (lines of constant latitude).

The most common projection used in Australia is the Universal Transverse Mercator (UTM) projection, which utilises a zone width of 6˚ and ensures that the scale is very close to unity across the entire zone. When applied to GDA94 coordinates, the resulting projected coordinates are known as the Map Grid of Australia 1994 (MGA94).

For many years, the conversion between curvilinear and grid co-ordinates was performed using Redfearn's (or Krueger l-series) equations, which originated in 1948 if not earlier. However, now it is preferred to use the much more accurate Karney-Krueger (or Krueger n-series) equations – particularly if working across zone boundaries. Refer to the GDA2020 Technical Manual for more information and tools to apply these equations in practice.

Transformation parameters are required to transfer data between datums. These are commonly provided by national or international agencies, generally in the form of a 7-parameter or 14-parameter similarity (or conformal) transformation or as a transformation grid. The 7 parameters account for three translations, three rotations and a scale factor. In a 14-parameter transformation, each of these 7 parameters also includes a rate to account for the change of the parameter over time. A transformation grid, on the other hand, can include not only the conformal component mentioned above, but may also account for local distortions. You could think of this as a different set of block-shift values for each location.

As new datums are defined (or existing datums are refined) based on increased amounts of data and improved processing techniques, new and better transformation parameters (and transformation grids) are published. While there may be a significant delay between their initial availability and eventual adoption in software via updates or patches, it is important to apply the latest set of transformation parameters or transformation grid in order to achieve the highest possible quality of output coordinates.

DRIVERS FOR DATUM MODERNISATION

Datum modernisation is required in order to accommodate the increasing accuracy and improved spatial and temporal resolution available from modern positioning technologies to an ever-broadening user base. The goal of datum modernisation is to supply all users with the most complete yet most straightforward datum products that can define a locally consistent set of coordinates, such that their positioning device agrees with the physical world and associated spatial data to an acceptable level of accuracy.

Figure 2 illustrates the following main drivers for datum modernisation in Australia:

- Including up-to-date geodetic observations and increased precision: A significant amount of additional data has been gathered since GDA94 was introduced. As an example, Figure 2a shows approximately 90,000 new GNSS baselines (blue) overlying the network of GPS observations that were used in the GDA94 adjustment in NSW (green).
- Removing known distortions: Systematic distortions of up to 0.3 m (horizontally) and ±0.3 m (vertically) have been demonstrated in GDA94 across NSW (Figure 2b). Consequently, a site transformation is currently required to relate CORSnet-NSW and AUSPOS derived positions to the legal datum as realised by the Survey Control Information Management System (SCIMS). These distortions will be removed based on 26,000 common points across NSW.
- Providing seamless coordinates across state borders through a nationwide simultaneous adjustment: This removes coordinate jumps at jurisdictional boundaries often introduced by running separate adjustments using different methods (Figure 2c).
- Accounting for tectonic plate motion since 1994: The Australian tectonic plate is moving at up to 7 cm/yr and has moved about 1.6 m north-east since 1994. By 2020, it will have moved by approximately 1.8 m (Figure 2d).
- Accounting for tectonic plate rotation: If ignored, errors of up to 7 mm are introduced for baseline lengths of 30 km over a 20-year period (Figure 2e).
- Introducing a truly 3-dimensional datum by appropriately considering ellipsoidal heights in the definition: This is crucial in order to realise the benefits of precise satellite-based positioning across the nation and unlock the potential for GNSS heighting (Figure 2f).

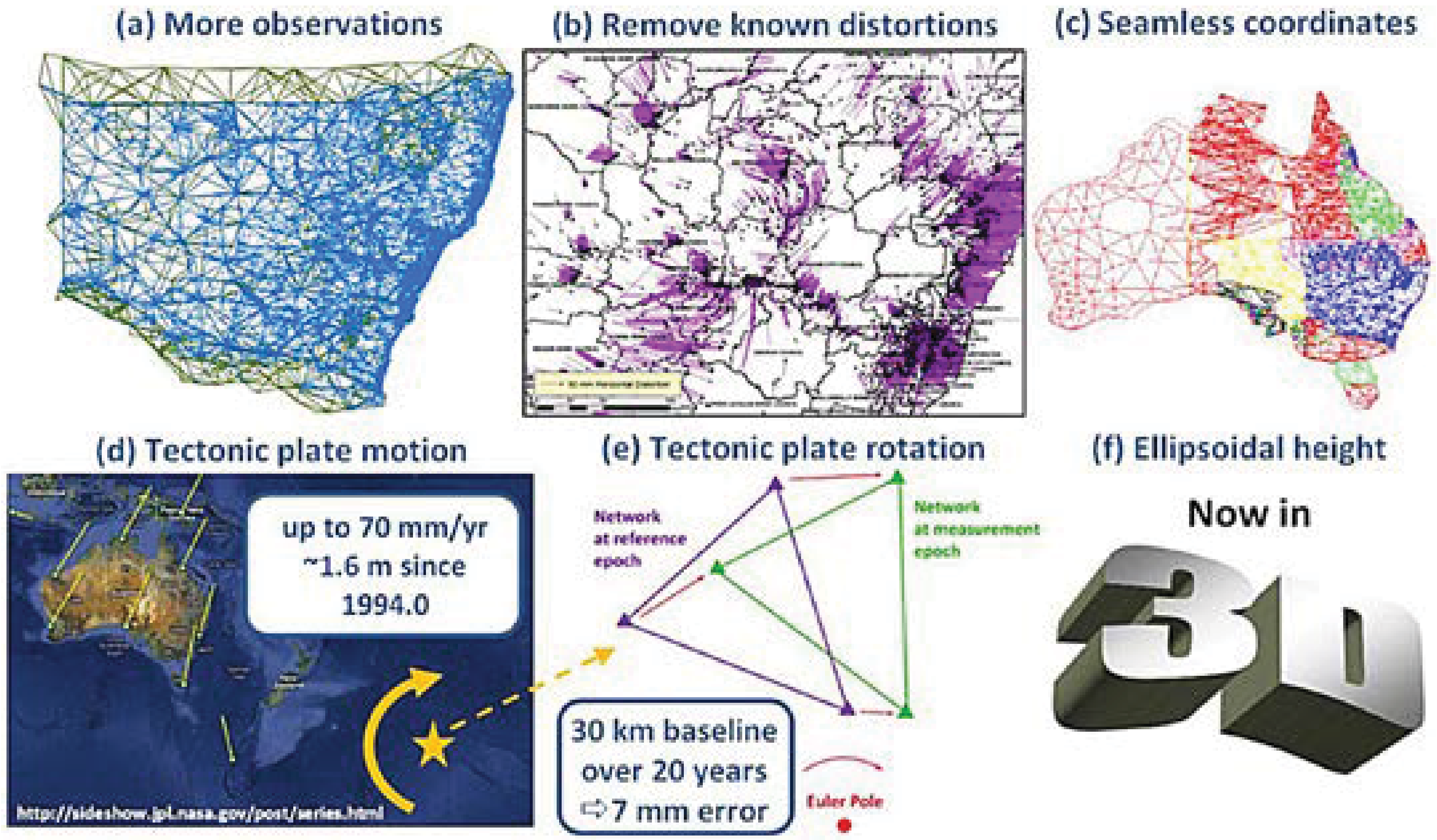

Figure 2: The main drivers for datum modernisation in Australia.

Figure 3: Geodetic control underpins all spatial data (image courtesy of ICSM).

It is important to emphasise that geodetic control underpins all spatial data (Figure 3). This includes applications such as mapping, surveying, construction and mining, agriculture, environmental and asset management, transport, insurance, emergency services, communication and research. The growing trend to 'big data', 'open data' and 'plug-and-play data' is only possible if these datasets are built on a solid foundation provided by geodetic control, so they actually fit together and can facilitate meaningful results.

PLATE-FIXED DATUMS

A plate-fixed datum is attached to the tectonic plate and therefore also known as a static datum. It is 'frozen' at a certain instant in time (the reference epoch), essentially preventing the coordinates from changing over time due to (normal) tectonic plate motion.

However, as the time difference between the reference epoch and the current epoch increases, the plate-fixed datum deviates more and more from the true position of the plate (and the earth-fixed datum used for GNSS). Consequently, it needs to be updated at frequent intervals in order to meet user requirements into the future. GDA94 and GDA2020 are examples of plate-fixed geocentric datums.

GDA94

GDA94 was defined in the then state-of-the-art global reference frame, the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0. It was initially realised by 8 AFN sites and re-gazetted with improved accuracy for 21 AFN sites in 2012, but has been 'frozen' in a geodetic sense at 1994.0 in order to avoid changing coordinate values.

This definition was justified by the relatively uniform drift of the Australian continent at about 7 cm/yr to the north-east. However, tectonic plate motion causes the difference between absolute ITRF coordinates and GDA94 coordinates to increase over time, amounting to about 1.6 m at present.

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This is generally not an issue for differential GNSS applications within Australia, as both ends of a baseline move at the same rate if we ignore rotation. However, the ever-increasing number of real-time mass-market applications routinely operates in the ITRF, causing this offset to be a confusing annoyance for the layperson.

GDA2020

GDA2020 is a much more homogeneous plate-fixed datum, based on a single, nationwide least squares network adjustment that rigorously propagates uncertainty. GDA2020 is defined in the current state-of-the-art global ITRF2014 reference frame at epoch 2020.0. The coordinates are extrapolated into the future to 1 January 2020 in order to extend the lifespan of the datum. GDA2020 is realised by gazetting an expanded AFN consisting of 109 GNSS CORS contributing to the Australian Regional GNSS Network (ARGN) and the AuScope network (refer to the GDA2020 Technical Manual for a list of these stations).

The UTM projection will continue to be used to project latitude and longitude to grid coordinates (Easting, Northing, Zone), albeit based on the new Karney-Krueger equations. These grid coordinates will be expressed in the Map Grid of Australia 2020 (MGA2020).

Following a transition period, GDA2020 is planned to be adopted by 1 January 2020, although most jurisdictions may decide to make the new datum available earlier. This move from GDA94 to GDA2020 will cause the horizontal coordinates of a mark to shift by approximately 1.8 m to the north-east (due to tectonic motion), while the ellipsoidal height will decrease by about 0.09 m (due to improvements in the ITRF over the last two decades).

AUSGEOID2020

In order to connect to the Australian Height Datum (AHD), it is therefore crucial to apply AUSGeoid2020 to GDA2020 ellipsoidal heights, while AUSGeoid09 must be used to convert GDA94 ellipsoidal heights. Due to the aforementioned 0.09 m difference in ellipsoidal heights between GDA94 and GDA2020, you should *never* mismatch AUSGeoid2020 with GDA94 or AUSGeoid09 with GDA2020.

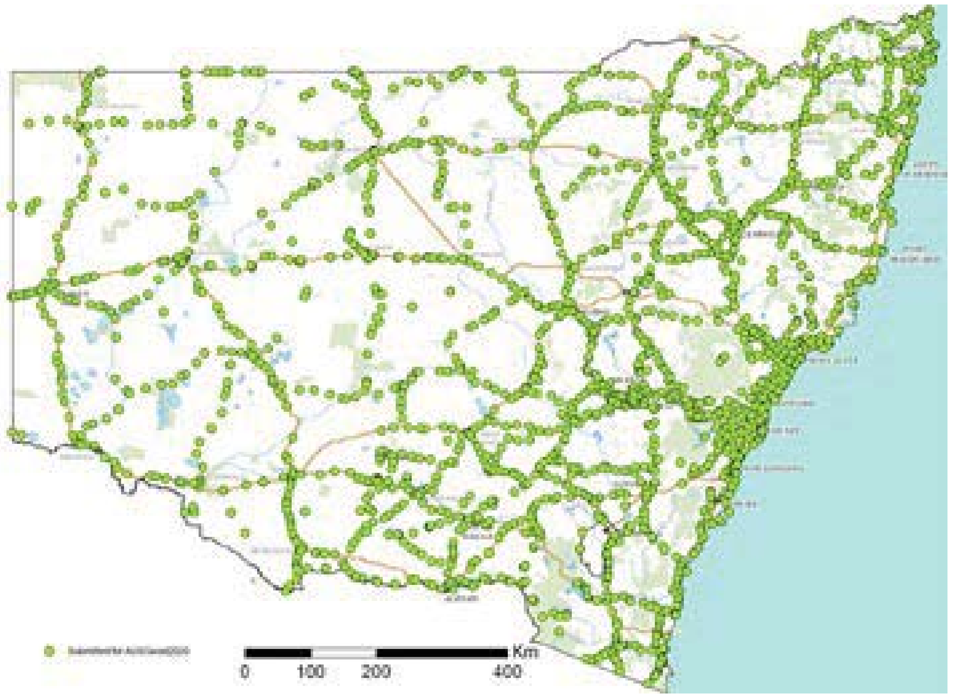

Figure 4: 6+ hour GNSS datasets observed on levelled marks by DFSI Spatial Services, contributing to AUSGeoid2020.

While AUSGeoid2020 has the same extent and density as its predecessor AUSGeoid09, it is based on a much larger and much more homogeneous dataset. For example, DFSI Spatial Services has collected over 2,500 extended (6+ hour) GNSS datasets on levelled benchmarks across NSW as part of its 'Saving AHD' project (Figure 4). These datasets feed into AUSGeoid2020, thereby helping to provide a much improved connection to AHD for GDA2020 ellipsoidal heights.

As a world-first, AUSGeoid2020 also provides a rigorous uncertainty value associated with the offset between the ellipsoid and AHD, varying as a function of location. In contrast, AUSGeoid09 only provides a constant uncertainty estimate.

EARTH-FIXED DATUMS

An earth-fixed datum accounts for the Earth's dynamics by allowing tectonic plates to move within it over time, i.e. it is 4-dimensional. It is fixed to the Earth but not its crust and therefore also known as a dynamic datum – however, this is a term to be avoided because the datum is not dynamic but the Earth is!

Consequently, the coordinates of a given ground mark are constantly changing. It is critical to attach a time stamp to each position (and also the observations) given in an earth-fixed datum, so a position given at a reference epoch can be propagated to the current or any other epoch using station velocities. Tagging observations and results with better metadata, such as date and uncertainty, can be interpreted as a 'love note to future users' and will no doubt be much appreciated.

The reference epoch represents a date and time that is conveniently agreed upon to assist with the meaningful transfer of coordinates, measurements and other parameters. ITRF, ATRF and WGS84 are examples of earth-fixed geocentric datums.

ITRF

The International Terrestrial Reference Frame (ITRF) is the most precise earth-centred, earth-fixed datum currently available – the global gold standard if you like. It was first introduced in 1988 and has since gone through 13 versions, including the current ITRF2014. The ITRF is updated regularly in order to account for the dynamics of the Earth and now sufficiently refined to ensure that the change between future ITRF versions is in the order of a few millimetres.

The epoch should be declared in decimal years, e.g. ITRF2014(2017.738) indicates a positon in ITRF2014 valid at 12:00 UTC on 27 September 2017. The decimal is calculated by UTC day of year (270) minus one, plus UTC time in the day (0.5 days), divided by the number of days in the year (365, considering that 2017 is not a leap year).

ATRF

The Australian Terrestrial Reference Frame (ATRF) will be a regional realisation of the ITRF, possibly based on the AFN sites within the context of the Asia-Pacific Reference Frame (APREF) network consisting of about 500 stations. As a consequence, Australian spatial information will be directly interoperable with GNSS measurements, i.e. mass-market applications will not see a discrepancy between global ITRF coordinates and Australian ATRF coordinates.

It is anticipated that the ATRF will be implemented from January 2020 with adoption planned to be complete by 2023. However, it is important to note that GDA2020 and ATRF will exist in tandem for the foreseeable future.

Practically, GDA2020 and ATRF can initially be thought of as one product – the former being fixed to epoch 2020.0, while the latter refers to the current epoch (or any other user-specified epoch). Over time, however, GDA2020 will meet the fate of all plate-fixed datums and become outdated as we slowly drift across the Pacific Ocean.

WGS84

The World Geodetic System 1984 (WGS84) is the nominal datum used by GPS. It is based on the WGS84 ellipsoid, which can generally be assumed identical to the GRS80. The WGS84 datum was introduced in 1987 and has since been refined several times to be closely aligned with the ITRF in order to prevent degradation of the GPS broadcast orbits due to plate tectonics.

For most purposes, WGS84 and the most current ITRF can be assumed identical. However, it should be noted that WGS84 is based on a much smaller number of globally distributed CORS and the level of agreement worsens as the time gap between WGS84 and the latest realisation of ITRF grows.

TRANSITION TO GDA2020 AND ATRF

The Intergovernmental Committee on Surveying and Mapping's (ICSM's) GDA Modernisation Implementation Working Group (GMIWG) is responsible for assisting with the transition to GDA2020 and ATRF (http://www.icsm.gov.au/gda2020/gmiwg.html).

This is achieved through stakeholder engagement and the provision of tools, technical resources and educational material in order to facilitate a smooth transition with minimal disruption to existing systems and processes. For example, a short animated video explains the basic concepts of datum modernisation in general terms (https://vimeo.com/191566518/f1daaae92d).

Following a transition period, it is envisioned that GDA2020 will be adopted by 1 January 2020, although most jurisdictions may decide to make the new datum available earlier. The move from GDA94 to GDA2020 will cause the horizontal coordinates of a mark to shift by approximately 1.8 m to the north-east, while the ellipsoidal height will decrease by about 0.09 m. In order to connect to AHD, it is therefore crucial to apply AUSGeoid2020 to GDA2020 ellipsoidal heights, while AUSGeoid09 must be used to convert GDA94 ellipsoidal heights.

The GDA2020 Technical Manual was released in July 2017. It provides detailed information about the new datum and its products, including AUSGeoid2020, GDA2020 transformation parameters, grids and tools. Gazettal of the coordinates for the 109 AFN sites realising GDA2020 is imminent, while AUSGeoid2020 and the transformation grids are currently being finalised at the national level.

The two national transformation grids (conformal only and conformal + distortion) will provide a simple and nationally consistent method to transform between GDA94 and GDA2020, and are ICSM's preferred method for transforming. The distortion component of these 1' by 1' grids is mainly caused by the different strategies applied by jurisdictions to propagate GDA94 coordinates from the AFN to the ground survey control network as well as surface movement of parts of the Australian crust. ICSM provides separate transformation recommendations for each State and Territory (see Table 3.4 in the GDA2020 Technical Manual).

It is important to note that these transformation grids are only provided in 2-dimensional format and therefore cannot be used to transform ellipsoidal height data. In order to transform ellipsoidal heights, it is recommended to convert your curvilinear coordinates to Cartesian coordinates, apply the 7-parameter transformation from GDA94 to GDA2020, and then convert back to curvilinear coordinates.

Looking further ahead, it is planned to move from a plate-fixed datum (GDA2020) to an earth-fixed datum (ATRF) from 2020 to fully reap the benefits of modern-day positioning infrastructure and services. However, GDA2020 and ATRF will operate together as a dual-frame system for the foreseeable future.

CONCLUSION

It is hoped that this article has clarified the terms GDA2020, AUSGeoid2020 and ATRF. The ongoing datum modernisation will provide a much improved Australian national datum that will ensure that Australia is well positioned into the future. The modernised geodetic foundation will allow users to make the most of modern satellite-based positioning, open up new industries, increase productivity and hopefully make life easier for all of us.

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