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## GMIWG ADVICE TO JURISDICTIONS REGARDING WEB MAPPING AND THE USE OF WGS 84 / WEB MERCATOR – Updated June 2020

### INTRODUCTION

For several years Australian jurisdictions have been aware of challenges with mixing GDA94 and GDA2020 data through the web mapping medium. The issue originates from early days of web mapping when WGS 84 and its common ‘Web Mercator’ projection were adopted globally as the default or hub datum for web mapping. In 1994, GDA94 and WGS 84 were considered equivalent, so null transformation parameters between GDA94 and WGS 84 were introduced as EPSG codes.

Since WGS 84 is a ‘dynamic’ (or ‘time-dependent’) datum in which coordinates of features slowly change as a result of ongoing tectonic motion, this equivalence with the ‘static’ GDA94 slowly degraded until it remained accurate only at the metre level. However, since WGS 84 was generally used for low accuracy positioning or web-mapping applications (meter level or greater) no processes were compromised.

When GDA2020 was defined almost 25 years later, a similar argument was employed to create another null transformation between GDA2020 and WGS 84, since WGS 84 was now equivalent to GDA2020. As a consequence, the EPSG registry describes  $GDA94 \approx WGS\ 84 \approx GDA2020$  for low accuracy applications. **This equivalence doesn’t hold for higher accuracy applications.**

With the increased use of higher accuracy web mapping applications, we also witness an emerging multi-datum and multi-epoch environment characterised by a mixture of authoritative ‘static’ and ‘dynamic’ datums. The persistence of the null transformation paradigm described above and the conventional treatment of WGS 84 as a static datum will cause misalignment of GDA94 and GDA2020 data for higher accuracy data sets, typically those with accuracies better than one metre.

### INTERNATIONAL ENGAGEMENT

GMIWG formed a subcommittee in mid-2019 to further explore solutions to the null transformation issue and engage with EPSG and other key industry participants. Recognising that the issue is a multinational one, not just an Australian problem, the subcommittee established connections and dialogue with the EPSG maintainers, the Open Geospatial Consortium (OGC) and the International Standards Organisation (ISO).

These relationships culminated with an invitation to address a technical meeting of the OGC in Banff, Canada in September 2019 on these matters in conjunction with the EPSG. ICSM funded the attendance at that forum and the presentations and face to face engagement generated some tangible outcomes and resolutions. The subcommittee has continued to meet and engage remotely with the overseas community since Banff.

## THE FUTURE OF WGS 84: AN ENSEMBLE OF LOW ACCURACY FOR MOST USERS

The problems troubling WGS 84 result from more than just its (often ignored) dynamic nature. What most spatial data users call WGS 84 is actually also a collection or ‘ensemble’ of at least 6 significantly different realisations of WGS 84, starting from an initial version based on pre-GPS satellite technologies and with subsequent realisations aligned to 4 different ITRF realisations to date.

In practice, since 1997, WGS 84 has been maintained within 10cm of the current (at the time) ITRF. The result is a group or ‘ensemble’ of similar datums whose members have different fundamental definitions, and significant differences in coordinates, (up to 0.7m). Additionally, while the specific realisations are accurate at the decimetre level, in practice most users only access WGS 84 at the metre-level anyway, via stand-alone GPS positioning using autonomous receivers such as phones or other personal devices. For the purpose of this document, metre-level is considered low-accuracy.

Despite these issues, WGS 84 was adopted and remains the defacto standard largely due to accessibility and the built in dependencies by software platforms. WGS 84 provided access to the first mass market positioning capabilities, and until recently that mass market had no choice and limited knowledge about accessing positioning of increased accuracy. Engagements with the international community have indicated that WGS 84 will remain a significant component of low-accuracy positioning and web-mapping applications.

However, the increase in availability of augmented high accuracy positioning systems is driving the need to cater properly for time-dependence; The development of the dynamic [Australian Terrestrial Reference Frame \(ATRF\)](#) to support the centimetre-level ‘anytime anywhere’ [Positioning Australia](#) service and the associated economic benefits of these capabilities are a case in point. And Australia is not alone, with the North American market anticipating its own time-dependent datums by 2022.

As a result, IOGP has determined to describe [WGS 84 \(EPSG:6326\)](#) as a ‘datum ensemble’ in its upgraded EPSG registry v10.0. This decision formally recognises the remarks that have accompanied this description for many years. This will affect ensemble WGS 84 CRS (EPSG: 4326, 4978 and 4979) and any associated projections or derivative CRS, while specific realisations such as the current WGS 84(G1762) will remain unchanged. This decision reflects the current common usage of a generic ‘WGS 84’: when data is associated with ‘WGS 84’, it may not be possible to identify which specific WGS 84 realisation was used. The low internal accuracy of an ensemble is then further degraded through the common practice of ignoring Coordinate Epoch and tectonic movement when using lower accuracy reference frames.

The issue becomes one of education. Until all spatial data users are provided with the capability to adopt a truly time-dependent datum (such as ATRF or ITRF) for positioning applications at all accuracies, then spatial data and applications must be divided into two notional (and subjective) camps: high and low accuracy, and their data must be treated accordingly. In the long term, all users must be able to easily access high accuracy datums to benefit from the application of high accuracy data.

## SHORT TERM: OPTIONS TO CATER FOR WGS 84 DATA FOR IMMEDIATE APPLICATION

Australian spatial information users are currently faced with the practical issue of overcoming data misalignments resulting from the low accuracy WGS 84 ensemble paradigm. From discussions across Australia's spatial industries and jurisdictions, it is apparent that there is no single solution which will address all current issues.

There are, however, a number of common scenarios which can be addressed in the short term for data custodians and consumers of WGS 84 or Web Mercator data. The following options may be considered as they best apply to their data. In all cases, due care must be taken to properly determine and record the origin of the data, and the known or estimated accuracy of the data.

- 1) Many authoritative datasets or services are currently supplied as 'WGS 84' for historic reasons to support web mapping. However, it is not currently possible to distinguish using CRS metadata alone (e.g. EPSG codes) whether the version of WGS 84 or Web Mercator supplied is based on GDA94, GDA2020 or another data epoch. As a result some state and territory authorities and other data custodians have decided to supply data explicitly as "WGS 84 equivalent to GDA94". This is intended to support the significant amount of data currently available in this format, until a medium term solution provides additional capabilities to align WGS 84 data based on both GDA94 and GDA2020.

Ask your data supplier for more information about data nominated as WGS 84.

- 2) Where the origin of the data is well known, users may reconstruct a more accurate description of datum (and coordinate epoch) of the data. For example, data supplied as "WGS 84 equivalent to GDA94" can be re-labelled as GDA94. In contrast, data captured on WGS 84 with a handheld GPS receiver on 14 February 2020 is likely to have been observed using the latest WGS 84 revision WGS 84(G1762)@2020.045. If necessary, such data can be accurately transformed or propagated to another datum of choice.

Note: Care must be taken with augmented, differential, PPP, RTK or other specialised services which 'improve' or 'correct' GPS / GNSS stand-alone positioning and provide results to better than 1 metre. Often these data are collected with reference to another datum such as IGS, ITRF, ATRF or even GDAXX) while still nominated as WGS 84 by software. Refer to your software and positioning provider for more information.

- 3) Where the origin of WGS 84 data is not well known, users may:
  - a) Rectify data onto a dataset of known datum, coordinate epoch and accuracy;
  - b) Accept data as low accuracy in the WGS 84 ensemble and nominate as such in metadata;
  - c) Transform from WGS 84 ensemble to GDA94 or GDA2020 using currently published EPSG NULL transformations and accept the nominal 3 metre accuracy of the resulting data. Misalignments will remain, reflecting the low accuracy of the data and or datum.

For more information on appropriate metadata handling, including examples, refer to the Australian advisory '[Preparing metadata for GDA2020 and the AGRS](#)' from the [ICSM Metadata Working Group](#)

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## MEDIUM TERM: DEVELOPMENT OF EPSG TRANSFORMATIONS AND SOFTWARE UPDATES ANTICIPATED ADOPTION DURING 2021

As already noted, many authoritative datasets and services intending to supply accurate GDA94 and GDA2020 data are stored and supplied as 'WGS 84' Web Mercator data for historic reasons including an increased efficiency in high-volume web service delivery. In addition, some software platforms and data formats *require* data to be stored as WGS 84.

Web services, in general, allow the user to define the CRS of data delivery, with transformation of data undertaken at the server side prior to delivery. Unfortunately, web services based on WGS 84 data cannot currently be delivered in both GDA94 and GDA2020 due to the current EPSG Null transformation limitation. Indeed, a web service stored as GDA2020 suffers a similar fate and cannot be delivered as 'WGS 84 equivalent to GDA94'.

A medium term approach is required, in which new EPSG codes are created and widely supported in software in order to provide meaningful transformation options to the WGS 84 ensemble. This will require collaboration between government, EPSG, software vendors and users in order to:

- 1) Create and adopt additional EPSG codes which allow the user to transform to their choice of:
  - a. WGS 84 equivalent to GDA94 (i.e. at epoch 1994.0)
    - i. GDA2020 <7P or NTV2-CPD> WGS 84
    - ii. GDA94 <via existing NULL Tf> WGS 84
  - b. WGS 84 equivalent to GDA2020 (i.e. at epoch 2020.0)
    - i. GDA94 <7P, or NTV2-CPD> WGS 84
    - ii. GDA2020 <via existing NULL Tf> WGS 84
- 2) Explicitly define and communicate the nature and origin of WGS 84 data where it is used as a proxy for other authoritative datums, i.e. in web mapping and web services. In most cases, this will be equivalent to a particular static datum, e.g. 'WGS 84 equivalent to GDA94' or 'WGS 84 equivalent to GDA2020'. WGS 84 associated metadata should declare this explicitly.

Once these medium term steps are addressed and the EPSG codes made available through software updates, users will be able to mix and match datasets from different Australian datums / epochs, depending on the users' level of sophistication and software platform. This will also support the continued request of data in WGS 84 for web mapping in current applications.

In the case of most Australian land agencies, the software employed to provide data is the ESRI platform. GMIWG has been engaged with ESRI Australia and ESRI US for some time now, and continues to work cooperatively towards solutions, including the joint development of educational frameworks and content for jurisdictions to use and disseminate. GMIWG has also worked with QGIS developers to address aspects of GDA2020 implementation and will engage with all platforms as required.

It is important to note that this medium solution does NOT support all known WGS 84 applications. For example, there is much GPS / GNSS positioning data gathered in real-time in WGS 84(G1762), or other

higher accuracy datums, yet nominated as WGS 84 or Web Mercator. It is imperative that a longer-term solution to adopt true time-dependent capability in software is still pursued.

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## **LONG TERM: ADOPT TIME DEPENDENCE IN SOFTWARE AND STANDARDS, ADVOCACY ONGOING AVAILABLE WITHIN 5 TO 10 YEARS**

The long term solution is to adopt the proper treatment of time-dependence across standards and software. This remains a technical and implementation challenge on which Australia will continue to strongly advocate a position.

Recent deliberations with major software providers at the international level have demonstrated a broad acceptance that WGS 84 is not a suitable long-term platform on which to base modern spatial information management systems. Similarly, Web Mercator as a mapping projection is known to have significant deficiencies and should be replaced with a more suitable alternative. Moving software onto a more appropriate and time-dependent paradigm is imperative, but will take considerable time and investment.

The International Standards Organisation has also already been working toward this long term solution. ISO19111 *Referencing by Coordinates* was updated in 2019 to include all the necessary framework for time-dependent coordinate operations and dynamic datums. In a similar fashion, ISO19115 *Geographic Information – Metadata* is currently under review to require Coordinate Epoch for the unambiguous description of coordinates in dynamic datums. Those updates are expected within the year.

While it is recognised that changes away from the WGS 84 paradigm are in their infancy, Australia and GMIWG are in a unique position to demonstrate and advocate for the benefits of high accuracy and time-dependent datum in a world of modern, high accuracy positioning for the mass market.

As we continue working toward this longer term solution, adopting and implementing the short-term, medium-term and educational components of this advisory are of utmost importance.

### **TIMING**

The timetable for a medium solution to be available depends on the following factors, not all of which are within the control of GMIWG:

- Development of new transformations and submission to EPSG for consideration.
- Consideration by EPSG and adoption for publication (likely several months).
- Ingestion by software houses and release for customers (timing unknown at this stage).
- Completion of international standards and metadata standards (within the year).
- Deployment / adoption by jurisdictional land agencies (timing variable)

The timing of the long term solution is contingent on the acceptance by the international community of the need for change, and the collective will to execute this. Australia will continue to engage and advocate for an improved treatment of datum use in web mapping by software.

Glossary of Terms –

Term	Acronym	Definition
The [Australia and New Zealand] Spatial Information Council	ANZLIC	The Spatial Information Council is a joint initiative of the Australian and New Zealand Governments, and the State and Territory Governments of Australia. ANZLIC is the peak Government body in Australia and New Zealand with the core responsibility for the stewardship of spatial information.
Australian Plate Motion Model	APMM	A 2-dimensional model which can be used to propagate GDA2020 coordinates through time in accordance with the movement of the Australian tectonic plate, to ATRF.
Australian Terrestrial Reference Frame	ATRF	A regional densification of the International Terrestrial Reference Frame. ATRF is a time-dependent reference frame, defined from a large number of permanent CORS on the Australian mainland and external territories. ATRF is equivalent to GDA2020 at 01/01/2020 and changes over time according to the Australian Plate Motion Model. The extent of ATRF is the same as GDA2020.
Coordinate Epoch	-	Epoch to which coordinates in a dynamic coordinate reference system are referenced; The time-stamp at which the coordinate apply. Note, this is often but not always equal to the date of capture, and can be changed by propagating coordinates through time to another Coordinate Epoch.
Coordinate Reference System	CRS	A coordinate reference system that is related to an object or objects by a datum. A CRS is typically referenced in Web Service calls by an EPSG code.
Datum	-	Datum (more recently called a Reference Frame) is a mathematical model of the earth that defines the origin, scale and orientation of a coordinate system against which features can be represented as coordinates.
Dynamic Datum or more appropriately: “Time-dependent Datum”	-	A reference frame in which the defining parameters include time evolution. With a dynamic datum, the reference frame is fixed to the earth as a whole. As the earth’s tectonic plates move (by a few centimetres a year), a feature’s coordinates also change to reflect that movement. Examples include the WGS 84 datum used by Global Positioning Systems (GPS), and the International Terrestrial Reference Frame (ITRF).



Term	Acronym	Definition
Datum Ensemble	-	A group of multiple realizations of the same terrestrial or vertical reference system that, for approximate spatial referencing purposes, are not significantly different
Epoch		A point in time, as applied to time dependent datums, expressed in decimal years to at least 2 decimal places. Example 2017-03-25 in the Gregorian calendar is epoch 2017.23.
European Petroleum Survey Group Code	EPSG Code	Online database that contains definitions of numerous datums and map projections, along with formulas to translate between them. Each is uniquely identified via an EPSG code. See <a href="https://www.epsg-registry.org/">https://www.epsg-registry.org/</a> Note that ISO 19127:2019 has been developed to further standardise this information and will in future replace the EPSG defacto standard
Global Positioning System / Global Navigation Satellite Systems	GPS / GNSS	Satellite delivered navigation systems which provide geo-spatial positioning with global coverage, allowing small autonomous receivers to determine position, altitude and time.
Geocentric Datum of Australia 1994	GDA94	The national Australian mapping datum in force from 1994 to 2017, superseded by GDA2020.
Geocentric Datum of Australia 2020	GDA2020	The current Australian mapping datum, first gazetted by the Commonwealth in 2017 in the National Measurement (Recognised-value Standard of Measurement of Position) Determination 2017.
Map projection		Coordinate conversion from the earth's ellipsoidal coordinate system to a plane.
Open Geospatial Consortium	OGC	The Open Geospatial Consortium is an international not for profit consortium of over 535 companies, government agencies and universities participating in a consensus process to develop open, publicly available interface standards.
Static Datum		A reference frame in which the defining parameters exclude time evolution. With a static datum, the reference frame is locked to the regional tectonic plate; features on a static datum have coordinates which remain the same over time. For example, both GDA94 and GDA2020 are static datums for Australia.



Term	Acronym	Definition
Web Mercator		WGS 84 Web Mercator (EPSG::3857) is the defacto standard projection used in web-mapping. (Its official name is “Pseudo Mercator”). WGS 84 Web Mercator is projected from the WG84 datum ensemble (EPSG::6326).
World Geodetic System	WGS 84	<p>WGS is a geocentric mapping datum first developed by the United States Department of Defense [sic] in 1960 (as WGS60). WGS has since evolved with continued improvements to the measurement and modelling of the global system and is currently referred to as WGS 84.</p> <p>The ‘WGS 84 datum’ is not a single unique reference frame; it has been updated six times to date, with significant changes (up to 0.7m) especially between older realisations. WGS 84 is also time-dependent, changing coordinates in Australia at 7 cm per year. Together, these realisations form a datum ensemble, which should be taken to have an accuracy of several metres, and to be appropriate for approximate spatial referencing purposes only.</p>