Which GDA94-GDA2020 transformation grid should NSW surveyors use?

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The Geocentric Datum of Australia 2020 (GDA2020) is now the official national datum of Australia, but how should surveyors bring their existing datasets from GDA94 to GDA2020?

The Intergovernmental Committee on Surveying and Mapping (ICSM) recommends transformation grids, which can be easily obtained online and used with existing software, as a simple and nationally consistent method for transforming between Australian datums. To this end, two grids have been produced to cater for different realisations of GDA94.

With a focus on NSW, this article explains the composition and purpose of each GDA94-GDA2020 transformation grid. It identifies accuracy and data origin as the two key factors determining their appropriate use.

Performance analysis results indicate that both grids are fit for purpose in NSW when used in the appropriate circumstances. Prior to transformation, users must know if their existing GDA94 dataset is affected by known GDA94 distortions (present in the Survey Control Information Management System, SCIMS), or if those distortions have already been removed by other methods.

Background

In October 2017, GDA2020 was gazetted as Australia's new, improved national datum. When spatial information users wish to adopt the new datum, they may consider transforming their legacy datasets from the now superseded GDA94 to GDA2020. The following recommendations apply whether transforming data permanently to GDA2020, or instead using a transformation on-the-fly to combine data from multiple datums at the time of application.

In recent years, spatial data utilisation has soared, aided by open-source Geographic Information Systems (GIS) and government efforts to deliver open spatial data. As a consequence, the important role datum plays in meaningfully aligning data from a variety of sources is highlighted.

Failure to correctly manage datum across multiple datasets could compromise any analysis. Further, decimetre-accurate or better real-time positioning (e.g. RTK, DGNSS or SBAS-based positioning) now means tagging datasets with appropriate metadata, such as datum and even date observed, has become critical. The user must know their data, know their date and know their datum.

In Australia's previous datum modernisation efforts, transformation grids were utilised as a simple and efficient method for transforming datasets to the new national standard. This strategy is now continued to aid uptake of GDA2020 from GDA94 with the development of two transformation grids and a number of tools, plug-ins and services.

GDA94-GDA2020 transformation: The harder way

A conformal (often called a similarity) transformation can be used to transform between reference frames. This transformation owes its name to its characteristic of preserving angle and shape throughout the process.

The 3-dimensional conformal transformation between GDA94 and GDA2020 is described in the GDA2020 technical manual and accounts for the difference in scale, rotation and translation between reference frames. This transformation method is suitable for 3D data and requires coordinates to be expressed in an earth-centred Cartesian (XYZ) system.

The transformation can be computed using just 7 parameters. However, the formula can appear daunting to users without a background in geodesy and cannot be applied to 2D data. Furthermore, conformal transformations cannot compensate for localised survey network distortion because this method only accounts for simple mathematical differences, and tectonic plate motion, between the frames.

GDA94-GDA2020 transformation: The easier way

A grid transformation is a 2-dimensional method of transforming between reference frames and is ICSM's preferred method of transforming between Australian datums. When creating the grid, transformation components (i.e. a series of latitude and longitude shifts across all of Australia) are initially computed across a grid at a set interval.

Given a transformation grid, various interpolation methods can then be applied at the user end to compute shifts at an exact user-determined location (Figure 1). Bi-linear interpolation is adopted by most GIS packages, but other interpolation strategies are possible.

Just like the similarity transformation, a grid transformation is considered 'reversible', i.e. each transformation can be undone by applying the grid parameters in the opposite direction. It is also 'traceable' and 'reproducible' by all users.

Transformation grids in exactly the same format were produced to aid users in the transition from the Australian Geodetic Datum (e.g. AGD66, AGD84) to GDA94. As such, the new GDA94-GDA2020 transformation grids are backward compatible with any existing software that can accept a user-input grid.

Two GDA94-GDA2020 transformation grids have been developed: 'conformal only' and 'conformal and distortion'.

Transformation grids

For some time, DFSI Spatial Services has been simultaneously providing two realisations of GDA94 for use in NSW. The first, based on the original GDA94 adjustment, termed GDA94(1997) in NSW, is available via SCIMS and suffers from adjustment deficiencies in the original GDA94 definition, and the subsequent accumulation of distortion in further adjustments.

The second realisation, based on the most recent national realisation of GDA94, termed GDA94(2010) in NSW, is available via more modern positioning technologies such as CORSnet-NSW and AUSPOS, and is effectively distortion-free. Because of this difference, the NSW Surveyor General's Directions recommend performing site localisations to align CORSnet-NSW-based surveys (distortion-free) to SCIMS (with inherent GDA94 distortion).

Consequently, two transformation pathways from GDA94 to GDA2020 were required: one which assumes distortion-free input data, i.e. GDA94(2010), and one which compensates for the localised distortions embodied in SCIMS, i.e. GDA94(1997).

Regarding 'site localisation' versus 'site transformation' terminology: In previous articles, DFSI Spatial Services used the term 'site transformation' to describe the process of matching GDA94(2010) to GDA94(1997), e.g. from CORSnet-NSW to SCIMS. This article uses the term 'site localisation' to avoid any potential confusion regarding transforming between reference frames compared to transforming a site to match local survey control.

Conformal only transformation grid

The conformal only transformation grid, often denoted 'con', is simply a grid representation of the similarity transformation. It contains the latitude and longitude shifts between GDA94 and GDA2020 for each grid node, based solely on the 7-parameter similarity transformation parameters.

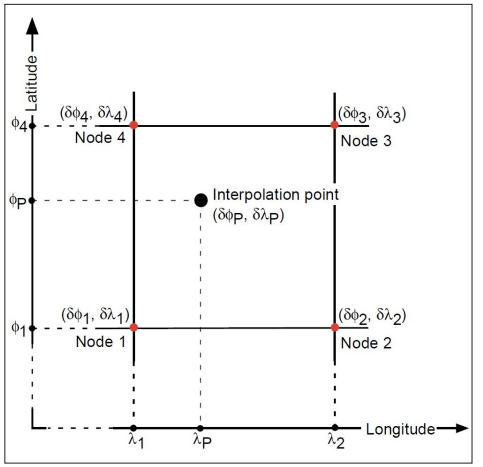


Figure 1: Grid interpolation principle (courtesy of Phil Collier).

Conformal and distortion transformation grid

The conformal and distortion grid, often denoted 'cpd' for conformal ***plus*** distortion, is designed to compensate for any known localised distortions present in the control survey networks of each state and territory in Australia. In NSW, DFSI Spatial Services has contributed approximately 26,000 marks, which are common between the GDA94 and GDA2020 networks, in order to compute the localised distortion across NSW (Figure 2).

The distortion component at each grid node has been computed based on the surrounding input data falling within a search radius of 45.5 km. If there are no input data points within this critical distance, the computation reverts to a conformal only solution and no distortion will be apparent.

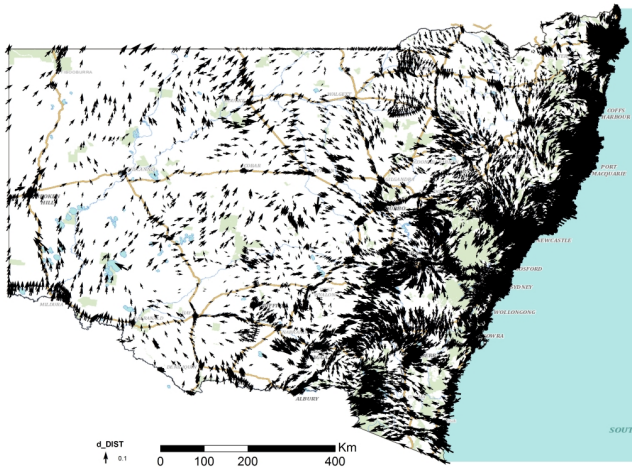
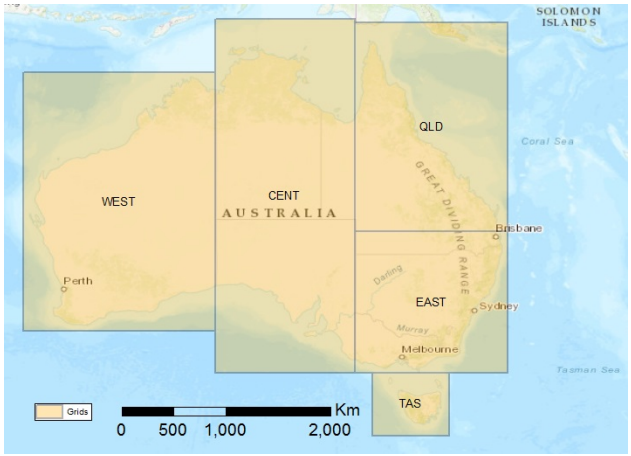


Figure 2: GDA94(1997) to GDA94(2010) distortion vectors across NSW in metres.



(Left) Figure 3: Transformation grid composition and extents.

(Below) Figure 4: ASCII sample sub-grid in NTv2 format. Reliability values of -1 denote that no reliability figure could be computed (conformal only solution).

Sub grid header

SUB_NAME	EAST_DC5
PARENT	NONE
CREATED	17102017
UPDATED	21112017
S_LAT	-140940.0
N_LAT	-97200.0
E_LONG	-554760.0
W_LONG	-507240.0
LAT_INC	54.0
LONG_INC	54.0
GS_COUNT	714491

Sub grid metadata

Sub grid extents (arc-seconds)

Grid interval (arc-seconds)

Total nodes in sub grid

Sub grid Transformation components (left to right): Latitude shift, Longitude shift, Latitude reliability, Longitude reliability (arc-seconds)

0.047533	-0.022141	0.000471	0.000206
0.047532	-0.022074	0.000473	0.000137
0.047536	-0.022083	0.000045	0.000103
0.047539	-0.022088	0.000046	0.000102
0.047782	-0.022046	-1.000000	-1.000000
0.047785	-0.022056	-1.000000	-1.000000
0.047788	-0.022066	-1.000000	-1.000000
...			

Grid composition and extent

Both national transformation grids are divided into five non-overlapping sub-grids (Figure 3), with grid nodes every 54 arc seconds (about 1.5 km). Currently, the transformation grids cover mainland Australia and Tasmania. Several offshore territories, such as Lord Howe, Norfolk, Christmas and Cocos (Keeling) islands, are not included at this stage.

NTv2 format

The National Transformation version 2 (NTv2) format was developed by the Canadian Geodetic Survey of National Resources Canada for the North American Datum transition from NAD27 to NAD83. Since then, NTv2 has been widely adopted for datum transformations by many international survey organisations and is supported in most GIS software packages.

It provides a simple, efficient and comprehensive file structure for storing latitude and longitude shift parameters for each grid node (Figure 4). The file structure is relatively small because the coordinates of each grid node are not stored.

Instead, the grid extents, grid interval and total number of grid nodes are given, linking the node shifts to their coordinates through a pattern specifying their order of occurrence. The NTv2 format is compatible with sub-grids, which can be used to alter the overall coverage area or densify areas with high rates of change.

In addition to latitude and longitude shifts, NTv2 provides space to report on the known or estimated accuracy of these shifts. In the GDA94-GDA2020 conformal and distortion transformation grid, this is a measure of the consistency (i.e. reliability) of the distortion surrounding the grid node rather than an absolute accuracy statement.

Furthermore, reliability figures can only be computed where distortion is modelled, and hence grid nodes without any distortion influence exhibit a reliability figure of -1. It should be noted that the GDA94-GDA2020 transformation grids are supplied as binary grid shift (.gsb) files and are not human readable unless converted to text.

EAST sub-grid (conformal and distortion) behaviour

NSW users will primarily be concerned with the performance of the EAST sub-grid, which covers the whole of NSW, ACT, Victoria, as well as some of Queensland and South Australia. The performance of the conformal only grid is uniform and does not require further review.

The performance of the conformal and distortion transformation grid, however, varies with location. This variation is mapped in Figure 5 and provides a useful indication of the magnitude of distortion across NSW and Victoria.

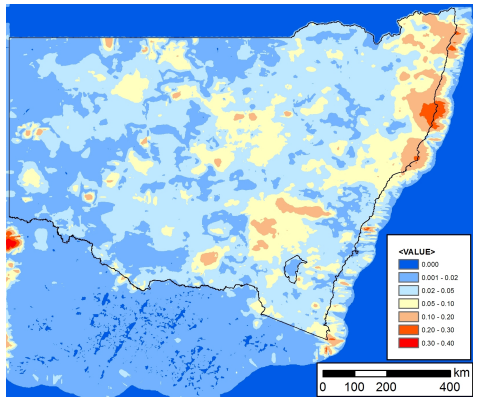


Figure 5: Distortion component across the EAST sub-grid in metres.

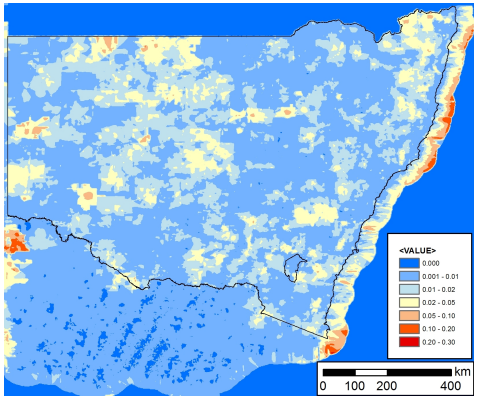


Figure 6: Reliability component across the EAST sub-grid in metres.

In addition, reliability figures have also been mapped (Figure 6), which indicate the consistency of distortion within each grid node computation.

How do I access and apply the grids?

A suite of transformation products and tools has been published online by ICSM (http://www.icsm.gov.au/datum/gda-transformation-products-and-tools). Users are guided towards the grid (.gsb) files, an online transformation service that can be operated with simple 'drag-and-drop' functionality, as well as software and plug-ins.

How do I decide which grid to use?

The accuracy and the origin (i.e. provenance) of the dataset both need to be considered when applying a transformation grid from GDA94 to GDA2020. The difference between GDA94 and GDA2020 horizontal positons in NSW is about 1.5 m. Therefore, any dataset referenced to GDA94 with an accuracy of worse than a few metres is already GDA2020 compatible and does not require transformation.

However, users may still choose to transform this data to avoid introducing an extra 1.5 m of known error. In addition, as with all decisions regarding dataset transformation, it is important to consider the topological relationship between your datasets, e.g. if your GIS has established coincident locations between different datasets. Regardless of their accuracy, it is best to transform all ***related*** datasets using the same transformation parameters.

In NSW, the largest known horizontal distortions are in the order of about 0.3 m. The conformal only transformation grid is sufficient for any GDA94 data with an accuracy of 0.5 m (but either grid could be applied at these accuracy levels).

For data more accurate than 0.5 m, the origin of the data must be considered. If the data is derived from local (SCIMS) survey control, then the conformal and distortion transformation grid is appropriate.

If the data is derived directly in GDA94(2010), e.g. from CORSnet-NSW (without a site localisation) or from AUSPOS, then distortions in local survey control are already eliminated and the conformal only transformation grid is appropriate. Figure 7 provides a decision-making flow chart to guide NSW users in this regard.

If the origin of a GDA94 dataset is unknown, then it is not possible to transform to GDA2020 and retain a nominal accuracy better than the known local distortions. For this reason, metadata is critical and has been affectionately described as a "love note to the future".

Where the original survey measurements (with connections to GDA2020 stations) are available, a new least squares network adjustment based on GDA2020 control will provide the most accurate and rigorous solution. However, this can be far more time consuming and is not applicable to point-based datasets.

Evaluation of the conformal only transformation grid

The conformal only transformation grid was evaluated by transforming the 250,000 marks across Australia comprising the GDA2020 national adjustment from GDA2020 to GDA94 using the 7-parameter conformal transformation, and then back to GDA2020 with the conformal only transformation grid. The resulting coordinates were compared against the original GDA2020 coordinates.

The results show that the conformal grid will introduce a negligible amount of computational error when compared to the 7-parameter conformal transformation: a maximum difference in Easting and Northing of ±0.001 m, with standard deviations of 0.0003 m.

The conformal only transformation grid is considered fit for purpose for use in NSW. It may be simpler to use than the alternative 7-parameter conformal transformation method.

Evaluation of the conformal and distortion transformation grid

Two tests were conducted to evaluate the conformal and distortion grid across NSW, based on 26,000 common points as well as independent (terrestrial) data.

Test 1: Common stations between SCIMS and GDA2020

The conformal and distortion transformation grid was first evaluated by transforming the coordinates of

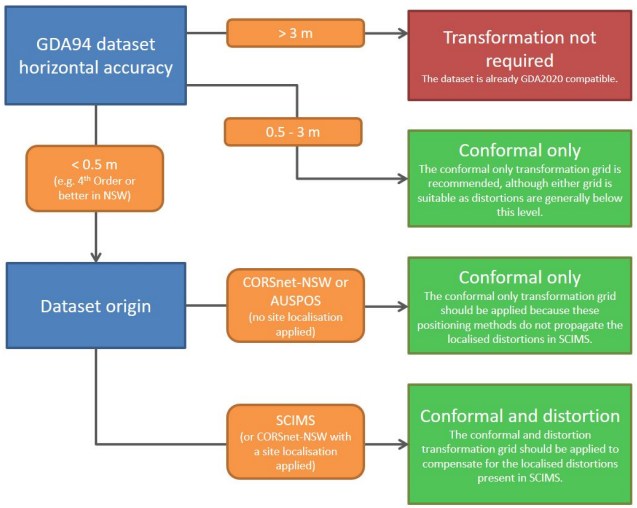


Figure 7: Decision-making flow chart for selecting a GDA94-GDA2020 transformation grid in NSW.

approximately 26,000 SCIMS marks from GDA94 to GDA2020, and comparing against the adjusted GDA2020 coordinates. The chosen marks were part of the GDA2020 national adjustment and required SCIMS coordinates with horizontal Order 4 or better and GDA2020 coordinates with horizontal Positional Uncertainty (PU) of 0.1 m or better (1 sigma).

We found that 86.3%, 96.4% and 99.6% of SCIMS-to-GDA2020 transformed coordinates are within 0.01 m, 0.02 m and 0.05 m, respectively, of the expected GDA2020 adjusted coordinates. There are no notable differences between Easting and Northing components.

Differences of up to 0.27 m are evident at a very small number of the marks analysed (i.e. < 0.1%). These rare outliers occur where SCIMS behaves inconsistently, e.g. where a remote trigonometrical station was re-surveyed and its position improved, but its eccentric marks were not updated in SCIMS, altering the relationship between trigonometrical station and eccentric marks

Test 2: Independent data

CORSnet-NSW started delivering services in both GDA94 and GDA2020 in February 2019, while DFSI Spatial Services is planning to make available GDA2020 (along with GDA94) in SCIMS from July this year. Some early proof-of-concept studies were carried out to assess the value in transforming versus readjusting our terrestrial 'street corner' traversing networks in SCIMS, which currently are not in the GDA2020 national adjustment.

Terrestrial survey networks in six NSW towns containing a total of 1,881 direction sets, 4,337 distances and 2,635 height differences at 2,759 stations were examined in this evaluation. Each network was readjusted based on constraints from the national GDA2020 adjustment. The results of the adjustments were compared with the results of simply transforming the SCIMS coordinates via the conformal and distortion transformation grid.

On average, the difference in horizontal position between the two methods was 0.006 m, with the largest being 0.04 m. This analysis provides a high level of assurance that transforming SCIMS control will deliver a result close to the more rigorous (and far more time-consuming) method of readjusting.

The conformal and distortion transformation grid is considered fit for purpose for use in NSW. Again, it may be simpler to use than the alternative 7-parameter conformal transformation method, which has the additional disadvantage that it cannot compensate for local distortions.

FAQs

In order to provide further advice to the profession, we have compiled frequently asked questions related to the GDA94-GDA2020 transformation grids in NSW. More information can be found in the GDA2020 technical manual and on the ICSM website.

Why are there two grids?

Separate grids are required for the different realisations of GDA94 used in NSW: GDA94(1997), which is based on SCIMS and includes localised distortions of up to 0.3 m horizontally, and GDA94(2010), which is sympathetic with AUSPOS and CORSnet-NSW and is essentially distortion-free.

How do the grids differ?

The conformal only transformation grid is the 2D equivalent of the 7-parameter similarity transformation. It accounts for mathematical differences between reference frames and does not compensate for any localised distortions in the state or territory realisations of GDA94. The conformal and distortion transformation grid is composed of the conformal component and a distortion component that will compensate for any known localised distortions in the state and territory realisations of GDA94.

What does conformal mean?

Shape is preserved throughout the transformation, i.e. the 7-paramater transformation accounts for the difference in scale, rotation and translation between each reference frame. The term 'similarity transformation' is often used to describe a conformal transformation.

Do any other jurisdictions besides NSW have distortions?

Yes, to varying extents. Both transformation grids cover all states and territories across mainland Australia and Tasmania.

What happens at the NSW-ACT/QLD/SA/VIC border?

Since the GDA94 adjustment, different jurisdictions have adopted different business rules for maintaining and propagating their survey networks. For example, NSW chose to preserve and hold fixed the original GDA94 adjustment (and its distortions) while Victoria and Queensland have readjusted their networks over time to remove distortions.

The grid computation strategy is such that each node is influenced by contributing marks within 45.5 km, weighted according to proximity. This ensures the behaviour of the grid accurately represents the survey networks of each jurisdiction.

There is one exception to this rule: Queensland, having periodically readjusted their survey network to remove distortion, opted for zero distortion to be present in both transformation grids across Queensland. In effect, this means distortions from NSW, SA and NT were only able to influence the first grid node into Queensland. After this point, the grid nodes revert to a conformal only solution.

Is there a difference between using the 7-parameter conformal transformation and the conformal only transformation grid?

There is no significant ***horizontal*** difference between the conformal only transformation grid and the 7-parameter transformation. However, it is important to note that the 7-parameter transformation provides a 3-dimensional transformation whereas the grid transformation is only 2-dimensional.

How should I transform 3D data?

3-dimensional data can be transformed using the transformation grids provided, but only the latitude and longitude components will be affected, i.e. height will be preserved (remains unchanged). If the height component is referenced to the Australian Height Datum (AHD), no height transformation should be undertaken between GDA94 and GDA2020 anyway.

The 7-parameter transformation can provide a true 3D transformation for data with ellipsoidal heights, but will not compensate for localised distortions. The GDA2020 technical manual recommends users with ellipsoidal heights first convert their data to earth-centred Cartesian (XYZ) coordinates, apply the 7-parameter conformal transformation, and then convert back to geodetic or grid coordinates as required. The manual provides the formulae and a number of spreadsheets to perform these computations.

It is possible to apply a simple 'block shift' of -0.095 m to transform ellipsoidal heights from GDA94 to GDA2020, but each user will need to assess if this approximation is suitable for their datasets and applications. Across NSW, the ellipsoidal height difference from GDA94 to GDA2020 varies by just one centimetre, from -0.10 m in the north-east to -0.09 m in the south-west.

Which transformation grid should I use if my GDA94 data is based on…?

As a general rule, data that is based on absolute positioning technologies such as CORSnet-NSW or AUSPOS should use the conformal only transformation grid, except when a site localisation has been applied to align it to SCIMS. Data that is based on SCIMS should apply the conformal and distortion transformation grid.

What do I do if I have a problem?

There are several communication avenues available. Fact sheets, videos, FAQs and even an online forum have been produced by ICSM. Alternatively, your local state or territory geodetic agency may provide assistance. For example, DFSI Spatial Services publishes its technical papers online to assist the profession.

Conclusion

Since October 2017, GDA2020 is Australia's new, improved national datum. With AUSPOS and CORSnet-NSW services now providing GDA2020 data, and with SCIMS and other DFSI Spatial Services datasets soon to be available too, GDA2020 can now be used in NSW for practical applications. In this context, it is critical that users know their data, know their date and know their datum.

This article has shown that the GDA94-GDA2020 transformation grids provide a fast, accurate and simple method for spatial professionals to transform their existing datasets from GDA94 to GDA2020. Two transformation grids have been developed to cater for the different realisations of GDA94 currently available to users. Accuracy and data origin are the two key factors determining their appropriate use.

Prior to transformation, users in NSW must know if their existing GDA94 dataset is affected by known GDA94 distortions (present in SCIMS) or if those distortions have been removed by other methods. Spatial professionals transforming datasets based on SCIMS should use the conformal and distortion transformation grid, while the conformal only transformation grid should be used for datasets based on AUSPOS or CORSnet-NSW services where a site localisation has not been applied.

Each transformation grid has been evaluated across NSW and found to be fit for purpose. The conformal only transformation grid accurately represents the 7-parameter conformal transformation, and the conformal and distortion transformation grid provides centimetre-accuracy in almost all cases. Spatial professionals are encouraged to properly understand the accuracy and lineage of their GDA94 datasets before selecting a transformation grid to transform to GDA2020.

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Career Pathways

An Investment in Future Generations

AUTHOR: Tiffany Wagstaff, General Manager, LTS Lockley

If we're going to actively address the ongoing resource shortage in our industry, we need not only to promote the industry generally but also to provide an environment and a culture where our graduates and technicians can engage their passion for the surveying craft, while continuing on a pathway of learning, ultimately allowing them to achieve their personal and professional goals.

Passion drives commitment and commitment perpetuates success. If we can facilitate this through our organizational culture and career offering, our 'next generation' will undoubtedly both modernize the stereotypical view of the surveyor and inspire a resurgence of interest throughout our industry.

We were delighted recently to see our Daniel Vicente, Georgia Rooney and John Casey, successfully complete their final registration exams. This will see them as Registered Surveyor No. 12, 13 and 14 in our business.

Dan, Georgia and John all commenced with LTS as graduate surveyors and they epitomize the ideology that passion, commitment and hardworking brings success, which is contrary to the view of the modern day millennial.

Indeed they attest to the strength and benefit of a carefully structured career development program. Watching them develop both professionally and personally has been a privilege.

These three, most certainly represent the future leaders and voice of our industry.. We sat down with them to understand their thoughts on surveying as a profession and how they have found the journey so far.

When asked **what had attracted them to a career in surveying,** the view was relatively unanimous "I loved the prospect of being able to work outdoors" Georgia offered, "understanding the 100% employment rate after graduation also helped." For Dan it was "the mix of office and field work together with the variety of work. Not getting stuck on the same site for months on end was a big attraction".

So, did the initial attraction become the reality? We then asked them **what they enjoyed about surveying?** Dan replied "the ability to be outdoors and involved in so many different projects each with their own different challenges", very similarly Georgia responded with "every day is different whether it be driving (or flying!) to different locations around NSW to laser scanning iconic Australian Heritage Buildings. It makes every day a challenge so I'm always learning".

It's clear, the nature and variety of work, which offers an every changing work day landscape, comprising of both indoor and outdoor components, is of great appear.

In terms of career development we asked **what it was that motivated them to become Registered Surveyors?** "The cadastral side of surveying was what I found most interesting" said John. Dan agreed "it felt like the natural progression after getting my degree. I also enjoy the unique challenges and problem solving that comes in the cadastral side of surveying". Georgia also understood that "it opens up a whole new career".

We also asked them **how they found our 'Candidate Registration Program' and mentoring process through registration?** "Very helpful" was the sentiment expressed by all. "I was able to use real jobs for my projects which meant I had a good understanding of the whole process from start to finish. There are so many knowledgeable colleagues who are more than willing to help and share their thoughts and ideas" said Georgia. John concurred "there is a great variety in range of work and variety in expertise. Whatever the problem, there was someone to talk to about it and nut it out. Being paired with a specific mentor who was happy to stick in their own time too was also beneficial".

The overriding sentiment is that the registered surveyor pathway provides interesting, challenging and rewarding work, which in turn offers a career path that will enable them to achieve their personal and family goals.

Finally, we were interested in their view on what they considered to be the most interesting/exciting thing for the profession, moving forward?

As with many elements of modern society, 'technology' was a recurrent theme, with new tools presenting great appeal "the new technology we are using like the laser scanner and drone to capture a huge amount of data in such a short time is game changing. Capturing is the easy part but being able to process and interpret all this date will become our specialty".

The insights provided by Dan, Georgia and John are valuable, reassuring and is representative is the next generation. The appeal of the surveying profession continues to transcend generational divide, providing an enviable work environment and an enormous variety of interesting, challenging work. Add in the technological 'fun factor' and it certainly ticks many boxes.

If, as businesses we can add the elements of structure and security with a defined career path and plan for progression, we can facilitate the achievement of personal goals, which will maintain an energized, fulfilled workforce, ultimately selling itself.

LTS take great pride in providing both the cultural platform and the career path for our team members. Indeed it's difficult to understand any downside in investing in our most valuable assets.

If we all take the time to invest in the future generation of surveyors, our industry will continue to thrive and we can enjoy the energy and the innovation that our future leaders bring to the table.