GNSS and the Convergence of Geodesy and the Cadastre in Australia

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Key words: Geodetic network, Cadastre, GPS, CORS networks

SUMMARY

At the time of settlement in Australia, all land was proclaimed as belonging to the King of England. To expedite settlement, land was granted as quickly as possible by only three overworked surveyors from the New South Wales Department of Lands. With no survey control, rudimentary measuring devices and pressure to grant land promptly, the cadastre evolved in an unstructured manner. Additionally land was granted in an old system style (imported from England) of "metes and bounds". This system was subsequently superceded by the far simpler and more robust Torrens Title system which remains in place today.

The fundamental obligation of cadastral surveying in Australia is to mark out the boundary as was the original intention of the first surveyor. Redefining the boundary of a subject lot of land must fit with surrounding properties and the cadastral surveyor is charged with the responsibility of redefining that land based on all the evidence. Cadastral surveying therefore works from the part to the whole in direct contravention of the fundamental role of geodesy: "working from the whole to the part".

In Australia, the geodetic network has really only evolved from the 1950s with the introduction of the Australian Geodetic Datum (AGD66) 1966 followed by AGD84 and finally the GPS compatible Geocentric Datum of Australia (GDA94) in 2000. However geodesy and cadastral surveying have always been separate. With the advent of space based measuring techniques in particular GPS, new higher precision, very long lines have been included in readjustments of the geodetic network (AGD84 and GDA94) which has reduced the distortions in the network brought about by weaknesses in traditional measuring techniques over long distances. Subsequent re-adjustments of the geodetic network including this new GPS data have allowed cadastral connections to the geodetic framework.

Other services such as online survey mark query services, the AUSPOS online GPS coordinate processing service, local and positional uncertainty measures, modernised GPS, reinvigorated GLONASS, the European GALILEO system and the rollout of CORS infrastructure in major population centres in Australia have all contributed toward a closer union between geodesy and the cadastre. The implications of this convergence are profound. The cadastre can act as a significant layer of a Spatial Data Infrastructure for Australia improving efficiencies and advancing new and innovative spatial applications. This paper will give an overview of the evolution of this convergence with particular emphasis on the situation New South Wales (NSW) and the application of CORS networks in Australia.

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1. DEVELOPMENT OF THE CADASTRE IN AUSTRALIA

At the time of settlement in Australia, English settlers assumed Australia to be "Terra Nullius" (unclaimed land). Indigenous people were nomadic and therefore not settled inhabitants and there was no recognizable legal system. All land was therefore proclaimed Crown Land (belonging to the King) and laws were introduced into the colony by importing from England directly, adapting English law to the colony and framing laws unique to the colony (Kearsley, 2004).

Early surveyors were faced with a country devoid of physically defined boundaries other than natural features (i.e. no fences, roads, walls etc) and no existing survey control. Consequently, land granted could only be defined by "metes and bounds" (measurements and limits of the boundary lines) or by relating a land parcel with respect to a recognisable feature, or, after some time, relating a land parcel to an existing parcel.

Crown Land was granted (freehold or leasehold) by the Governor to free settlers or emancipated convicts. However descriptions of the land granted by the Governor were often ambiguous. The grants often carried no plan, and even when they did, the locations were unclear (eg bearing 10 degrees for 350 links from the *bend in the river*), and the dimensions were scaled off a small scale index map, so they where very approximate.

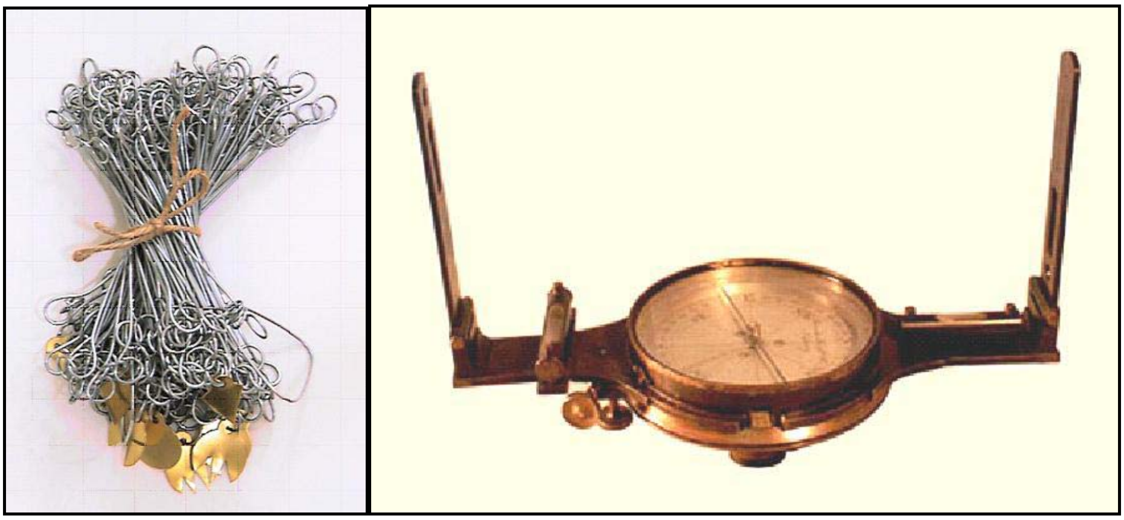

Figure 1 – Gunters Chain (left) and Surveyor's Compass or Circumferentor used in early surveys (Courtesy www.gmat.unsw.edu.au/currentstudents/ug/projects/f_pall/html/index.html School of Surveying and Spatial Information Systems, Virtual Surveying Instrument Collection).

Techniques of land measurement in the early 1800's were very rudimentary. Directions were defined by magnetic compass to +/- 2 degrees, and subject to local magnetic variations. Distances were measured by Gunters Chain, perambulator (calibrated wheel) and pacing. Often, an extra link was placed in the chain to deliberately give more land than was actually granted. Consequently, the dimensions between the boundary marks where often inaccurate – making it hard to relocate using the *correct* measurements.

Land was sometimes transacted before it was marked on the ground! To begin with, there were only three surveyors employed in the NSW Department of Lands to mark out the grants, and the occupation of land therefore preceded its definition on the ground by survey - by many years, in some cases. Often, when the surveyor visited a district to survey and mark a property, the owner was not there. In some cases the land was sold to another party before the original land was surveyed! (Hallman, 1973).

The uncertain description, definition and occupation of land in the early days of the colony have conspired to produce an inhomogeneous system of land administration. These factors have shaped the way the laws for boundary definition have evolved in Australia.

2. EVOLUTION OF THE GEODETIC NETWORK IN AUSTRALIA

As the cadastre spread rapidly across NSW for over 40 years since 1788, it was recognised that settlement was being stalled as new lands could not be granted due to lack of description of the localities. The then Governor Darling recognised the importance of a trigonometrical system of survey across the colony. Sir Thomas Mitchell was commissioned to produce a map of the colony where he used Parramatta observatory for longitude and latitude determinations at Lake George, Warrawolong and other trig sites as a datum (McLean, 1967; NSW Dept of Lands, 2006).

The result of this work was the famous "Map of Nineteen Counties", the first geodetic survey in New South Wales. It covered an area of 38,000 square miles with scale derived from three accurate baseline measurements and some astronomical observations for further control. In 1854, an accurate map of the city of Sydney was required which led to a local trigonometrical survey and later in 1859, another such survey in the District of Albury, 500km south west of Sydney, was conducted for more accurate County maps of that region.

The primary motivation behind these geodetic surveys was the need to provide mapping for administration purposes which needed to be tied together in some homogeneous framework. Consequently trigonometrical surveying activity continued from the 1860s for the remainder of the 19^{th} century intermittently depending on prevailing political and financial conditions. By 1895, one third of the state of New South Wales was covered with 2,700 stations; 2,100 of which had positions determined (McLean, 1967).

Geodetic work stalled during the war years with the notable exception of reconnaissance work toward a triangulation chain linking Queensland, New South Wales and Victoria primarily along the coast and northern tablelands (Ibid, 1967). This work was carried out by the Australian Army Survey Corps who were later involved in emergency mapping along the northern coast of Australia in response to the threat of attack from the north during World War 2. In some cases there was no suitable mapping to aid a defence of northern Australia.

The Central Mapping Authority was set up in 1946 and charged with the responsibility of accelerating the trigonometrical survey of New South Wales. This work was greatly aided by the introduction of the Tellurometer (a long range, microwave distance measuring device) in 1958. Indeed much of this work was included in a national geodetic adjustment of Australia in 1966. Later, the introduction of electronic distance measuring technology (EDM) accelerated and significantly improved distance measurement which in turn improved the accuracy of both the cadastral and geodetic networks.

Until this time, many different datums were used in the eight States and Territories of Australia but the most prominent was the Clarke 1858 spheroid. There was some confusion as to whether the definition of the semi-major axis of this spheroid was based on either the Clarke Foot or the British Foot. Maps based on different origins, uncertainty of astronomical observations, inaccuracies of long distance measurement techniques as well as unaccounted deflections of the vertical led to differences of several hundred metres between maps (Geoscience Australia, 2006).

Laplace stations (points with both geodetic and astronomic position) were needed in the original Australia wide triangulation and traversing to keep the azimuth of the growing network aligned to true north. The geodetic co-ordinates were based on the Johnston Geodetic Origin (a trig station near Kulgera in the NT) where values of latitude, longitude and ellipsoidal height were adopted and N, the geoid-ellipsoid separation, was given as zero. A national least squares adjustment of the Australian geodetic network performed in March 1966 used the Australian National Spheroid based on the ellipsoid recommended by the International Astronomical Union at that time.

This adjustment produced a set of coordinates known as the Australian Geodetic Datum 1966 coordinate set (AGD66). The adjustment sought to minimise (indirectly) the geoid-ellipsoid separation N across Australia so that geodetic distances measured on the Earth's surface would not incur a scale factor due to large N values. (As a rule-of-thumb, 6m of N is equivalent to 1ppm in distance). This however meant that the origin of the datum was shifted from the geocentre of the Earth by around 200m. The Australian Map Grid (AMG66) coordinate set was based on a Universal Transverse Mercator (UTM) projection of the AGD66 geodetic coordinates.

In 1982 a new national adjustment was performed using all data previously included in the 1966 adjustment as well as additional, modern terrestrial and space-based observations (predominantly from Transit Doppler). These long line observations had the effect of reducing the distortions in the network, however this new coordinate set was only adopted in South Australia, Western Australia, Northern Territory and Queensland. The coordinate set resulting from this adjustment was known as the Australian Geodetic Datum 1984 (AGD84) with associated UTM projected AMG84 grid coordinates. Again, the origin of the datum differed from the geocentre of the Earth by around 200m.

In the early 1980s the Global Positioning System (GPS) began to evolve with an ever growing constellation and associated observation window. The long line accuracy of GPS and relative ease of use compared to other geodetic techniques saw its utilization grow in the late 1980s largely by State government departments for the improvement of the geodetic network. However in order to conform with Australian conditions, complicated transformations were required between the World Geodetic System 1984 (WGS84), the native coordinate system in which GPS operates, to the existing AGD66 or AGD84 data set (depending on the State).

It became clear that Australia would have to move to a geocentric coordinate system to accord with the increasingly popular GPS measuring technology. In truth, this realisation was known even before the readjustment of the AGD84 data set and in part explains why some States changed and some did not.

The Geocentric Datum of Australia (GDA) is based on the GRS80 ellipsoid (Geodetic Reference System 1980). This is identical to the WGS84 ellipsoid, except for one minor difference with regard to the gravity model, which meant that GPS could be used directly in Australia without the need for complicated transformations. The reference frame for GDA is the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0 hence the name of the datum in Australia; GDA94. An associated UTM projection produces the grid coordinate set the Map Grid of Australia (MGA). This new geocentric model of Australia was adopted on January 1, 2000. GDA94 is realised by 10 Australian Fiducial Network (AFN) sites distributed across the Australian mainland.

The AFN network was densified with a network of stations with approximately 500km spacing called the Australian National Network (ANN) (Morgan, P et al, 1996). In NSW, a State-wide adjustment, called the Spine adjustment (Bosloper, 2006), further densified the geodetic network producing 3000 sites with GDA94 coordinates at that time (NSW Dept of Lands, 2006). Ironically, this new, more homogenous coordinate set (MGA) contained less class C or better points for surveyors to use. (The number of class C points is increasing as the NSW Lands Dept connects new points to the network) The remaining points not included in the adjustment were transformed using the NTv2 grid interpolation method used previously in Canada (Ibid, 2006).

3. CONVERGENCE OF GEODESY AND THE CADASTRE

The previous sections have introduced the evolution of both the cadastral and geodetic networks in Australia. Surveyors in the past have tended to distinguish themselves as either cadastral or geodetic due to the differing nature of their work brought about by the different networks to which their work contributed. However, as both networks have improved in accuracy, the gulf between geodesy and cadastral surveying has reduced.

Perhaps the first contributing factor toward this convergence stems from the introduction of the Torrens Title system in South Australia in 1856. This new titling system superceded the complicated chains of previous land ownership, description of land by wordy metes and bounds and produced a single document attached to a single portion of land upon which all transactions were recorded and a map of the parcel relating to a plan of survey was provided. The other States and Territories in Australia quickly adopted the Torrens Title system. *Old System* land still exists in the cadastre and cadastral surveyors must retain the skill of converting any subsequent transactions over this land into Torrens Title. The single Torrens Title with an associated plan of survey of the parcel of land was a revolution in producing a more homogeneous land titling system in Australia.

GPS techniques, and more recently, with the addition of modernised GPS, reinvigorated GLONASS, the promise of the European GALILEO system in a few years, Global Navigation Satellite System (GNSS) techniques have challenged the user community to change their thinking. Cadastral surveying has traditionally relied on angles and distances whereas GPS techniques produce coordinates. Government organisations have produced Internet survey mark searching services for surveyors such as the Survey Control Information Management Service (SCIMS) in NSW. Other Australian States offer a similar service with different acronyms. These services provide surveyors with detail about survey marks across the entire state such as quality, locality sketches and coordinate information – whether they need it or not! In NSW, cadastral surveyors are required to show MGA orientation on Deposited Plans (DP) - the primary plans prepared and lodged by Registered surveyors to maintain the cadastre - and connection to at least two permanent marks with MGA coordinates (NSW Survey Regulations, 2001). It would be a simple task for government to coordinate all the boundary corners from modern DPs to survey accuracy if required.

Despite cadastral surveyors traditionally "working from the part to the whole" (or fitting in with surrounding tenure as per the original intention of the first surveyor), regulation is gently nudging surveyors toward a coordinate based approach – although there is no short term benefit for them! Government organisations however see the long term benefit of combining the cadastral and geodetic layers as a fundamental layer in a Spatial Data Infrastructure of Australia. This was never possible before GPS.

3.1 GPS in Australia

The first GPS continuously operating reference station (CORS) network in Australia was the AFN established by Geoscience Australia (then AUSLIG). This has since been expanded with some extra sites in Australia and surrounding islands to form the Australian Regional GPS Network (ARGN). ARGN sites also contribute to the International GNSS service (IGS) network (see Figure 2).

As GNSS techniques become more robust, private surveyors are beginning to use satellite techniques for a wider range of surveying tasks. Data from these ARGN sites is freely available to users but is often of little value with baselines as long as 1000 kms requiring scientific software – out of reach for commercial survey operators. In response, Geoscience

Australia developed their AUSPOS service in the late 1990s. Users simply observe 6 hours of dual frequency data and send their RINEX files to the AUSPOS server which computes a coordinate of the base station and emails this information back to the user within 15 minutes. This service uses scientific processing software connected to the IGS network – indeed it is designed to service Australian users but can be used anywhere on Earth.

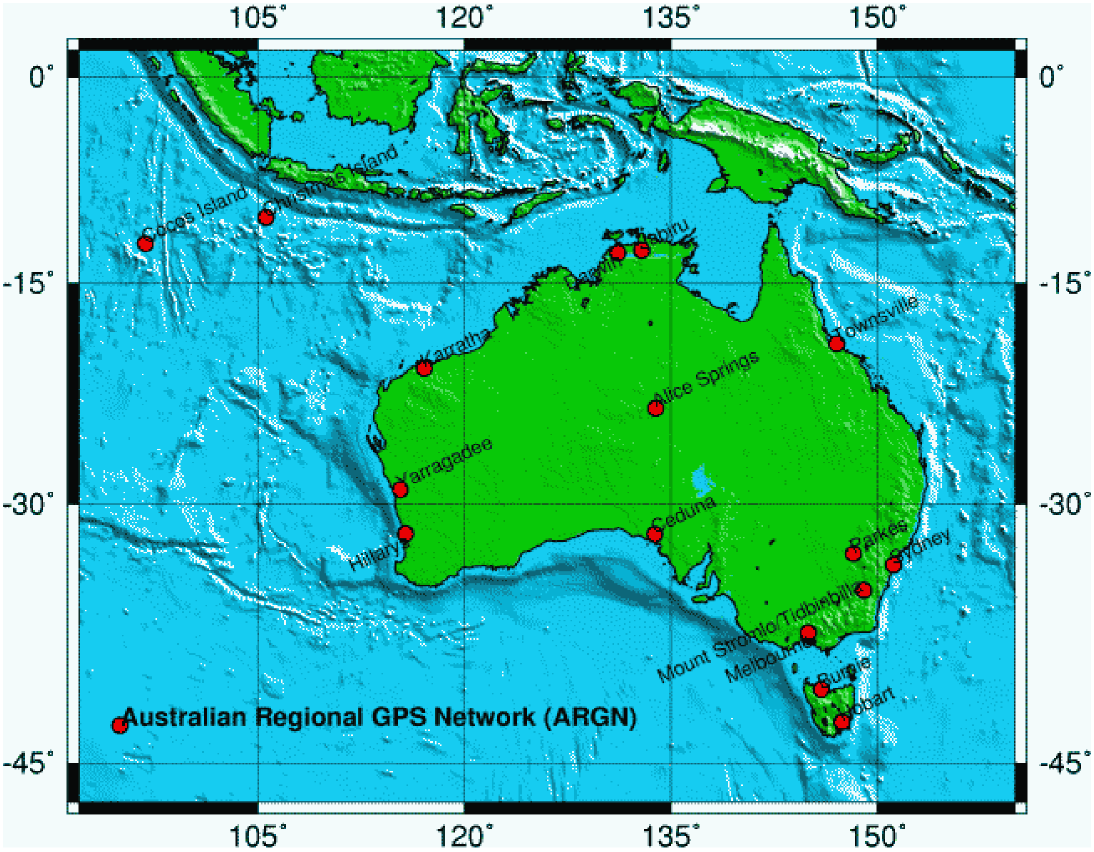

Figure 2 – The Australian Regional Geodetic Network (Courtesy Geoscience Australia)

The success of AUSPOS has however presented a number of new challenges for users in Australia.

1) AUSPOS computes a coordinate in ITRF and derives an MGA coordinate using a backward velocity vector based on geodynamic modelling.
2) The derived coordinate sometimes does not accord with that given by the relevant State government authority (for example via SCIMS).
3) GNSS techniques now provide a direct connection to the datum, requiring new accuracy standards.

These issues will be discussed below.

3.1.1 A stable GDA94 versus the moving ITRF

The Australian Tectonic plate can be thought of as one stable plate shifting approximately northeast at a rate of about 7 cm per year. However the GDA94 (and therefore the MGA) coordinate set is locked in time. Because the whole of Australia is moving uniformly, this movement can be ignored when obtaining positions relative to other MGA positions. However, if a position is obtained directly from a GNSS system (such as GPS) the difference may be apparent. If the global position has a large uncertainty – such as a standard GPS point position with accuracy of about 10 metres – then it can still be ignored. However when an accurate wide area global position is obtained – such as a global high accuracy differential GPS system with an uncertainty of a few decimetres or an AUSPOS solution with 2cm accuracy – the difference is noticeable considering 12 years of motion (equivalent to ~84cms).

Commercial service providers overcome this discrepancy by providing transformation parameters for their users updated on a quarterly basis. Paradoxically, it is this requirement for transformation parameters which the move to GDA set out to avoid.

3.1.2 Distortions in the geodetic network

Due to inferior measurement techniques which were used as observations in the AGD66 and AGD84 adjustments, the resultant coordinate set contains distortions in a random manner. Because of the long line accuracy of GPS, these distortions are exposed. This was a motivation for the readjustment of AGD84 using the improved long line accuracy of Transit Doppler measurements to tighten the network. In a similar fashion, GPS measurements were used to tighten the GDA datum which is now much more homogeneous. Despite this improvement however, coordinates derived by AUSPOS using data from the ARGN network sometimes do not coincide with coordinates in Statewide geodetic networks. This issue will gradually diminish as the geodetic network improves but remains a source of concern for surveyors.

3.1.3 Local and positional uncertainty

GNSS techniques such as AUSPOS and wide area differential GPS services are global and require *absolute* as well as *relative* accuracy standards. Surveyors are comfortable with the concept of *class* and *order* whereby *class* refers to the internal relative accuracy and *order* refers to the external relative accuracy ie the goodness of fit with local control. In Australia, the Inter-governmental Committee on Surveying and Mapping (ICSM) have produced a document, predominantly for geodetic surveying, called “Standards and Practice for Control Surveys” (SP1) (ICSM, 2006). This document introduces two new accuracy standards namely *Local* and *Positional Uncertainty*. It states that Local Uncetainty will supercede the term order being a relative accuracy standard and Positional Uncertainty is a new absolute standard referring to the coordinate accuracy with respect to the datum, in this case GDA94. The fact that the ICSM have moved toward these new standards is a recognition of the forseeable utility of GNSS techniques for future surveying tasks.

3.2 Development of CORS networks in Australia

Since the establishment of the AFN network, State governments have sought to provide their own CORS densifications as a spatial infrastructure for their regions. Victoria was the first State in 1994 to develop their now Statewide GPSnet. This is a cooperative network administered by the Dept of Sustainability and Environment now comprising over twenty stations and providing sub-metre accuracy across Victoria with the VicPos service and 2cm accuracy in and around Melbourne using MelPos (Zhang et al, 2006) (see Figure 3a).

The SydNet CORS infrastructure was setup in partnership between the NSW Dept of Lands and the School of Surveying and Spatial Information Systems and services the Sydney Basin region with seven stations (see Figure 3b). At present SydNet provides RINEX data for users via the Internet and will soon deliver real-time correction information to users using the GPRS mobile phone network. Syd*Net* is currently being extended to form MetroNet, which will consist of 10-15 reference stations and will service the eastern seaboard from Nowra to Newcastle and west to Bathurst (Ibid, 2006).

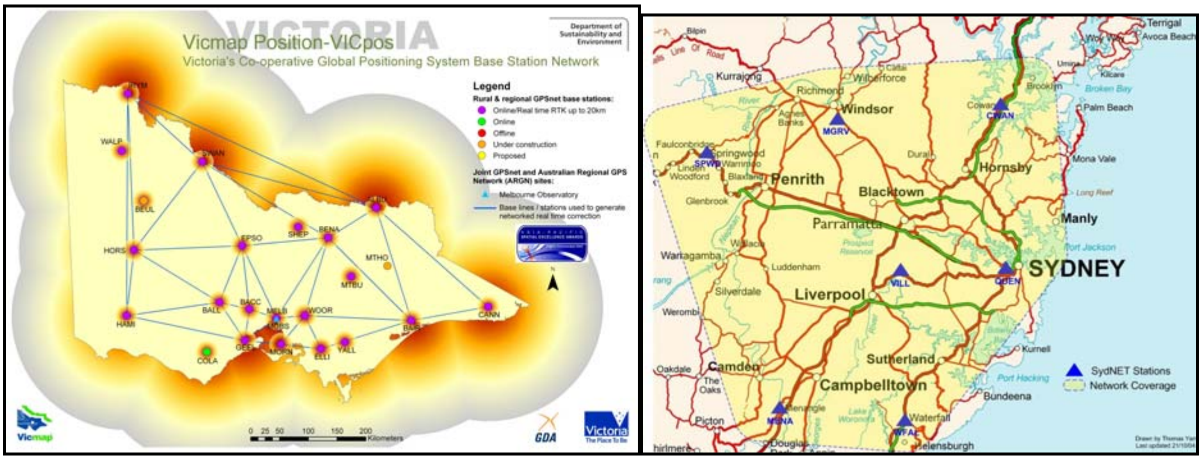

Figure 3 – a) The VicPos sub-metre service across Victoria and MelPos 2cm service focussed around Melbourne bottom centre of figure (courtesy Dept of Sustainability and Environment, Victoria) and b) SydNet servicing the Sydney basin region.

SunPoz was set up by the Dept of Natural Resources, Mines and Energy, Queensland to service the Brisbane region comprising 5 reference stations. In contrast to GPSnet and SydNet, SunPoz is a wholly commercial service using a single manufacturer. GPSnet and SydNet use a range of different GPS manufacturers for base stations and will offer a range of services from competing providers.

All of these CORS networks provide (or will soon provide) network-based RTK corrections. This is of particular significance to Australia which covers a vast land mass. The density of the reference stations impacts the economy of the system. Research is underway to try and extend the baseline length between neighbouring reference stations whilst preserving cm-level accuracy (Roberts et al, 2004).

CORS networks require accurate reference station coordinates (in MGA in Australia) in accordance with the existing geodetic network. The distortions in the network between adjacent reference stations must be overcome to around 2 cm of accuracy in order for the network RTK algorithms to function correctly. Given the vast distances in Australia this has been a challenging task - a one centimetre error in 100km is 0.1ppm! Coordinates between neighboring States still present problems to achieve a homogenous data set.

More recently, GPSnetwork in Perth, Western Australia became the first privately owned and run VRS network in Australia, launched on Jun 29, 2006. It comprises 5 stations with plans for expansion of two more. Improvements in the geodetic network have allowed this network to become operational in just 6 months from the initial concept. The Dept of Land Information, WA coordinated and integrated the new base stations into the geodetic network with a fit at around 2cm (Morgan, L. 2006). This rapid installation illustrates the advantages of a tight, homogenous geodetic framework.

CORS networks in Australia are growing in major population centres. They provide users with real-time positioning to cm level accuracy, without the need for a base station. For urban environments, utilizing the mobile phone infrastructure to deliver corrections and network RTK algorithms provide a more robust solution. It is anticipated that many other applications will follow on from this infrastructure.

4. IMPLICATIONS FOR CADASTRAL SURVEYING IN AUSTRALIA

Surveyors in Australia have been reluctant to use GPS surveying techniques for cadastral surveying. Generally rural cadastral surveying has seen the greatest application of GPS/GNSS techniques. With the growth of CORS networks in metropolitan areas, it is anticipated that urban cadastral surveying utilisation will grow – however overall the number of surveyors adopting GPS/GNSS techniques remains in the minority. Although the geodetic and cadastral networks have been converging over recent years, and although government services have been provided to encourage surveyors to adopt GPS practices for cadastral surveying, legislation still precludes the economic use of GPS in many circumstances.

An example of this in NSW arises from Reg 27 of Survey Practice Regs NSW (2001) which prescribes length requirements such that:

> "When making a survey, a surveyor must measure all lengths to an accuracy of 6mm + 30ppm or better at a confidence of 95%."

This requirement therefore gives rise to the NSW Surveyor Generals direction to check all RTK GPS derived distances under 120m using EDM! (6mm + 30ppm @ 120m = 0.0096m → manufacturer standard error for RTK GPS) (Roberts, 2005). Victorian legislation requires a similar length measurement accuracy of 10mm + 60ppm. This is also a restrictive length requirement.

In South Australia, regulations allow for a postional tolerance of 20mm in the city centre and as much as 150mm in rural regions as well as distance and angular tolerances (South Australian Manual of Survey Practice, 2006). This regulation permits the use of GPS/GNSS techniques for cadastral surveying, yet across the border in NSW or Victoria, no such permission is allowed.

State government regulations also require legal traceability of measurement. Effectively surveyors must be able to ensure that their measuring systems, whether they be a steel band or an EDM, can be traced back to some legal standard. This is a simple case for length measuring devices and gives rise to the regulation (for example) for surveyors to carry out an annual calibration of their EDM device over an approved baseline.

However GPS/GNSS measures position and position could be anywhere! The issue of legal traceability now refers to chapter 11 of the Verifying Authorities Handbook [NMI, 2005] produced by the National Measurement Institute (NMI). The primary standard for measurement of position in Australia is now defined by the Australian Fiducial network (AFN). So called “Regulation 13” points are properly connected to the AFN and considered legally traceable. A surveyor need only connect a survey to a Regulation 13 mark to claim legal traceability – however at present in NSW, only the SydNet reference stations are considered of this standard. In the meantime, cadastral surveyors connecting to high quality surrounding control in accordance with the existing survey regulations are considered legally traceable – although this has never been tested by law.

The use of GPS/GNSS techniques also raises the concerns for surveyors about the maintenance of physical survey marks in the ground. The downsizing of government departments over the years has put increasing pressure on maintaining survey mark infrastructure due to the high cost. It is a contentious issue to suggest replacing survey marks in the ground with survey marks from the sky. McDougall, K. (2005) gives a recent overview of survey mark infrastructure in Australia.

The NSW Dept of Lands is currently drafting new survey regulations to accommodate GPS/GNSS surveying techniques for cadastral surveying in a prudent manner. The issue of restrictive length measurements will be revisited as well as legal traceability. Also surveyors will be encouraged to exploit the long line accuracy of GNSS techniques and provide longer connections to geodetic control than was previously prescribed in the 2001 regulations. Again surveyors will contribute to converging the geodetic and cadastral networks without any perceivable benefit to themselves.

4.1 Comparison with cadastral surveying in Germany

From Johann Jacob Baeyer’s proposal to connect the astronomical observatories across central Europe with a triangulation network in 1862 (IAG, 2006), the European geodetic network has always been more homogeneous than the geodetic network in Australia. This has also been aided by the fact that the Australian land mass is approximately 20 times larger than Germany!

More recently, the German cadastral authorities are establishing a standardised cadastral data system called ALKIS (Hawerk, 2006). This system is recognition that cadastral data provides a strong fundamental layer for public administration and must marry legal, technical and administrative concerns. But more than this it links existing digital cadastral data with topographic data and uses powerful GIS techniques to manage this spatial database. This capability presupposes a homogeneous geodetic and cadastral network.

From a technological perspective, the 250 station SAPOS CORS network has been in operation in Germany for some years now providing users with a number of positioning services in real-time and post processing modes at a range of accuracies. The highest precision real time service provides a network RTK solution to 1-5cm accuracy which is sufficient for cadastral surveys (Ibid, 2006). Clearly German regulations are written so as to accommodate new technologies.

The Land administration system in Germany has been modernised to exploit GNSS technologies as well as advances in GIS spatial data management. The convergence of the geodetic and cadastral networks in Australia will allow similar advances – at least on a regional basis – in the future.

5. CONCLUDING REMARKS

This paper has given an overview of the evolution of the cadastral and geodetic networks in Australia. It has attempted to show how recent initiatives, such as the move to the GPS compatible Geocentric Datum of Australia, have seen the convergence of these two networks. Services such as AUSPOS have raised other questions such as how to deal with geodynamic motion, issues with distortions in the existing network and the imposition of new accuracy measures. The paper has also highlighted some of the teething problems presented by implementing GPS/GNSS techniques to well established cadastral surveying methods. State government authorities are working hard to modernise regulations to accommodate this new technology for private cadastral surveyors who in return densify and tighten the network which benefits state government spatial data infrastructures.

Despite all these changes, the fundamental goal of cadastral surveying is to mark the land as per the intention of the original surveyor. “Monuments over measurements” remains and GPS/GNSS techniques are simply another measuring tool. The professional surveyor must decide the best technique for the job. It is anticipated in Germany that the implementation of new techniques, such as integrated surveying supported by CORS networks combining GNSS and total station, will reduce the cost by approximately 25% (Hawerk, 2006). The challenge for the modern surveyor is to use this new infrastructure to provide value-added services to their clients and expand their businesses in non-traditional areas.

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BIOGRAPHICAL NOTES

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