GNSS and the Professional Surveyor: A Practical Overview

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ABSTRACT

This paper provides a discussion on the use of Global Navigation Satellite System (GNSS) techniques in general and specifically for cadastral surveys. It is not a scientific investigation but presents a collection of observations and experiences gained by the author in the day-to-day use of GNSS equipment in a broad range of everyday survey projects. GNSS has been in commercial use since the early 1990s. In the last few years, hardware and software development has empowered those 'without skill in geometria' to enter the world of geodesy. Typically surveyors were the first to adopt new computer-based technology, including programmable calculators and computer-aided drafting (CAD), because of the high number of observations and calculations required to present a project. Today, with relatively cheap advanced software and technologically advanced equipment, we are seeing young engineers adopt software and GNSS as part of the Gen Y trip through life. This means the surveying profession is poised to lose a great deal of its traditional work. The use of static, Real Time Kinematic (RTK) and continuously operating reference stations (CORS) in daily applications is discussed in undertaking surveys in different types of applications. Differences between coordinates and vectors derived from GNSS observations are examined, considering that the cadastral world is one of vectors, while the GNSS world is one of coordinates. Einstein put forward the proposition that everything is relative. In the cadastral world, everything is relative to the ground or the monument. The GNSS observation is also relative – relative to the base station and the last observation made. It is shown that, in the world of cadastral surveying, GNSS is an ideal tool with which to re-establish a rural cadastral boundary.

KEYWORDS: *GPS, GNSS, cadastral surveying, rural boundaries.*

1 INTRODUCTION

The term Global Positioning System (GPS) is the most common term used by the general public to describe any technology associated with satellite-based position fixing. This is derived from the constellation of U.S. satellites commissioned in 1993. Considering similar systems originating in other countries (e.g. Russia's GLONASS, China's BeiDou and Europe's Galileo), these are known as Global Navigation Satellite Systems (GNSS). In recent years, the third generation of GNSS includes the use of mobile phone technology.

The surveying profession has always been at the cutting edge in adopting new technology for data processing. The large amounts of data surveyors collect on a daily basis and the relative complexity of processing this data has prompted surveyors to be the first and most enthusiastic adopters of computer and software technology. The introduction of the New South Wales Integrated Survey Grid (ISG) in the 1970s was incomprehensible to the general public and complicated for the general surveying profession (Lands, 1976). We have now adopted the Geocentric Datum of Australia 1994 (GDA94) and its Map Grid of Australia

(MGA) projected coordinates as the standard (ICSM, 2009). The MGA is the latest incarnation of a Universal Transverse Mercator (UTM) grid system for Australia and is indispensable to the operation of any large-scale survey projects such as highways and railways. For a review of coordinate systems, datums and related transformations, the reader is referred to Janssen (2009).

In 1980, the only people who could undertake any work on the ISG were specially trained university graduates. Today, technology has enabled 'the man on the Clapham omnibus' to undertake any number of measurements and calculations using GNSS technology. It is at this point in time that the paradigm of the professional surveyor has changed forever. Today, with relatively cheap advanced software and technologically advanced equipment, young engineers adopt software and GNSS as part of the Gen Y trip through life. This means the surveying profession is poised to lose a great deal of its traditional work.

The surveying profession consists of a collection of university graduates trained and competent in the skill of geometria. Today, there is a definite erosion of the profession's monopoly in geometria. This paper introduces a range of issues in using GNSS in private practice, particularly in cadastral surveying.

2 THE PARADIGM

2.1 Available GNSS Methods

Reference to Surveyor General's Direction No. 9: GNSS for Cadastral Surveys (LPI, 2014) notes the accepted methods of GNSS as being:

- static
- static using Continuously Operating Reference Stations (CORS)
- AUSPOS
- Real Time Kinematic (RTK)
- RTK or Network RTK (NRTK) using CORS
- Precise Point Positioning (PPP)

2.2 Professional Users

Over the last few years, the author had the opportunity to speak at several surveying gatherings on the use of GNSS in one form or another. It was surprising to see a general lack of knowledge in the profession on the use of GNSS for different types of surveys. There seem to be a number of camps:

- Those who are competent and knowledgeable.
- Those who use it well.
- Those who are cowboys (these have some knowledge but take every shortcut possible).
- The plainly incompetent.
- The doomsayers.
- The non-interested.

2.3 New Users

Today a new set of users is adopting GNSS technology with significant impacts on the professional surveyor. GNSS technology is now being adopted by:

- Younger civil engineers.
- Local government authorities.
- Construction companies.
- Mining companies.

2.4 Some Examples

It has been the author's experience to date that, with the possible exception of mining companies, none of these users have the required level of knowledge in surveying or the consequences of using GNSS. Some years ago at an Australia Day Conference a surveyor made a presentation in which they stated "GPS is great, we employ farmers and pay them $12 an hour to do our surveys." This presentation incited either great mirth or anger in the audience. The interesting thing is that this surveyor was predicting the future. Nowadays GPS units are affordable and useable by the non-surveyor. The commissioning and ongoing expansion of the CORSnet-NSW network of permanent GNSS reference stations across NSW (e.g. Janssen, 2014; LPI, 2015a) has further encouraged this uptake because the user does not have to use their own base station. It could be argued that some product salesmen are overselling the equipment to those who are untrained in its use. A typical response when querying untrained users on their methodologies is "That's what the salesman told me to do."

3 WHAT IS THE DATUM?

The best feature of GNSS is that you always have the same azimuth. This can bring conflict and confusion in some instances where there are distortions in the ground control marks contained in the Survey Control Information Management System (SCIMS – see LPI, 2015b). There are inconsistencies within the SCIMS network due to the hierarchy of various adjustments. These are probably more pronounced in rural areas because of the greater distances.

The SCIMS network is based on a series of adjustments using many thousands of observations. In the 1990s, the NSW Government undertook intensification in the network, resulting in many adjustments over a short period of time. CORSnet-NSW is based on a different realisation of the Australian datum, i.e. the SCIMS coordinates and the coordinates used in CORSnet-NSW are different (Janssen and McElroy, 2010).

In cadastral surveying everything is relative to a monument. If boundary definition remains based on common law, the surveyor is more interested in the monuments and vectors connecting these monuments.

3.1 Localisation

The term even causes confusion and argument. This term should not be confused with validation, see section 4 of the Surveyor General's Direction No. 9 (LPI, 2014). A localisation (or better site transformation) is undertaken by observing one or a greater number of points and allowing the GNSS unit to adjust its observations to the ground control (Haasdyk and

Janssen, 2012). In the case of multiple points, this effectively distorts the observations to fit the observations into the existing fabric of surrounding control. From a practical point of view, it is not possible to repeat a localisation as there will always be some differences in the derived coordinates. Therefore if there is an error in a localisation, that error will be spread throughout the job and the next surveyor may not agree with the measurements.

Our practice is to ban localisations (except for machine control) and we now refuse to help other people (both surveyors and non-surveyors) who have problems because a localisation was undertaken.

3.2 What Should Be Adopted?

This is a question for all surveyors to ponder rather than for the author to answer.

3.2.1 Case Study 1

As with any survey measurement, there is a quantum of uncertainty in measurements derived from GNSS observations. Surveyor General's Direction No. 9 states that for rural surveys, CORS RTK is acceptable.

When undertaking large control surveys for aerial purposes, we often use a combination of GNSS techniques. The process is often a combination of static and RTK observations. We will undertake RTK with two rover units set at different heights, i.e. one rover on a tripod and the other on a fixed height pole. This gives an independent check on height, one fixed pole height and one variable (measured) at each station. If phone reception is available, we also use CORS RTK. Table 1 shows a summary of part of a dataset.

The interesting points to note are:

- Point numbering.
  - points numbered 3xx have been taken to a mark using RTK
  - points numbered 5xx have been taken to the same mark using CORS RTK
- Point 501 is a star picket established on top of a hill with good skyview.
  - this was measured using CORS RTK and adopted for the field survey as the base station for other RTK measurements
- Point 1 shows the coordinates calculated from a set of 8 hours observations based on SCIMS A1 control approximately 20 km away and CORS static as check calculations.
- Points 355 & 555 are the same witness mark in close proximity to the base station measured using RTK and CORS RTK.
- Points 310 & 510 and 312 & 512 and 314 & 514 are points of interest measured using RTK and CORS RTK.

Our use of CORS RTK in this case was for gross error detection. The four points were chosen for good skyview and lack of interference. In this case, it would appear that the differences are due to elevation. The horizontal coordinate differences are significant but the vectors in the case of the last three points are acceptably close.

Table 1: CORS and RTK comparison.

Point	Easting (m)	Northing (m)	AHD71 Height	Comment
1	282619.930	6508662.196	645.411	8 hours static from SCIMS
501	282619.935	6508662.177	645.396	CORS & adopted for RTK field base
Static-CORS	-0.005	0.019	0.015	
The base station was given the field coordinates of the CORS observations as this would allow quick verification in the field. The CORS base station is approximately 50 km away. The calculated and observed coordinates are remarkably close. The height difference in this case may be considered as a control.				
355	282617.810	6508660.035	645.262	RTK witness mark
555	282617.817	6508660.031	645.219	CORS witness mark
RTK-CORS	-0.007	0.004	0.043	
Similar differences are evident in the Easting and Northing. In this case the height difference is an indication of the delta height attributable to the observations using RTK and CORS RTK.				
310	281594.051	6508631.324	453.024	RTK (1.02 km to base)
510	281594.089	6508631.489	452.980	CORS
RTK-CORS	-0.038	-0.165	0.044	
This point is about 1.02 km from the base station to the south-west. This is the first point of interest and the delta values have changed considerably.				
312	282286.509	6510655.614	441.861	RTK (2.02 km to base)
512	282286.577	6510655.780	441.924	CORS
RTK-CORS	-0.068	-0.166	-0.063	
This point is about 2.02 km from the base station to the north-west. The delta Easting and Northing values are consistent with those of point 310/510 above.				
314	282292.042	6510659.187	441.569	RTK
514	282292.108	6510659.342	441.606	CORS
RTK-CORS	-0.066	-0.155	-0.037	
This point is in close proximity to point 312/512. The delta Easting and Northing values are consistent with those of point 310/510 and 315/514 above.				

3.2.2 Case Study 2

This job was to replace a Permanent Mark (PM) that would be destroyed by Council road works. In this case, SS34224 (Class A Order 1) and PM31456 (Class C Order U) were chosen as the datum of the survey. The new mark (PM182136) was installed in close proximity to PM31456 to maintain the inter-visibility of the existing marks.

In this case, a conventional traverse was undertaken and a series of observations using the nearby CORS station were undertaken on the tripods at the same time as the terrestrial survey thus eliminating centring errors.

The three observations stated above the line in Figure 1 are the point of comment:

- SCIMS ground was used for azimuth.
- CORS RTK is the same.
- The ground distances are the more interesting as the CORS RTK and Electronic Distance Measurement (EDM) observations agree with each other but are significantly different to the SCIMS ground distance.

The CORS RTK coordinates (after adjustment to the SCIMS network for the CORS station) differed to the coordinates in SCIMS.

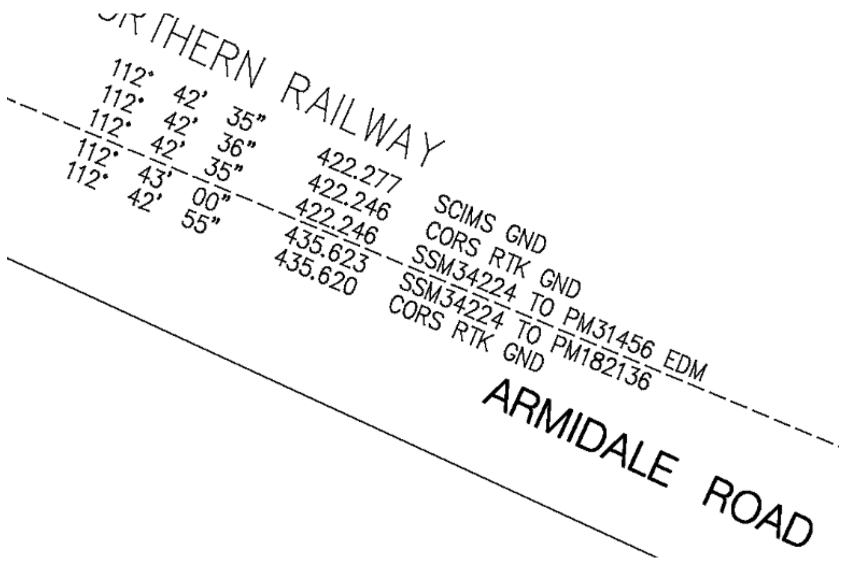

Figure 1: CORS RTK and traverse lines.

3.3 What Is Practical?

When undertaking a cadastral survey in a rural area, the author does not yet have the confidence to use CORS RTK. I do believe that CORS static is a very good solution where there is a dearth of coordinated SCIMS marks. Currently, we use RTK with connections to either the SCIMS network or to our own CORS static observations. We also like to use CORS RTK to track the usability of CORS RTK in a rural environment. A practical approach is to set up the job in MGA 56 and AUSGeoid09 set as the default in the GNSS unit. The azimuth will be consistent.

4 WHAT ARE THE TRAPS?

There are many opportunities for making mistakes when using GNSS to undertake any type of survey. It is especially important to be conversant with the operation of the equipment one is using. Each brand has its idiosyncrasies. There are settings that allow the operator to achieve higher accuracies. There is a tendency for users to set the equipment to instantaneous and move as fast as possible. The time taken making a couple of minutes of observations can be utilised to make good field notes.

4.1 Some Tips

4.1.1 Base Station

Choose the site for the base station carefully. The base station is the most important point in the job. Anything that interferes with the efficiency of the base station will affect every other point in the job.

- Avoid stations near trees.
- Avoid power lines and transformers where possible.
    - o If the only coordinated marks are near trees or a power line, set up a base station in a suitable place and observe back to the SCIMS marks.
    - o Use a theodolite and traverse into the control marks if they are under trees.
        - ▪ It is easy to get a good long azimuth with a GNSS unit.

- If working in a hilly area, establish a base station on the top of a clear hill.
- Use an aerial on the radio that suits the environment, broomstick aerials are good on the plains but do not perform well in the mountains.
- Always use a height for the base station, even if it is derived by the GNSS unit as a 'here' point.
- Measure the height of the base station and use the height of the witness mark as a check. Heights are the most sensitive indicator of a problem.
- Establish a witness mark near the base station.
  - Check onto the witness mark at the beginning and end of each job.
    - Record your observations.
  - Check onto the witness mark at any available opportunity during the survey.
  - The witness mark is your personal verification.

4.1.2 Rover

- Use a tripod to measure points.
- Pogo sticks and other adapters are often useful for measuring non-ground points.
- If using a pogo stick, it is best practice to use a bipod.
- If using a pogo stick to take measurements, be aware of the error due to the height and the sensitivity of the bubble.
  - Take four measurements and rotate the receiver by 90º for each measurement.
- Take a number of measurements at a point.
  - Download the points and look at the spread of coordinates.
    - Take four measurements. This allows one to be discarded with three still remaining.
  - Have the instrument set so you can choose not to accept a measurement. Experience has shown that discarding the first measurement as a general practice seems to group the subsequent measurements more closely.
- The author concludes that taking four measurements at a 30-second epoch is a more reliable methodology that taking one measurement of 120 seconds.

Figure 2 shows a rover with an adaptor used for measuring posts and fences. In this case, the mile post is on the side of a hill that is almost impossible to walk along. We also took a measurement at the base of the post as it had a significant lean. In addition:

- Establish pairs of marks, so the survey can be infilled with a theodolite.
- Measure between these pairs of marks as a form of continuous verification.

4.1.3 Validation

Measuring a point twice at a different time of the day is not a difficult task on a rural job. Using the EDM to check measurements at opportune times is also a good validation practice.

Figure 2: Adaptor for measuring posts.

5 A PRACTICAL APPROACH

There are a number of methodologies for undertaking a rural cadastral survey with GNSS. It is probably more important to be aware of the methodologies and use the most appropriate method in any particular circumstance.

The least favoured methodology is 'radiation sickness' (a non-academic term coined by Henry Werner). This entails loading all the data in the GNSS and looking for the points. This methodology is generally favoured by the less experienced. A clever trick is to load this data as a separate job and you can easily extract vectors between points in the field.

The author's preferred method is to use MGA and scale ground distances and rotate magnetic bearings to MGA grid. This is exactly the same methodology we used to use when we measured with a wire and did our calculations on a HPxx. The most important thing is to establish a base station in a good location. If no suitable SCIMS marks are available, choose either 'here' on the GNSS unit or, if phone coverage is available, take a CORS RTK reading.

5.1 How To Obtain An Azimuth Comparison

Obviously, the easiest way to achieve an azimuth comparison is to find two marks on the one plan. This is not always as easily done as it is said. A good trick is to take a measurement on a point that can be seen from some distance, e.g. the top of a fence post is a good target. Walk a good distance from the post, take a GNSS observation, and now make an observation to the post with your compass.

If you are going to an area where it may be difficult to find survey marks, check the photography on Spatial Information Exchange (SIX – see LPI, 2015c) maps. Locate a fence on SIX maps that may be on the boundary and calculate the bearing from the photography on SIX maps. You now have an approximate MGA position from SIX maps and a magnetic bearing from the plan.

The mile post shown in Figure 2 was located on the second day of the survey by using a combination of these methodologies. Inspection of SIX maps showed no fencing approximating the boundaries in or around the job. The azimuth comparison was taken from SIX maps from a fence about 5 km from the job. The cadastral overlay was examined and a couple of trees were chosen that may have been reference trees. The data was swung onto MGA and a block shift undertaken to get an approximate location. On the first field day, a reference tree was located and some measurements taken around a bend in the creek. The data was then shifted to suit these observations. On the second day, the approximate location of some of the boundaries was walked using the rover. It was on this day that some other reference trees, the mile post and some remains of old fencing were located.

6 CONCLUDING REMARKS

Most of the author’s GNSS experience has been gained not in the cadastral world but in areas such as large-scale control for photogrammetry and LiDAR, working in the mines, mining exploration, civil construction and conducting detail surveys. Using a GNSS for up to 10 hours a day gives the user valuable insight into the vagaries of the equipment. For example, on one job we realised there was a ‘hole’ in the satellites at about 11:00 hrs EST. After a few days, we noticed the accuracies returned about half an hour later. Over the course of the job we watched the ‘hole’ move a little each day.

Sometimes a site can pose a particular problem. One site was most difficult as the GNSS unit failed to perform regularly. The author has not been able to determine the cause of the problem except that it was localised. A colleague had a similar situation – in that case it was traced to the intercom system in a nearby gaol interfering with the radio.

GNSS in the right hands is a wonderful tool. Its use for rural cadastral surveying is far superior to the traditional terrestrial methods. In one case using the practical approach outlined above the author found a number of stone locks pits where there was no fencing within close proximity of the boundaries. Locating two of the original marks allowed scaling and rotating the data to MGA. It was then possible to walk the boundary and subsequently find a number of stone locks pits (in the long grass) along the boundary line.

GNSS users should not become obsessed with accuracy. Modern GNSS is accurate and repeatable, and users should develop good field, office and checking techniques. Then you will re-establish cadastral rural boundaries in accordance with the principles of boundary surveying and common law.

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