

# **The Integration of CORS Networks and the Cadastre and its Application in NSW, Australia**

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**Key words:** digital cadastre, CORS, GNSS, cadastral system

## **SUMMARY**

In many countries, CORS networks are now the predominate and preferred method of cadastral surveying. These networks have been seen to provide an efficient way of managing cadastral boundaries.

In Germany, Switzerland, Sweden and Cyprus, the government has invested heavily in creating a digital cadastre. These point based systems have steered such countries away from the traditional hierarchical boundary systems toward a system where a coordinate is the 'ultimate reference'. In these countries, surveyors need not reference corners with marks anymore.

A major reason for the reliance on the CORS networks for cadastral surveying results from stations in Germany, Switzerland and Sweden being fully networked and providing users with high levels of availability and repeatability. This is not currently the case in New South Wales (NSW) where the network is still in a preliminary stage in much of the State.

In the aforementioned countries, the accuracy requirements of cadastral surveying also make the CORS networks more suitable for this work. Throughout urban areas accuracy of between 20 -35mm is required which is readily achievable using their CORS networks.

With relation to cadastral boundaries, a common trend in Europe is to execute three main points:

- Produce a digital cadastre where the boundary coordinate points are seen as the final reference
- Reduce the cadastral accuracy requirements for these points to between 20 - 35mm
- Manage the locating of these cadastral points using a fully networked CORS Real Time Kinematic (RTK) service

This has provided an extremely efficient and effective way of managing cadastral boundaries. Most notably, it takes advantage of the speed of survey that CORS RTK can allow.

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## **1. SURVEYOR GENERALS INTERNATIONAL FELLOWSHIP**

The Surveyor General of NSW, Australia established the ‘NSW Surveyor General International Fellowships in Surveying and Spatial Information’. The purpose of the fellowship is to:

- “Provide an opportunity for personal and professional development for spatial professionals and surveying graduates in emerging areas
- Promote the broader opportunities for surveyors and spatial professionals both in Australia and overseas in surveying and spatial information
- Gain knowledge of international, best practice and work experience through overseas travel to selected jurisdictions which may include public or private sectors or a staff exchange” (Office of the NSW Surveyor General, 2008)

In 2009 I undertook the Surveyor Generals International Fellowship. I travelled to Germany, Switzerland, Sweden and Cyprus to study the integration of CORS networks and the cadastre.

The information gathered from interviews, observations and demonstrations on this trip contributes to forming part of this paper.

## **2. CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)**

CORS networks have been established in many European countries. The networks provide a new RTK GNSS technique for position measurement as opposed to the traditional surveying approach of distance and angle measurement.

As with any measurement system, the technique has accuracy specifications and is commonly considered to be slightly less accurate when compared to traditional total station measurement which may be an issue when considering them for use in a cadastral surveying application.

The advantages of the system have been seen to be that they can provide a quicker, easier way of measuring particularly with regards to connecting to a specified survey datum.

## 2.1 Germany

In Germany SAPOS is the organisation responsible for the government satellite positioning service.

The first GPS reference stations in Germany were built in the early 1990's. Currently there are approximately 270 reference stations with an average spacing of about 40 km.

The stations are able to track both GPS and GLONASS satellites, and will be able to track GALILEO satellites once these come online. It is envisaged that when the GALILEO satellites are operational, surveyors in Germany will have a minimum of 23-25 satellites to observe at any one time.

The service provided by SAPOS is a fully networked CORS arrangement. The accuracy of RTK services has been stated as 10mm at the antenna phase centre.

## 2.2 Switzerland

In Switzerland the Swiss Federal Office of Topography is called Swisstopo. The commercial CORS service that Swisstopo provides is called SWIPOS.

Switzerland has two main reference frames. The first, named LV03, was established in 1903 upon a thorough triangulation control survey of the country. The second, LV95, was established under the banner of the National Geodetic Survey of 1995. Swisstopo established a new high-accuracy satellite based survey datum. The Swiss CORS network was integral to the establishment of the new survey datum.

The Swiss CORS network comprises of 31 stations with an average spacing of 35 – 50 km.

It is currently estimated that 70% of the CORS network usage is for cadastral purposes.

## 2.3 Sweden

The Swedish CORS network has been named SWEPOS. It consists of 170 stations with 20 more stations to be established in the near future. Of the 170 stations 21 are considered “main” stations which have dual receivers mounted on temperature controlled concrete pillars and are built on very stable bedrock. The average spacing of the CORS is 60 – 70kms

Besides the operational efficiencies that a CORS network provides surveyors, Sweden had other important reasons for implementing the CORS network. Rationales include the fact that Sweden has many different control networks and the SWEPOS system was seen as a way to tie all these different networks together, providing a national and easily accessible reference frame for the amalgamation of spatial data.

Land Uplift is also a very big issue in Sweden with the CORS Network playing a large role in the monitoring of the post glacial rebound of the land. The average up lift of the country is in the order of 7 millimetres per year.

## 2.4 Summary Table

The Table below shows a summary of the CORS and Cadastral information from varying countries the author visited while undertaking the Fellowship.

**Table 1 – Comparison of CORS and cadastral data**

<b>COUNTRY</b>	<b>No. of CORS Stn's</b>	<b>Area of Country (km<sup>2</sup>)</b>	<b>Area/ Stn</b>	<b>Average Spacing of Stn's (km)</b>	<b>Digital Cadastre</b>	<b>Cadastral Accuracy Requirements</b>
Germany - SAPOS	270	357,100	1323	40	yes	20mm – urban (Hannover)
Switzerland - AGNES	31	41,300	1332	40	yes	35mm – urban
Sweden - SWEPOS	190	441,400	2323	65	yes	30mm – high densities, cities 50mm – detached houses 100mm – other 1m – forestry
CYPRUS - CYPOS	7	9,250	1321	40	yes	15mm – urban 25mm – Rural

### **3. INTERNATIONAL CADASTRAL SYSTEMS**

Cadastral systems internationally vary in terms of boundary location accuracy, and procedural and reporting requirements.

Cadastral systems are integral parts of a governments' ability to effectively manage real property dealings. Careful consideration of the purpose, utility and founding logic behind all aspects of a system must be taken into account when technological innovations provide new opportunities for improvements in the administration of the systems.

Many countries in Europe have differing cadastral systems which have evolved with changing technology. Elements of these provide examples which may be learnt from.

#### **3.1 Germany**

The generally accepted technique for surveying cadastral boundaries in Hannover, Germany utilises the SAPOS RTK CORS service.

The surveyor sets up their rover in the regular manner taking three measurements to a control point they plan to establish for the purpose of the survey, resetting the system each time they measure the point.

The surveyor then waits 1 hour and re-measures the same point three times, resetting the system each time they measure the point. The difference of the average of the first three measurements must be less than 12 millimetres than the average of the second three measurements for the survey to proceed.

They then measure to the corners of the lot of the cadastral boundary based on the values given by the digital cadastre. The resultant measurement must be within 20 millimetres of the values calculated for the digital cadastre.

They then check their rover against a survey control point (equivalent NSW State Survey Mark/Permanent Mark or alike) which must be within 10mm of the value stated, if this is not achieved they must check it against another survey control point. If they are unable to agree with the local survey control then are able to perform a local transformation of those control points based on the values they measured.

#### **3.2 Switzerland**

The Swiss process for cadastral surveys may vary following a directive from Swisstopo to enable surveyors to have a freedom of choice of method when it comes to cadastral surveying subject to the product being of the required accuracy. The accuracy requirement for a cadastral point in Switzerland is generally 35mm.

As stated the surveyor may choose the method for achieving this and his reporting requirements may differ. However, Swisstopo requires that the method they choose and the report they produce should enable reproduction of their work by another surveyor.

A surveyor would generally need to show that the measurements of all their points of interest, including boundary points and control points, were within 35 millimetres of previously stated values. Where this is not possible a local transformation may be undertaken and the results shown.

As stated, it is currently estimated that 70% of the CORS network usage is for cadastral purposes.

### **3.3 Sweden**

In Sweden, the national body for cadastral surveying and management is Lantmäteriet. In the Swedish cadastral system this national body carries out all cadastral surveys. There are no private cadastral surveyors in Sweden.

Sweden utilises a cadastral accuracy system that varies according to land use. This was summarised in the preceding table.

Lantmäteriet has utilised the GIS environment to integrate some of their cadastral surveying processes. When a cadastral survey project comes into Lantmäteriat the following process is usually undertaken:

- A job file in the GIS's cadastral environment is created.
- The lot/s being dealt with are extracted and 'locked' so that no other changes can be made while the survey is being carried out.
- The surveyor performs the survey fieldwork, calculations and marking.
- They then upload the altered cadastral information into the GIS.

This cadastral information is then used in the GIS as a layer. It has been seen that the cadastral layer provides an important reference frame for much of the other data being managed by the GIS.

## 4. DIGITAL CADASTRES

A trend internationally is to convert traditional paper based cadastres into survey accurate digital cadastres based in a specified reference frame.

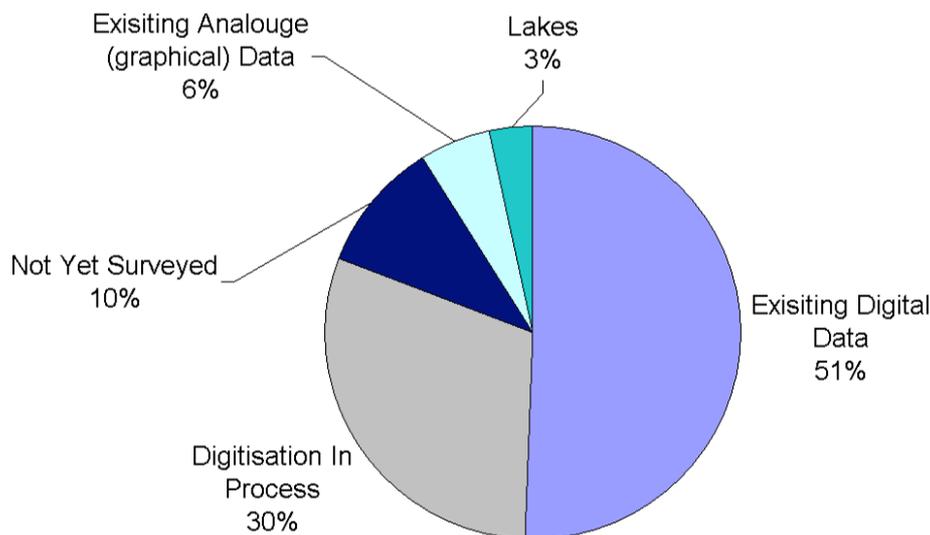
This has been thought to provide increased efficiencies in managing the cadastral process. Many European countries have adopted the idea that a coordinate from a digital cadastre would be the ultimate reference mark. In some cases it is no longer required that reference marks be placed as recovery marks to help reestablish boundary position.

The conversion has been seen to be an expensive and time consuming process in many cases.

The ease of extraction of ready to use boundary coordinates from a digital cadastre is one reason for this trend as the coordinate information can be used in a straight forward manner by a CORS based RTK GNSS survey technique.

### 4.1 Switzerland

Switzerland introduced the digital cadastre in 1993. A major part of implementing a digital cadastre was the conversion process from the paper based systems to the digital, computer based system. Switzerland has legislated that the cadastre must be fully converted to the new digital system by 2016. In 2007 the following percentages of cadastral data where converted to digital format:



**Figure 1 – Swiss cadastral data converted to digital format in 2009**

Swisstopo has detailed several ways in which the conversions were undertaken including:

- Field Survey; in some cases large areas of land are under contract to private surveyors for conversion to digital cadastre.
- GNSS; utilising the Swiss national CORS network.
- Photogrammetry
- Laser Scanning

The considerable cost of this conversion process has been acknowledged by Swisstopo but they have considered that the approximate value of the land asset in Switzerland is around €600bn and the proper management of this asset is paramount. It has also been seen that the digital cadastre is the base for other spatial information such as buried assets, ownership, valuation, etc. thus there are also flow-on benefits in having a totally digital cadastre.

## 4.2 Sweden

Sweden has invested heavily in the construction of a new GIS system to better manage and disseminate its spatial data. Fundamental to this is the digital cadastral elements that were described previously.

SWEREF, the Swedish national reference frame, underpins the whole GIS. This fact highlights the importance of the CORS network in monitoring and maintaining the reference frame. It also highlights the CORS networks connection to the digital cadastre which the bases of the GIS.

The value of the digital cadastre in the Swedish GIS is greatly increased by having accurate and easily applicable spatial coordinates. As the three elements are so closely associated, the CORS network is imperative in realising the greater functionality and usability of the digital cadastre.

## 4.3 Cyprus

In 1987 a group of nine South Australians including the then Surveyor General, John Porter, came to Cyprus to advise the government on the integration of government data which was largely paper based. One of the main recommendations from the visit was the implementation of a digital, integrated storage database for Cypriot spatial information.

The database in Cyprus is titled the Land Information System (LIS). The LIS was set up with the view of it being based on the cadastre with many layers held along with this.

There is currently a project in Cyprus to carry out a total cadastral resurvey of the country for inclusion in the LIS. At this stage 10% of the country has been resurveyed. The authority responsible has commented that the process is too slow.

The resultant data set is being stored as the Survey Data Base (SDB). This data is considered to be survey accurate and is being used as a digital cadastre. Surveys based on this data have a cadastral survey accuracy requirement of 15mm for urban land and 25mm for rural land.

## **5. CADASTRAL SYSTEM IN NEW SOUTH WALES, AUSTRALIA**

### **5.1 Current System**

#### **5.1.1 Traditional Cadastral Surveying**

The cadastral system in NSW is a traditional hierarchical cadastral system. Many forms of evidence can be used to re-establish the cadastre including natural features, reference marks, boundary marks, etc. Each of these types of evidence has their own weight of importance in the system.

In terms of the surveying process it can be gleaned from documents such as the Surveying and Spatial Information Regulation 2006 and the NSW Survey General's Directions, from books such as 'Legal Aspects of Boundary Surveying as Apply in New South Wales' by F. M. Hallmann (1973) and 'Notes on Survey Investigation' by R. W. Willis (1974), and from consideration of techniques of experienced NSW surveyors that the cadastral surveying system has evolved gradually since colonisation.

The cadastral survey process generally involves traditional survey methods of angle and distance measurement based on a control network which is linked to a reference frame (currently Map Grid of Australia (MGA)) to observe the position of the above described categories of evidence.

NSW is in the process of constructing its CORS network. As discussed, in many European countries the use of CORS RTK has superseded similar methods to those described above and has become the preferred method of cadastral surveying.

#### **5.1.2 The Cadastre**

Currently the cadastre in NSW is paper based where so called 'Deposited Plans' (DP) and other survey plans contain information regarding cadastral boundaries.

The NSW Department of Lands has created a Digital Cadastral Data Base (DCDB) which is a digital version of the paper system. This database was created in the 1980's into which new survey plans are continuously being updated. It is typically used for land administration, utilities management, environmental planning and valuation.

The DCDB is not considered survey accurate. The positional accuracy of the DCDB is quoted as “+/- 2 metres in urban areas and +/- 10 metres in rural and remote areas.” (Department of Lands, 2006)

If a system similar to many European examples were to be implemented in NSW where a digital cadastre was used to assist in administering the position of property boundaries it would be necessary to either improve the accuracy of the DCDB or create a new survey accurate digital cadastre as is being attempted in Cyprus.

### 5.1.3 Cadastral Accuracy

Currently in NSW the cadastral accuracy requirement is a uniform system that relates equally to properties such as high density urban land and large blocks of rural land. There has been some discussion of modifying the accuracy requirements to suit land use needs. “For better reliability... tailor the required accuracies to need” Parker, et al (1995).

Although cadastral accuracy requirements of a boundary point are generally not defined quantitatively in literature it can be noted anecdotally from the experience of the author (a practicing registered land surveyor in NSW) that if a discrepancy of over a centimetre is ascertained with regard to a previously described reference mark and can be supported by comparison to other related marks, the new observation should be adopted. Also, the NSW Surveying and Spatial Information Regulation 2006 in Reg 25 stipulates that, “In making a survey, a surveyor must measure all lengths to an accuracy of 10 mm + 15 parts per million or better at a confidence interval of 67%.” (New South Wales Government 2006) This equates to an accuracy of just over a centimetre for a length of 100 metres. Such evidence suggests a notional cadastral accuracy in NSW of approximately a 10 millimetres.

This can be contrasted to the information given in the summary table above where the majority of countries have a cadastral accuracy of between 20 – 30 millimetres. In addition it can be seen that the accuracies provided by a fully networked CORS system facilitates their use as an acceptable means of surveying the cadastre in such a situation.

## 5.2 Benefits of Change

It has been experienced in Germany, Switzerland and Sweden that the adoption of their CORS RTK as the preferred method of cadastral surveying as lead to greater speed and efficiency in the process.

Using the CORS RTK eliminated the difficulty sometimes associated with connecting a cadastral survey to the nominated reference frame.

When used in conjunction with digital cadastral information it eliminated the need to draft plans which increased speed of validation of new cadastral data. In Hannover, Germany a surveyor was not required to submit a plan of the survey. All that was required was a list of coordinates and statistical data proving their rigor.

This process in many cases also eliminated the need to place reference marks which simplified the cadastral surveying process. The repeatability that the fully networked CORS system gave, allowed the coordinate to be seen as the ultimate reference with confidence. Boundary marks were also used to provide some redundancy and confidence if boundary recreation was required by means other than the CORS.

### **5.3 Disadvantages of Change**

There may be some disadvantages of a cadastral system that utilises a digital cadastre along with CORS RTK as the primary means of measurement.

It can be argued that the cadastral systems used in places like Hannover, Germany where boundary corners are not required to be referenced to a mark result in a reduced ability to recreate cadastral boundaries. This would be seen to be a reduction in the reliability of the cadastral system. This argument is based on the idea that at some point in the future the CORS network may not be able to reestablish a coordinate defined in a digital cadastre. Reason for this cessation includes failure of the network or discontinuation/degradation of GNSS satellite signals.

The reduction of cadastral accuracy requirements in NSW may increase property related litigation particularly where issues arise regarding very small boundary distances, approximately 10 to 20 millimetres.

It has been the experience of both Swisstopo, in Switzerland and the DLS, in Cyprus that the conversion of the cadastre to a digital one is a time consuming and expensive process. Unless an innovative method of conversion can be developed NSW would have to accept this.

There is also an argument that there are many places where GPS does not work, for example in dense bush and in urban canyons. In these areas it is thought that the GPS system would be used to establish control close by the subject site and traditional survey methods used from there. In a case like this the proposed speed and efficiency of the CORS network would not be fully realised.

## 6. CONCLUSIONS

It is possible for a new cadastral system, which follows the system adopted by many European countries, to be adopted in New South Wales.

This may have to be established at the full completion of the currently planned CORS network, the creation of a survey accurate digital cadastre and a possible degradation of the current cadastral survey accuracy requirements.

This new system might also speed up the cadastral surveying process. This would flow on to more timely land administration functions.

It has been thought that the new system may reduce the ability to reestablish the cadastre, and degrade the reliability of the cadastre. It would be a very costly system to establish as a survey grade digital cadastre would have to be established from first principles.

The examples from Europe show how these new technologies and concepts can be harnessed to produce an innovative way of administering land in NSW.

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