Future Development of the New Zealand GNSS Continuously Operating Reference System - Positionz

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Key words: GNSS, CORS, New Zealand

SUMMARY

Land Information New Zealand (LINZ) is the Government Department in New Zealand responsible for managing Land and Seabed Information that includes the cadastral survey and land titles systems, hydrographic and topographic mapping, and the geodetic system. In 2001 LINZ commenced installation of a Continuously Operating GNSS Reference Station (CORS) network known as PositioNZ. Station stability was of prime importance and the network was designed to deliver 30 second RINEX hourly and 24 hourly files. Currently 32 stations operate in New Zealand at a spacing of about 100km with a further 2 stations on the Chatham Islands and 3 in Antarctica. The business case developed for PositioNZ's installation and operation was based on the premise that the network would be used to monitor and manage New Zealand's semi-dynamic datum. Explicitly excluded from the initial business case was the development and use of the network by LINZ as a real time positioning network for use in applications such as RTK. Now that considerable investment has been made in developing the network, interest has been shown in its use for real time positioning applications. LINZ now streams real time 1 second data from a number of sites. Tests have recently been carried out into the viability of using the network for real time applications. LINZ is exploring ways that it might work with third parties who would use the data and provide an integrated GNSS CORS across New Zealand that would deliver real time products to users. This paper discusses possible future development of the network.

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1. INTRODUCTION

Land Information New Zealand (LINZ) is the Government Department in New Zealand responsible for managing Land and Seabed Information that includes the cadastral survey and land titles systems, hydrographic and topographic mapping, and the geodetic system.

In 2001 LINZ commenced installation of a Continuously Operating GNSS Reference Station (CORS) network known as PositioNZ, in partnership with GNS Science (GNS). The network consists of 32 GNSS permanent tracking stations across New Zealand (Fig 1) with an additional two stations on the Chatham Islands and three in Antarctica. Data from the network and information on each site is available through the LINZ web site www.linz.govt.nz/positionz. The principal objective of the network is to monitor national-scale (tectonic) surface deformation within New Zealand's official geodetic datum, New Zealand Geodetic Datum 2000 (NZGD2000).

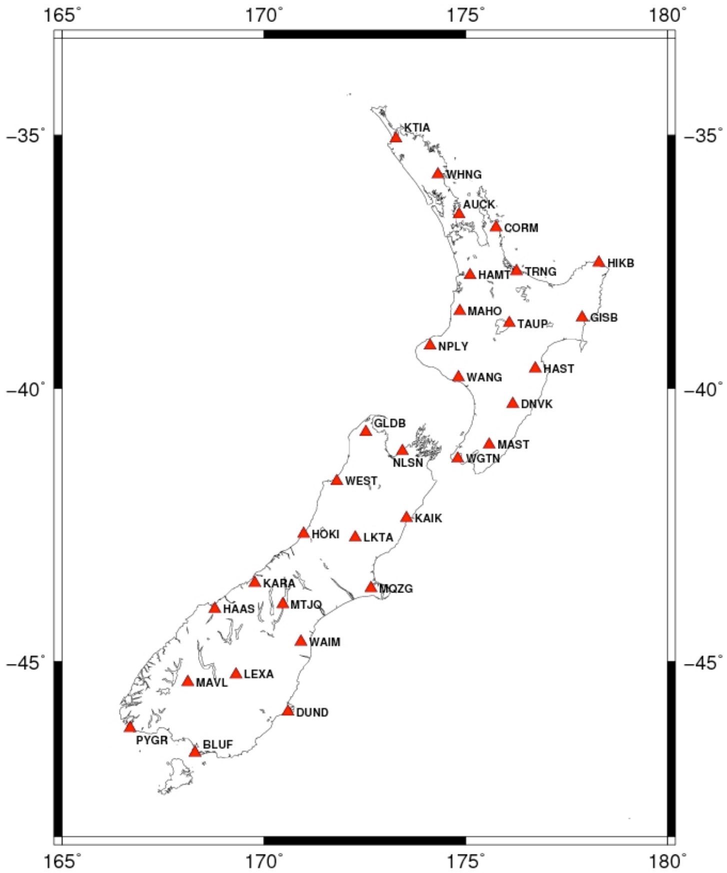

Figure 1-1 Sites of PositioNZ stations

The traditional geodetic networks in New Zealand consist of geodetic marks and trig beacons that were established by triangulation and more latterly by GNSS surveys. A connection to the official datum can be defined as "the acquisition of a position in terms of that datum to the required accuracy." The required accuracy may be at the millimetre or centimetre-level for cadastral and other high accuracy users. For navigation users where an accuracy of 1-10m might be required, the datum used may not be so critical.

Users can connect to the official datums (e.g., NZGD2000) in four, or a combination, of ways:

- Physically – by setting up directly over a geodetic mark (whether with GNSS or more traditional survey instruments)
- Remotely – by observing remotely to a trig beacon (which is over a geodetic mark)
- Mathematically – by using existing data which connects to a geodetic mark
- Electronically – by processing GNSS observations with data from a CORS station (e.g., PositioNZ).

Note that the above methods consider datum accessibility from a user perspective. All datum connections are physical at some level, but it is often convenient for the user to have some other party make that physical connection. With remote and mathematical connections, a previous surveyor has provided the physical connection (at a different epoch). With an electronic connection, the CORS operator provides the physical connection (at the same epoch as the user).

NZGD2000 is a semi-dynamic datum that incorporates a horizontal deformation model to accommodate the effects of crustal deformation in New Zealand. A connection to this datum may not be a trivial task because the datum dynamics (incorporated in the deformation model) need to be accounted for. The connection to the datum can be 1D (vertical), 2D (horizontal) or 3D (vertical and horizontal) depending on its application and purpose.

The traditional methods of connecting to the datums have been physically and remotely. Accordingly, LINZ's geodetic programme has focused on the installation and maintenance of geodetic marks and beacons. With the recent uptake of GNSS technologies there is an increasing demand from users for LINZ to facilitate the connection to the datum by electronic means. This has been partially addressed over the last five years with the establishment of the PositioNZ network which currently provides limited electronic access to the official datum.

Electronic datum connections have a number of advantages over the other methods of connection for users:

- CORS stations generally have very accurate official datum coordinates.
- The complexity of the semi-dynamic datum can be "hidden" as it is managed by the organisation providing the electronic connection. This is of particular benefit to non-surveyors.
- GNSS surveys can be completed more efficiently, as there is no need to set up a base station (physical connection).
- There may be no requirement to search for existing geodetic marks, which can be a time-consuming and challenging process.
- Different datasets have consistent coordinates, as they are connected to the same CORS network.

2. THE CHANGING SURVEY ENVIORNMENT IN NEW ZEALAND

Over the past five years the percentage of all cadastral surveys submitted to LINZ that use GNSS observations has increased from 2.6% to 9%. Class 3 surveys (boundary accuracy 0.25 m + 0.01 m/100 m), which are predominantly in rural areas, using at least one GNSS observation have increased from 9.5% to 23%. With this increase in the use of GNSS comes an opportunity for LINZ to provide datum connections electronically (as opposed to the direct observation of geodetic marks). Most GNSS cadastral surveys physically connect to the official datum by occupying geodetic marks. A small subset of these also connect electronically using data from a PositioNZ station.

Electronic connection can be provided through a CORS network by two methods:

1. Post-processed GNSS solutions
2. Real-time GNSS solutions

Post-processed electronic connections are made by static GNSS survey where two or more receivers are operated simultaneously on different marks for times ranging from ten minutes to several hours. The observations are then post-processed, typically in the office, to derive a vector between the marks. Users are able to make connections to the official datum using PositioNZ data. Data downloads from the PositioNZ network have increased from 40 files/month in 2003 to over 1000 files/month in 2007. The number of files specifically used for cadastral surveys is unknown, but is likely to be small. The on-going development of an automated post-processing service, PositioNZonline, will make it easier for users to make post-processed connections to the datum.

The real value to a user of a CORS network is the ability to make an electronic real-time connection to the datum. A real-time connection is typically achieved using a CORS base station that continuously transmits “corrections” to a roving GNSS receiver that is operated by the user. Modern, networked, systems transmit “corrections” using data from multiple base-stations in the vicinity of the user. This type of system operates in real-time and can directly determine a connection to the datum, typically within a few seconds.

In the foreseeable future (the next ten years), it is predicted that physical geodetic marks will continue to be the most important method of connection to the datum in New Zealand, although they may increasingly be complemented by electronic connections.

3. REQUIREMENTS FOR ELECTRONIC CONNECTION TO THE DATUM

3.1.1 Cadastral users

To achieve (Class 1) cadastral surveying accuracy tolerances of 20mm with current post-processed GNSS technology there is a balance between observation time and the distance to the CORS stations. For example, 10 min observation would suit a baseline of up to 20 km, however 30 min or more may be required for a baseline up to 100km. The advantage with this post-processing method is that there is no reliance on communication between the base and roving station and data can be downloaded and processed in the office at a later time.

To achieve (Class 1) cadastral surveying accuracy tolerances, current real-time GNSS technology restricts a user to being within about 5km of a CORS station when using a single base station, although research indicates that this distance will increase as better algorithms are developed to reduce error sources (Rizos 2006). This method is known as Single-base RTK.

It is now possible to obtain real-time positions using multiple (a minimum of 3) base stations using a method known as Network RTK. Current manufacturer recommendations for setting up Network RTK stations to obtain Class 1 cadastral tolerances are for a maximum station spacing of 70km. As with Single-base RTK, the user connects to these services using some form of communications media (e.g., cell phone, radio modem). Therefore, Network RTK (like Single-base RTK) requires communication coverage in the area being surveyed.

The advantage of Network RTK over Single-base RTK is that a similar level of accuracy can be attained over greater distances. This means that for national Network RTK coverage, only one third to one sixth the number of base stations is required (Wanniger L 2006). However, more complex data management and processing software is required.

3.1.2 Non-cadastral users

GNSS equipment is increasingly being utilised by non-cadastral users. While no specific data is available, customer queries and anecdotal evidence from GNSS instrument suppliers suggest that there are many other users (for example, GIS users, TLAs, utility companies, construction companies, topographic mappers and land managers) of the geodetic system that would benefit from electronic access to it. These are users for whom the current physical, remote and mathematical means of accessing the datum may not be useful.

It has been assumed in the past that the provision of marks in the ground and trig beacons for cadastral users, will also meet the needs of most other users. This assumption is also considered to be true for electronic connections.

4. CURRENT NEW ZEALAND GNSS INFRASTRUCTURE

4.1.1 PositioNZ network

The LINZ PositioNZ network of 32 stations across New Zealand (Fig 1) has a station spacing of 100-150 km. It was initially designed to deliver 30-second RINEX data (downloaded from a station every hour). This data is made available through the LINZ web site (www.linz.govt.nz/positionz) and can be used to obtain post processed electronic connections to the datum.

Twelve of the 32 stations also deliver real time 1-second data in addition to the hourly RINEX files. This enables users with appropriate software to connect electronically to the datum in real time. The use of the 1-second data is currently being piloted by selected users, and is not generally available to the spatial community at this stage. Those stations that rely on satellite communications have a high latency in this data and they currently prove too unreliable for the real time delivery of the 1-second data. Upgrades to communications at these stations are likely to be expensive.

The 1-second data that is currently delivered from the 12 PositioNZ stations comprises raw GNSS observations in the proprietary format of the GNSS receiver as well as the GNSS observations in the open format RTCM RTK corrections. This data can be used by the private sector to generate real time RTK solutions or, with suitable software, to generate their own proprietary single-station RTK and network RTK solutions.

The existing spacing of PositioNZ stations means that single-station RTK-type services could only be delivered over only a small percentage of New Zealand. When the PositioNZ stations were established, where possible they were located at sites close to population centres so that a higher proportion of the populated area is covered. International literature suggests that RTK methods might be feasible over longer distances in the future; this would mean that the existing PositioNZ network could service a larger area.

The (almost complete) PositioNZonline service will allow users to collect GNSS data and submit it to LINZ via its web site for automatic post-processing with data from adjacent PositioNZ sites. The resulting NZGD2000 coordinates (and ancillary results) will be delivered to the user by email. This service is expected to be operational during by the end of 2008.

4.1.2 Other GNSS Infrastructure

LINZ is not the only organization that has GNSS infrastructure in New Zealand. The GNS GEONET project (funded by the Earthquake Commission) has a network of 70 CORS stations that is being extended to 130 stations, predominantly situated in the North Island along the east coast tectonic shear belt and in the Taupo Volcanic Zone. The purpose of the network is to track earth deformation for hazard monitoring purposes. The GEONET team built and manages the PositioNZ network under contract and also uses data from these stations as part of its hazard monitoring network.

There are also privately operated CORS stations located in urban areas. The two major companies in this market, Global Survey and GeoSystems, operate 11 stations between them. Their infrastructure is used to provide their customers with single-station RTK corrections, generally in their respective proprietary formats. They are currently evaluating the establishment of network RTK services.

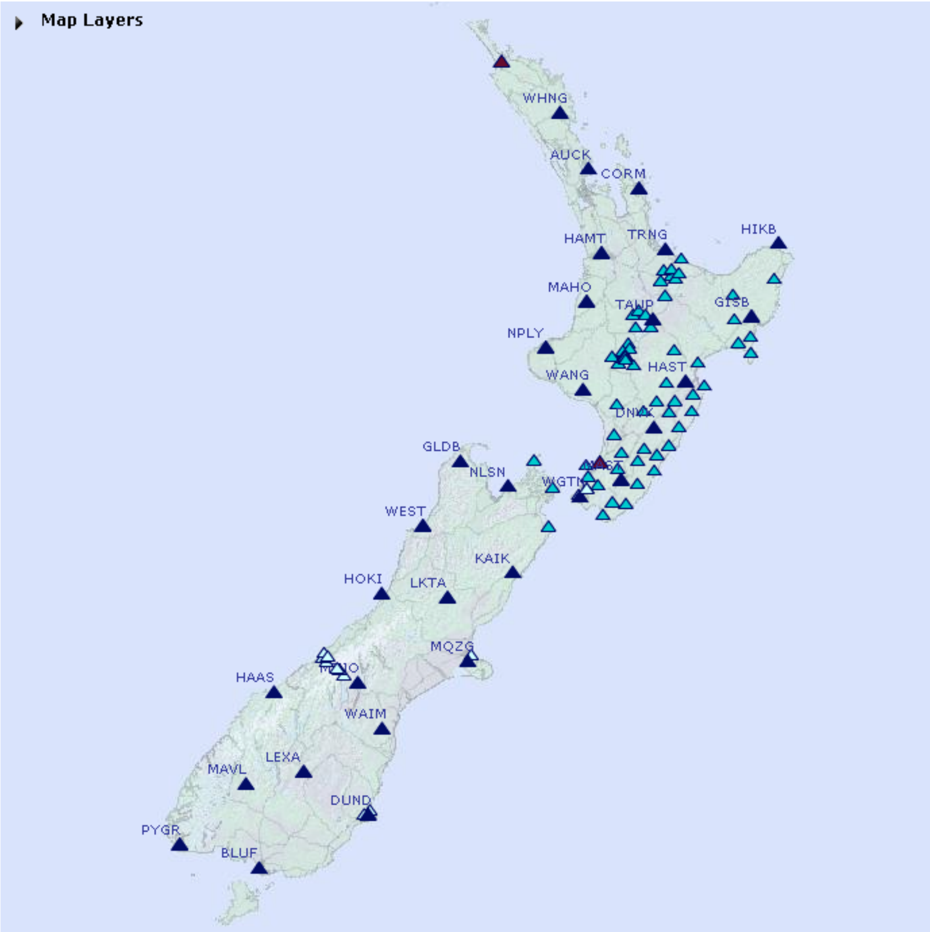

Figure 4-1: LINZ PositioNZ and GEONET CORS sites

5. FUTURE DEVELOPMENT OF A REAL TIME CORS NETWORK IN NEW ZEALAND

From LINZ's perspective the aim of a national CORS network is to enable monitoring and updating of NZGD2000. This is currently provided through the existing PositioNZ network. A secondary aim is to enable real-time electronic connection to the official datums of New Zealand which would require some modification and extension of the existing PositioNZ network.

Current development of the PositioNZ network is focussed on:

- Increasing the number of stations capable of streaming 1" data reliably.
- Developing the automated post processing of positions in terms of the official datum anywhere in New Zealand using PositioNZonline.
- Researching the use of the PositioNZ network, and use of other stations, for the provision of single-station RTK and network RTK solutions.

Tests were carried out in early 2008 using a subset of stations in the Wellington Region to investigate the suitability of the network for the provision of single-station RTK and network RTK solutions.

The tests also emphasised that if LINZ considers these applications to be an important use of PositioNZ, it should be looking to incorporate constellations other than GPS into their network. During the testing, it was found that a lack of common satellites between the reference stations and rovers meant that initialisation was difficult or impossible to achieve for an hour or two each day. Using reference receivers with GLONASS capabilities would have lessened these problems considerably.

It was also shown that the communications infrastructure for the network is generally lacking the stability required for reliable network RTK positioning. Stations tended to have many dropouts of small duration, resulting in a change in network configuration. This often caused delays in the field, particularly if the Master station had intermittent communications.

While results suggest that the spacing of the current PositioNZ network will be sufficient to provide a basic service, the spacing is such that at times the service can be unreliable. It appears that the network by itself has station spacing at an insufficient density for the provision of national reliable single-station RTK and network RTK solutions. However by incorporating stations from other networks such as the GEONET network a much more reliable service could be provided.

There are likely opportunities to see the GNSS infrastructure expanded in New Zealand in the future including:

- Development of networks in the large metropolitan and urban areas by commercial companies such as GeoSystems and Global Survey.
- Expansion of the GNS GEONET network, particularly into the South Island.
- In areas not adequately covered by the 2 options above, LINZ might provide additional stations, either alone or in partnership to extend either a multipurpose single-station or network RTK service.

It is evident that the GNSS infrastructure in New Zealand is expanding quickly. Through a collaborative approach it is likely that a national single-station RTK and network RTK solutions could be established across New Zealand. By LINZ having a major role in the delivery of such services, complexities in the dynamic nature of the datum can be managed and a consistent electronic spatial infrastructure across New Zealand can be delivered.

6. CONCLUSIONS

Geodetic data underpins cadastral and all information that is accurately spatially positioned in terms of official New Zealand datums (eg NZGD2000). As technology changes the way we access datums will also change and LINZ has a responsibility to ensure that users can access the datums efficiently and to a required accuracy.

The delivery of the geodetic system includes the provision of physical, remote, mathematical and electronic connection to the datum(s). Complexities in the provision of New Zealand's semi-dynamic datum, NZGD2000, require the development of processes to manage New Zealand's dynamic environment and their incorporation into systems used for electronic connections to the datum. LINZ needs to develop and manage these processes.

If it is shown that the PositioNZ network can be satisfactorily used to provide real time services LINZ will investigation means of delivery of such services. These may be carried out in partnership with other agencies such as GNS Science.

REFERENCES

Rizos C (2006) *The Future Of GNSS RTK Services and Implications for CORS Infrastructure* online at http://www.gmat.unsw.edu.au/snap/publications/rizos_2006c.pdf

Wanniger L (2006) *Introduction to Network RTK* online at http://www.network-rtk.info/intro/introduction.html

BIOGRAPHICAL NOTES

Graeme Blick, BSurv(Otago) MNZIS. After graduating from Otago University in 1980, he worked as a scientist for the Institute of Geological and Nuclear Sciences using geodetic techniques to study plate tectonics and crustal deformation. After joining Land Information New Zealand in 1995 he worked for the Office of the Surveyor-General as Geodetic Survey Advisor and worked on projects such as the development of a new geodetic datum and map projection for New Zealand. Early this year he moved to the Customer Services Group where he is Manager of Geodesy and Team Manager Specialist Processing and Data Management.

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Dave Collett, BSurv(Hons) (Otago).Dave has worked as a Geodetic Data Analyst at LINZ for 2 years. His areas of interest include the management and development of the PositioNZ network, and Antarctic Mapping.

Aaron Jordan, BSurv(Hons), MSurv (Otago). Aaron worked for 4 years as a Geodetic Data Analyst at LINZ for 2 years. His areas of interest include the management and development of the PositioNZ network and incorporating local deformation into the nation datum. A year ago he moved to Leica Geosystems.

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