The New Zealand Geodetic System Part 1 – Introduction and overview

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This is the first of a series of articles on the New Zealand Geodetic System to be provided by Graeme and others in future issues of Survey Quarterly

The geodetic system in New Zealand plays an important role in the development of our country. It comprises intellectual, physical and data components which provide authoritative coordinate systems for New Zealand's areas of territorial and administrative responsibility. Measuring and mapping continues today with the management of our natural and economic resources becoming increasingly dependent on the availability of accurate and consistent spatial geographic information. The foundation of our geographically based datasets, including the cadastral system, is an accurate spatial reference system, the geodetic system.

This article is the first in a series describing the geodetic system in New Zealand, its components, the annual maintenance and survey of control marks, and potential future developments of the survey control system. The focus of the articles will be on geodesy in New Zealand since the formation of LINZ in 1996. However I will begin here with an introduction to New Zealand's geodetic system and an overview of forthcoming articles.

Introduction

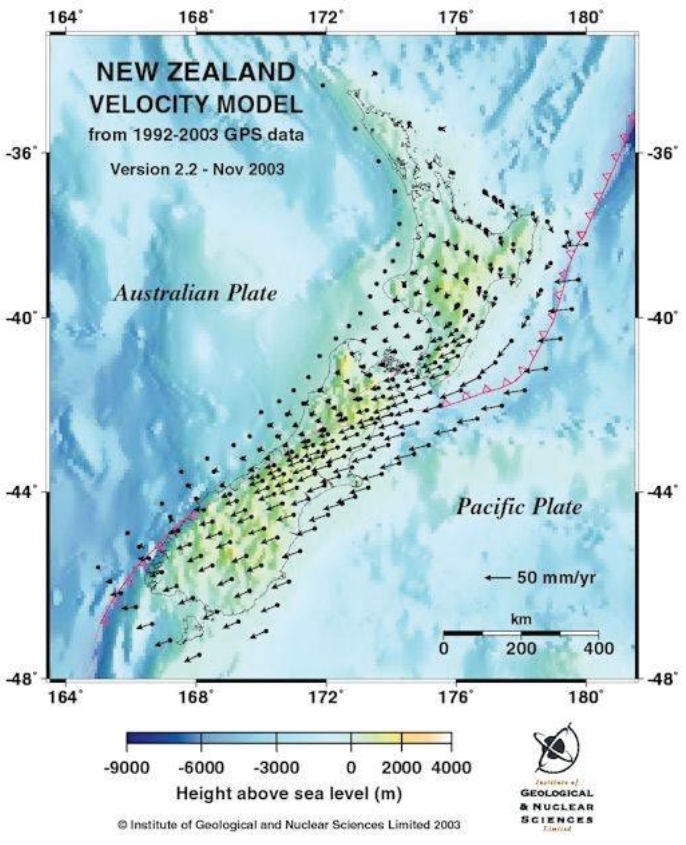
Control networks and geodetic datums

In New Zealand, as in many other countries, settlement and mapping often proceeded in advance of the triangulation survey networks that should have controlled them. When early triangulation surveys were done in the mid to late 1800s, smaller networks were done first and larger, more accurate, networks later. Each stage of triangulation thus led to much revision or recalculation of the earlier work.

The national geodetic triangulation of New Zealand is considered to have begun with the measurement of the Wairarapa Baseline in 1909. However triangulation surveys to control surveys for land development began much earlier in the early 1840s.

It was not until 1949, with the completion of the first order triangulation, that there was a national geodetic datum, New Zealand Geodetic Datum 1949 (NZGD1949) which used the Hayford (International) ellipsoid. For the first time New Zealand had an homogeneous triangulation and national survey control system across much of the country. A good history of the early triangulation of New Zealand is provided by Lee. Enhancements and extensions to the triangulation networks increasing coverage across New Zealand were to continue for the next 50 years.

By the mid 1990s a number of issues identified with NZGD1949 were becoming significant. Notably its accuracy was insufficient to support surveying technology such as high precision EDM and GPS, and because it did not account for the effects of crustal



NZGD2000 deformation model

deformation it was no longer able to meet modern requirements for a national datum.

A decision was subsequently made to implement a new geodetic datum, New Zealand Geodetic Datum 2000 (NZGD2000). This new three-dimensional semi-dynamic datum had increased accuracy and used the GRS80 ellipsoid. Notably it included a deformation model to convert geodetic observations made at different times to a common reference epoch of 1 January 2000 and accommodate the effect of crustal dynamics.The technology used to carry out surveys for this datum moved from the more traditional triangulation techniques to the use of Global Navigation Satellite Systems (GNSS) such as GPS, although many older triangulation observations were readjusted and included.

Projections

In 1877, 28 meridional circuits were established for cadastral surveying. Nine were located in the North Island and 19 in the South Island. Each had a physical initial station and they were assumed to be on a plane. In 1949 these circuits were upgraded to transverse Mercator projections. Each circuit was divided into survey districts and these formed the basis for cadastral surveying and mapping.

Following the introduction of NZGD2000, the 28 existing meridional circuits were redefined in terms of the new datum. Transverse Mercator projections were again used, but the origin of each circuit no longer related to a physically monumented location The circuits continue to be used primarily for cadastral surveying.

Separate North Island and South Island transverse Mercator projections were implemented for national one inch to one mile topographic mapping from the 1940s. During the 1970s, and pushed by decimalisation, a decision was made to metricate mapping in New Zealand. In 1973 a new national mapping projection unique to New Zealand was implemented and called the New Zealand Map Grid (NZMG). This was a conformal projection with a single national metric grid across New Zealand which was adopted for the new national 1:50,000 topographic mapping series introduced at that time. A proposal was also considered to adopt NZMG for cadastral surveying and mapping, however it was never adopted, possibly because of complexities in the definition and computations associated with the projection.

Following the move to NZGD2000 a decision was made to adopt a new single transverse Mercator projection for topographic mapping in New Zealand. Consequently, in 2001 the New Zealand Transverse Mercator 2000 projection (NZTM2000) was implemented for national mapping and is being used for the new 1:50,000 Topo50 map series.

Vertical datums

NZGD1949 was a two dimensional datum. Normal-orthometric (approximate sea level) heights were referenced to 13 separate levelling datums that were located across parts of the country. Each of these levelling datums has its origin at a tide gauge at which mean sea level was determined. Precise levelling was used to extend each network from each origin, primarily following the major road networks. As with triangulation, extensions to the levelling networks increasing coverage across New Zealand were to continue until the 1990s.

NZGD2000 is a three dimensional datum and uses ellipsoidal heights.

Modern statutory context

Before leaving the general introduction of the geodetic system it is worth noting its statutory context. The Cadastral Survey Act 2002 makes it a function and a duty of the Surveyor-General to maintain the national geodetic system and the survey control system. This Act defines a geodetic system as –

> a system that enables positions on the surface of the Earth to be determined by reference to a mathematical model that describes the size and shape of the Earth

and the national survey control system as –

> a system used to determine the position of points, features, and boundaries in cadastral surveys, other surveys, and land information systems.

The national survey control system is the network of control marks that are used by surveyors and others to position cadastral surveys, topographic surveys and other surveys in terms of a consistent reference system. It also includes information about control marks such as their position, descriptive information and observations between them. Control marks are also used to monitor deformation and to re-establish the cadastre following a deformation event such as an earthquake.

The geodetic system includes the control system, geodetic datums, vertical datums, projections and other information that is used to define a nationally consistent reference system.The coverage of the geodetic system includes mainland New Zealand as well as the Chatham Islands, other offshore islands within the continental shelf, and the Ross Sea region of Antarctica.

The Surveyor-General has delegated the function of maintaining the control system to the Customer Services group within LINZ. This maintenance is carried out in accordance with standards and guidelines developed by the Surveyor-General.

Current status and overview

Survey control networks

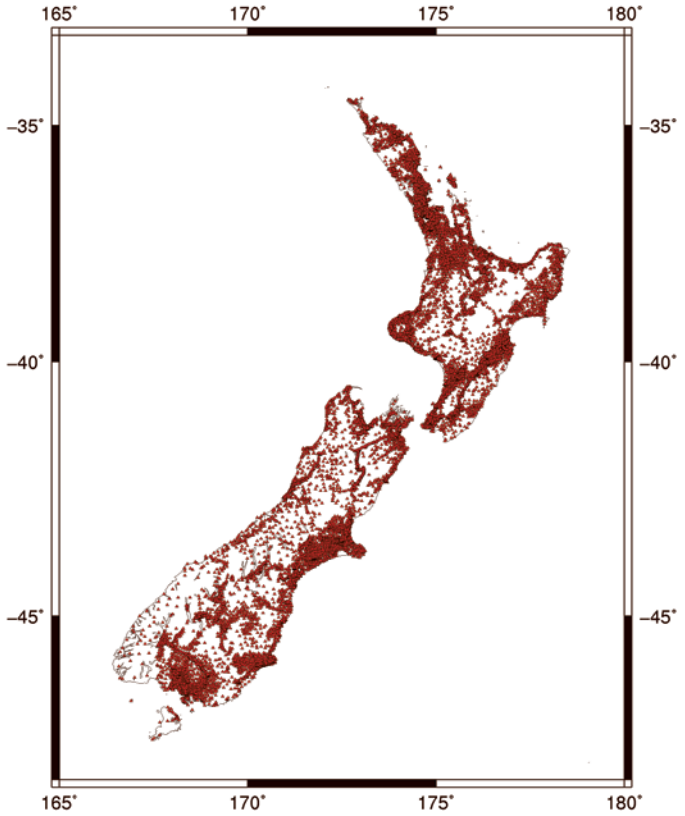
A survey control system consists of physical control marks, often with beacons to provide remote access to the network. Increasingly

Typical control mark with beacon

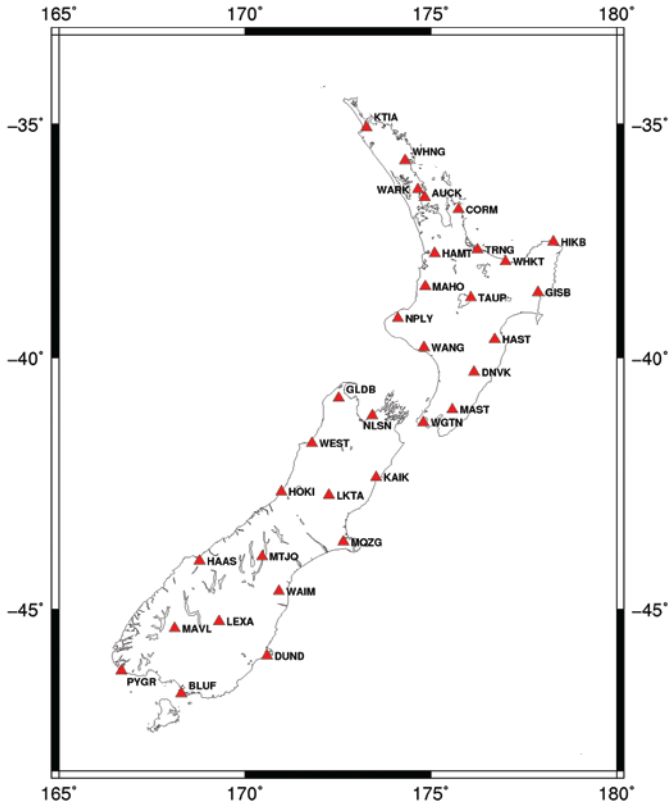
Typical CORS station

GNSS continuously operating reference stations (CORS) are forming an important component of the survey control system.

The traditional network of control marks consists of a hierarchy of marks based on accuracy called orders. The most accurate control marks (order 0) are the CORS stations. The least accurate control marks (order 5) are placed primarily to enable cadastral surveys to connect to NZGD 2000. There are currently more than 75,000 control marks and of these about 4,000 have beacons.



New Zealand control marks



PositioNZ stations on mainland New Zealand

The survey control network is continually being upgraded and extended to meet the needs of a range of users. Much of the focus over recent years has been on extending the coverage and accuracy of the order five control marks, particularly to enable the original NZGD 1949 triangulation networks and control traverses to be incorporated into NZGD 2000.

PositioNZ network

PositioNZ is a national network of 33 CORS stations located across New Zealand, the Chatham Islands and the Ross Sea Region of Antarctica. The main reason for this network is to monitor national-scale crustal deformation and to maintain the deformation model which is an integral component of NZGD 2000. (For further information on this see the June 2008 (issue 54) *Survey Quarterly*).

Several of the PositioNZ stations are also International GNSS Service (IGS) sites and it is through these stations that New Zealand connects and contributes to global reference systems. These connections ensure that New Zealand's geodetic system is compatible with international systems. Providing data from these stations assists with the development of accurate global reference frames.

Control system surveying and maintenance

Historically the surveying and maintenance of control marks was carried out by staff of the Department of Survey and Land Information and prior to that, the Department of Lands and Survey. When LINZ was formed in 1996 all of this work was outsourced to private providers. An annual survey control and maintenance programme is developed and contracted out to external geodetic survey and maintenance providers.

Control surveys are now made almost entirely using GNSS observations. This has greatly increased efficiency and the accuracy of control surveys and allowed control marks to be placed where users require them rather than where was best for triangulation visibility.

Protection of control marks

One of the greatest risks to the survey control system is the destruction of its physical marks. LINZ offers a survey mark advisory service whereby anyone undertaking a work activity that is likely to damage or destroy a control or survey marks can notify LINZ who will identify those marks likely to be damaged or destroyed. The agency carrying out the work activity must then take the necessary steps to protect or replace any affected marks. This process has met with mixed results and is often dependent on local authority requirements for works agencies to notify LINZ of any work being undertaken and the goodwill of works agencies such as utility companies.

A service developed in Australia called 'beforeudig' notifies works agencies of services in the roadway that might be affected by their activity. 'Beforeudig' is now being offered in New Zealand and LINZ is currently working with the providers of this service to include survey marks in their database so that users of the system will be automatically notified of survey marks likely to be affected by their activities.

Control system data and landonline

When Landonline was conceived it was designed to cater for the automation of not only the cadastral survey and title systems, but

also the survey control system. Since the initial implementation of Landonline all control surveys have been fully automated and electronic survey control datasets supplied by contractors are loaded into Landonline. Information on control marks, maintenance, coordinates, survey data, and accuracy are retained and managed in Landonline. However much of this information can be accessed from the geodetic database on the LINZ website. The geodetic database is updated daily from downloads of geodetic data held in Landonline. Searching the database for control mark information can be done textually or via a spatial search using Google Maps.

The geodetic system and the cadastre

When Landonline was implemented the division between control marks and cadastral marks, including boundary marks, became blurred because all marks are referenced to the same geodetic datum (NZGD 2000). The cadastre in New Zealand can be considered a geodetic cadastre. While New Zealand does not have a legal coordinate cadastre, accurate coordinates for cadastral marks improve the efficiency of cadastral surveys and enable the data to be used for a wider range of purposes.

With the strong connection of the cadastre to survey control, issues for LINZ now include managing the spatial alignment between the survey control and cadastral systems. Readjustment of control marks following resurvey, a deformation event such as an earthquake, or addition of new or more accurate survey data now flows through to the cadastre requiring readjustment of the cadastre also. Readjusting a relatively small number of control marks can be a relatively trivial task, however subsequent readjustment of a large number of cadastral marks connected to that control is a much more complex and time-consuming task. There is also an increasing focus on connecting cadastral survey networks in non-survey-accurate areas to survey control networks to enable the spatial accuracy of the cadastre in these areas to be improved.

Future developments

The geodetic system has been and will continue to be upgraded and enhanced. Often this is in response to increased accuracy requirements but it is also to meet the needs of an increasing range of users.

The focus of the annual survey control programme for the past few years has been the provision of control marks to meet the needs of cadastral surveyors. However the survey control system has other roles such as the provision of control for national mapping, and measurement of crustal dynamics to enable the accuracy of the official geodetic datum to be maintained. More attention will be made to these other areas in the future to ensure that the survey control system is maintained accurately and that all user requirements can be catered for.

NZGD 2000 is almost 10 years old. The accuracy of the datum, its deformation model and how they can be updated and maintained in the future are currently being considered.

Enhancements to the PositioNZ network, such as the provision of real-time data, are also being considered by LINZ in conjunction with several other public and private organisations across New Zealand.

Summary

The geodetic system enables consistent spatial positioning in New Zealand. Since LINZ was formed there have been major developments in the geodetic area including development of NZGD 2000 and the transition from triangulation-based control surveys to the extensive use of GNSS surveys and a national CORS network. Further developments are planned that will see the spatial accuracy of the datum maintained and new services offered.

Future articles in this series will cover –

- Control system surveying and maintenance
- Protection of control marks
- Control system data and landonline
- Survey control networks
- PositioNZ network
- The geodetic system and the cadastre
- Future developments

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