Toitu te whenua
Land Information New Zealand

Realisation of the New Zealand Geodetic Datum 2000

OSG Technical Report 5

Merrin Pearse

1 June 2000

Contents

Foreword

Land Information New Zealand

Land Information NZ (LINZ) was established on 1 July 1996 and took over the responsibility for the policy, regulatory and core government service delivery functions of the former Department of Survey and Land Information (DoSLI), the Land Titles Office, and for the purchase of hydrographic services from the New Zealand Defence Force (to be made contestable from 1 July 1998). From July 1998, as part of the restructuring of Valuation New Zealand, the Office of the Valuer-General was also established within LINZ.

LINZ is focused on advising Government, administering the Crown's interests in land and making Government held land information available to the public. It is the government spatial referencing authority, and the steward and standard setter for core national land databases including: the spatial referencing system, cadastral system, land titles, topography, hydrography, Crown property (excluding the conservation estate) and valuation. Its vision is to provide world class land and seabed information services.

Chief Executive:
Dr Russ Ballard
PO Box 5501
Wellington
Phone: 0-4-460 0110
Fax: 0-4-472 2244
Email: info@linz.govt.nz
Internet: http://www.linz.govt.nz

This technical report is issued under the authority of the Surveyor-General who is responsible for setting geodetic standards, specifications, and guidelines in accordance with departmental policy and statutory requirements.

Any comments or amendments should be forwarded to the Surveyor-General, Land Information New Zealand.

Tony Bevin
Surveyor-General

REALISATION OF THE NEW ZEALAND GEODETIC DATUM 2000

1 Introduction

New Zealand Geodetic Datum 2000 (NZGD2000) is the new national geodetic datum for New Zealand and replaces New Zealand Geodetic Datum 1949 (NZGD49). This report focuses on how the Zero and First Order NZGD2000 coordinates were computed but also outlines the GPS data collected, the processing of the GPS data, the computation of the velocity model and the adjustment of the lower order stations (e.g. Second, Third, Fourth and Fifth) in terms of the Zero and First Order stations.

2 Background

New Zealand Geodetic Datum 1949 (NZGD49) was introduced to meet the needs for an integrated spatial reference system and complete topographical and cadastral mapping database coverage of New Zealand. Since its completion in 1949 it has played a significant role in the subsequent development of New Zealand. Because of the long term nature of land use, spatial systems need to be robust and capable of supporting future applications and growth.

While NZGD49 has served New Zealand's needs well over the last 50 years, it cannot now match the accuracy of new technologies such as the Global Positioning System (GPS) or support unified high accuracy Geographic Information System (GIS) applications over large areas. To maintain a highly accurate spatial infrastructure there is a need to account for the effects of ground deformation. This, and the development of an accurate integrated automated survey and title system, Land*online*, means there is a requirement for a new geodetic network and datum, able to serve New Zealand's needs for the future.

The limitations with NZGD49 are that:

- the coordinates of the First Order stations are held fixed at their defining values;
- regional distortions are present in the network of up to 5m due to the lower precision of the survey observations and techniques used to define the datum and the effects of crustal deformation since it was surveyed (Bevin and Hall, 1994);
- the lower order breakdown has been built up and defined in a piecemeal fashion resulting in localised distortions;
- it is incompatible with global geodetic reference systems;
- it is of limited spatial coverage, covering most of the land mass of New Zealand but not outlying islands (i.e. Chatham Islands);
- it does not define a vertical datum;

For a comprehensive account of how NZGD49 was developed refer to Lee (1978).

Land Information New Zealand has implemented a new geodetic datum, New Zealand Geodetic Datum 2000 (NZGD2000), to replace NZGD49. NZGD2000 was officially released on 25 August 1999. The new datum provides an accurate spatial infrastructure in New Zealand for the 21st Century.

The decision to adopt a new datum was made following discussion and consultation with users, and an evaluation of options against business drivers (OSG, 1998a).

The characteristics of NZGD2000 are:

- the datum has a geocentric origin which is compatible with the Global Positioning System (Note: the centre of the NZGD2000 ellipsoid coincides with the centre of mass of the earth. The centre of the ellipsoid used to define NZGD49 is displaced approximately 200 m from the earth's centre of mass);

- in line with recommendations by the International Association of Geodesy, the datum is based on, and aligned with, the International Terrestrial Reference System (ITRS) and the ellipsoid associated with this datum is the Geodetic Reference System 1980 (GRS80) ellipsoid (Note: the ellipsoid associated with NZGD49 is the 1924 International Ellipsoid which is approximately 250 m larger than GRS80);

- the relationship between the new datum and the ITRS has been realised through International Terrestrial Reference Frame 1996 (ITRF96) coordinates, specified at epoch 2000.0 (a reference date of 1 January 2000). All points coordinated in terms of the new datum will have coordinates defined in terms of this epoch (Note: the ITRF96 and World Geodetic System 1984 (WGS84(G873)) reference frames agree with each other to within a few centimetres (Malays *et al*., 1997);

- the generalised motion of points in New Zealand with respect to the ITRS are modelled using an Institute of Geological and Nuclear Sciences (GNS) velocity model:
  - to ensure that Land Information NZ can generate epoch 2000 coordinates from observations made at other times;
  - to allow other specialised users to generate up-to-date coordinates for times other than the reference epoch.

- the NZGD2000 coordinates of marks will change where new observations provide more accurate values, or when marks are affected by unpredictable deformation such as earthquakes.

The advantages of the new datum (NZGD2000) are that:

- it is a three dimensional datum compatible with international geodetic systems, such as the International Reference System (ITRS) and the World Geodetic System 1984 (WGS84);

- the accuracy of the datum supports modern survey techniques;
- it supports a network of modern, accessible survey marks;
- the effects of slow crustal deformation (plate tectonics) amounting to about 5cm/year can be managed through the use of a velocity model;

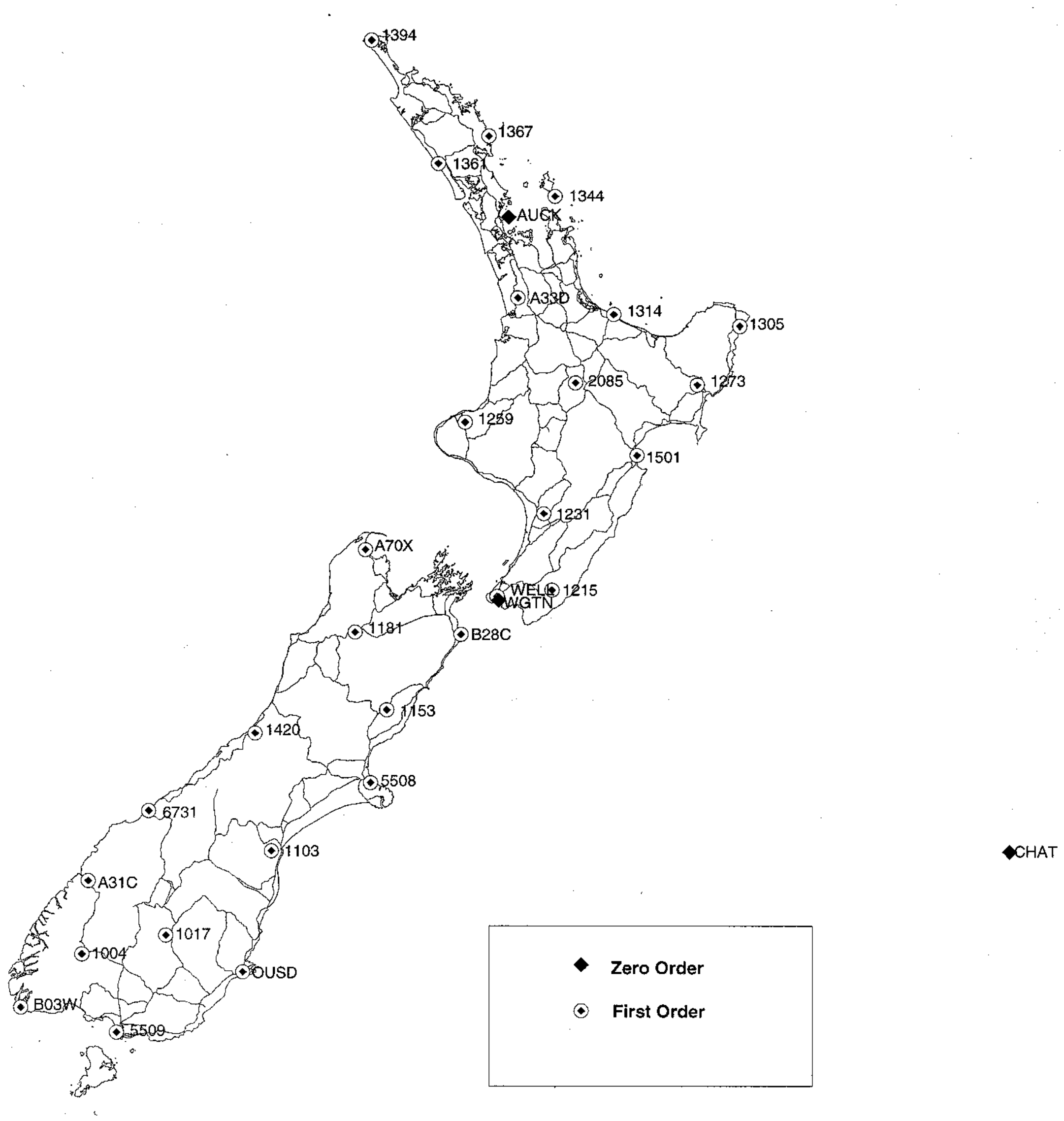
This report describes the technical computations that have resulted in the determination (realisation) of NZGD2000 coordinates.

3 GPS Data Collection

In 1992 the Department of Survey and Land Information (DOSLI) undertook a two day GPS campaign to investigate procedures for the observation of a national network of GPS stations. The results from the 48 hours of continuous data at five stations in the lower half of the North Island showed that suitably accurate coordinates could be obtained. This lead to a national campaign in 1993 to observe 30 stations (Figure 1) spread across the country which highlighted the distortion in NZGD49 (Bevin and Hall, 1994). The 1993 campaign is described in detail by Pearse (1997).

The 1993 network of 30 stations became the basis of the First Order NZGD2000 network which was subsequently observed yearly from 1994 to 1998. Observations were for approximately 3 consecutive 24 hour periods. Further details on the stations occupied and the dates of occupation is contained in Morgan and Pearse (1999).

During the time that the First Order NZGD2000 network was being observed the network was also being densified (filled in) through Second, Third and Fourth Order stations. The Second Order stations were placed at a nominal spacing of 70 km and had a minimum of two independent 8 hour observation sessions. The Third Order stations were placed at a nominal spacing of 20 km and had a minimum of two independent 1 hour observation sessions. The Fourth Order stations were placed at a nominal spacing of 1 km and had a minimum of two independent 15 minute observation sessions. The Second Order network covers the entire country, the Third Order network covers the populated areas of the country and the Fourth Order covers cities and larger townships. The process of densifying the network is ongoing, with the current focus being on the provision of Fifth Order stations to support cadastral surveys at an approximate density of 200 m in urban areas.



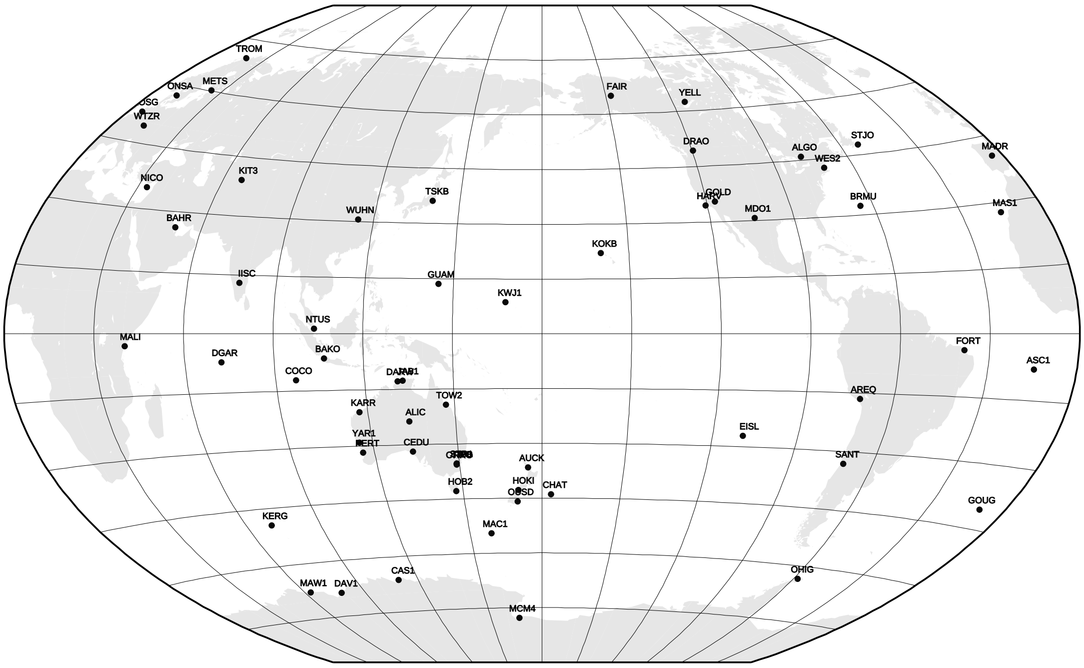
♦ Figure 1 : Network of NZGD2000 Defining (Zero and First Order) stations

4 Computation of ITRF96 coordinates at epoch 1996.5

LINZ contracted Dr Peter Morgan of the University of Canberra, ACT, Australia to compute coordinates for the Zero and First Order NZGD2000 stations in terms of ITRF96 at the epoch of 1996.5. This section summarises the methods and results of the contract. The full report is contained in Morgan and Pearse (1999).

The yearly 1st Order GPS campaign data from 1992 through 1998 was processed using the GAMIT/GLOBK/GLORG software suite (King and Bock, 1999 and Herring 1999).

The processing of daily data in GAMIT used two strategies. When there were five or less New Zealand stations in one daily network the New Zealand data were combined with GPS data from global stations and processed in one network. This was the case for all the observation days in the 1992, 1993 and 1994 data sets. For days when there were more than five New Zealand stations the New Zealand data were processed with regional stations (e.g. Australia, Pacific Islands and Antarctica) and the global stations were processed in a separate network. The two network approach was used for all the days in the 1995, 1996, 1997 and 1998 data sets. As an indication of the global stations used in the global networks the 1998 network is shown in Figure 2.



♦ Figure 2: GPS stations used in the 1998 Global Network solution

The daily GAMIT solutions produced station positions, satellite orbits and Earth orientation parameters. GLOBK was then used to unify the GAMIT solutions into a single system. To then constrain the GLOBK solution into ITRF96 the GLORG program was used, which basically only allows scale, rotation and translation of the GLOBK solution. To constrain the solution in GLORG the International GPS Service (IGS) coordinates and velocities (Sillard *et.al.*, 1998) of the original core group of IGS stations was used. The GPS codes for these stations are MADR, SANT, ALGO, YELL, GOLD, FAIR, TIDB, YAR1, HART, TROM and KOSG.

The highlights of the GPS processing are:

- GAMIT/GLOBK Software Suite;
- Single differences formed for all combinations of baselines;

- Double differenced phase ambiguities were estimated at both L1 and L2 frequencies. Ambiguities were not fixed to integer values;
- Only the elevation (not azimuth) component IGS_01 elevation-dependent antenna phase centre models (Rothacher and Mader, 1996) were used;
- Tropopheric estimates every 2 hours;
- Ionospheric models estimated every 2 hours;
- CVIEW used to examine the double-difference phase residuals for cycle slips;
- Coordinate and covariance files produced from a network solution of each observation session;
- The heights were computed in a Tide Free System.

The coordinates computed in terms of ITRF96 at epoch 1996.5 for the Zero and First Order NZGD2000 stations are shown in Table 1.

Geodetic Code	Name	X (m)	Y (m)	Z (m)
AUCK	Whangaparaoa	-5105680.990	461564.048	-3782181.773
CHAT	Chatham Island	-4590670.893	-275483.014	-4404596.787
WGTN	Wellington Airport	-4777269.350	434269.976	-4189484.652
1004	Mt York	-4371448.508	950019.355	-4531598.951
1017	Hyde Rock	-4408673.299	841182.570	-4518904.677
1103	Mt Horrible	-4509242.347	709568.151	-4440278.862
1153	Isolated Hill	-4660964.413	571445.661	-4302316.292
1181	Mt Murchison	-4727392.500	622413.005	-4224184.004
1215	Eringa	-4794050.724	364491.783	-4177890.168
1231	Mt Stewart	-4860522.601	383529.069	-4098473.496
1259	Huirangi	-4929040.037	498221.579	-4004033.171
1273	Okahuatiu	-4989460.451	191252.559	-3955756.527
1305	Te Pohue	-5042731.036	140230.637	-3890300.265
1314	Maketu	-5039298.757	311182.284	-3884430.072
1344	Ruahine	-5128814.165	401970.916	-3758286.418
1361	Mahora	-5138072.408	560948.499	-3724886.327
1367	Pukearenga	-5167214.344	496239.215	-3693852.201
1394	Te Paki	-5222589.733	662414.397	-3589435.368
1420	Mt Greenland	-4616400.196	745241.589	-4324328.213
1501	Bluff Hill	-4922647.771	265115.050	-4033578.818
2085	Marotiri	-4977955.116	355512.020	-3959577.453
5508	Windsor Castle	-4590826.049	584593.009	-4374757.107
5509	Three Sisters	-4303267.130	894811.292	-4606633.315
6731	Haast	-4521641.725	878624.013	-4396964.293
A31C	Milford	-4442644.982	950468.863	-4461626.486
A33D	Te Herunga	-5041355.010	441059.373	-3869624.530
A70X	Parapara	-4802026.173	617521.260	-4138427.835
B03W	Puysegur Point	-4305507.267	1024975.858	-4577337.960
B28C	Cape Campbell	-4741512.950	480470.749	-4225018.452
OUSD	Otago University	-4387888.550	733420.870	-4555178.594
WELL	Wellington	-4780648.764	436507.201	-4185440.238

◆ Table 1: ITRF96 Coordinates at epoch 1996.5

5 Determination of Velocity Model

The Institute of Geological and Nuclear Sciences (GNS) was contracted by LINZ to enhance the 1997 GNS velocity model (Beavan and Haines, 1997) with the GPS data used in the computation of the ITRF96 coordinates (Section 3). This section summarises the methods and results of the contract. The full report is contained in Beavan (1998) and the associated velocity model is version 2.1.

The same yearly GPS campaign data from 1992 through 1998 as processed by Morgan and Pearse were processed by Beavan. In addition to these data GNS also added in the following GPS data to provide essential detail for the velocity model:

Hawkes Bay/Taupo network (1990, 1991, 1993, 1995 and 1997)
Wellington network (1992, 1994, 1995, 1996 and 1997)
Marlborough fault zone network (1994 and 1996)
Arthurs Pass network (1995 and 1997)
Central South Island network (1994, 1995, 1996 and 1998)
Raukumara/East Cape network (1995 and 1997)
Southern North Island network (1995 and 1998)
Wellington-Palmerston North network (1994 and 1995)
Fiordland network (1995 and 1996)

The GPS data was processed almost entirely by GNS but some solutions were computed by the Universities of Oxford and Otago (Beavan, 1998).

The highlights of the GPS processing are:

- Bernese Software (Rothacher and Mervart, 1996);
- Single differences formed in such a way as to minimise baseline lengths and reduce antenna mixing between ends of baselines;
- Double differenced phase ambiguities were estimated at both L1 and L2 frequencies. Ambiguities fixed to integer values, where possible, using wide-lane/narrow-lane technique;
- IGS_01 elevation-dependent antenna phase centre models (Rothacher and Mader, 1996) used on most analyses;
- Tropopheric estimates usually made every 2-4 hours;
- Ionospheric models estimated to assist with the ambiguity resolution on longer baselines;
- UNAVCO graphics tool (gt) used in many cases to visually scan double-difference phase residuals for cycle slips, and occasionally to delete noisy data at low elevation angles;
- Coordinate and covariance files produced from a network solution of each observation session;

The daily coordinate and covariance results from each regional or national GPS campaign were then combined into a “static” solution for each campaign using the variation of coordinates program, ADJCOORD (Bibby, 1982; Crook, 1992). This gives the covariance scaling estimates for the step of combining all the daily coordinate and covariance files from repeated campaigns. The ten minimally constrained velocity solutions were then used as input into the velocity modelling software, DEFMAP. The methodology used in DEFMAP and its application to geological and earthquake strain data is reported in Haines *et al*. (1998). Beavan and Haines (2000) give a more succinct description of the methodology and its application to GPS data.

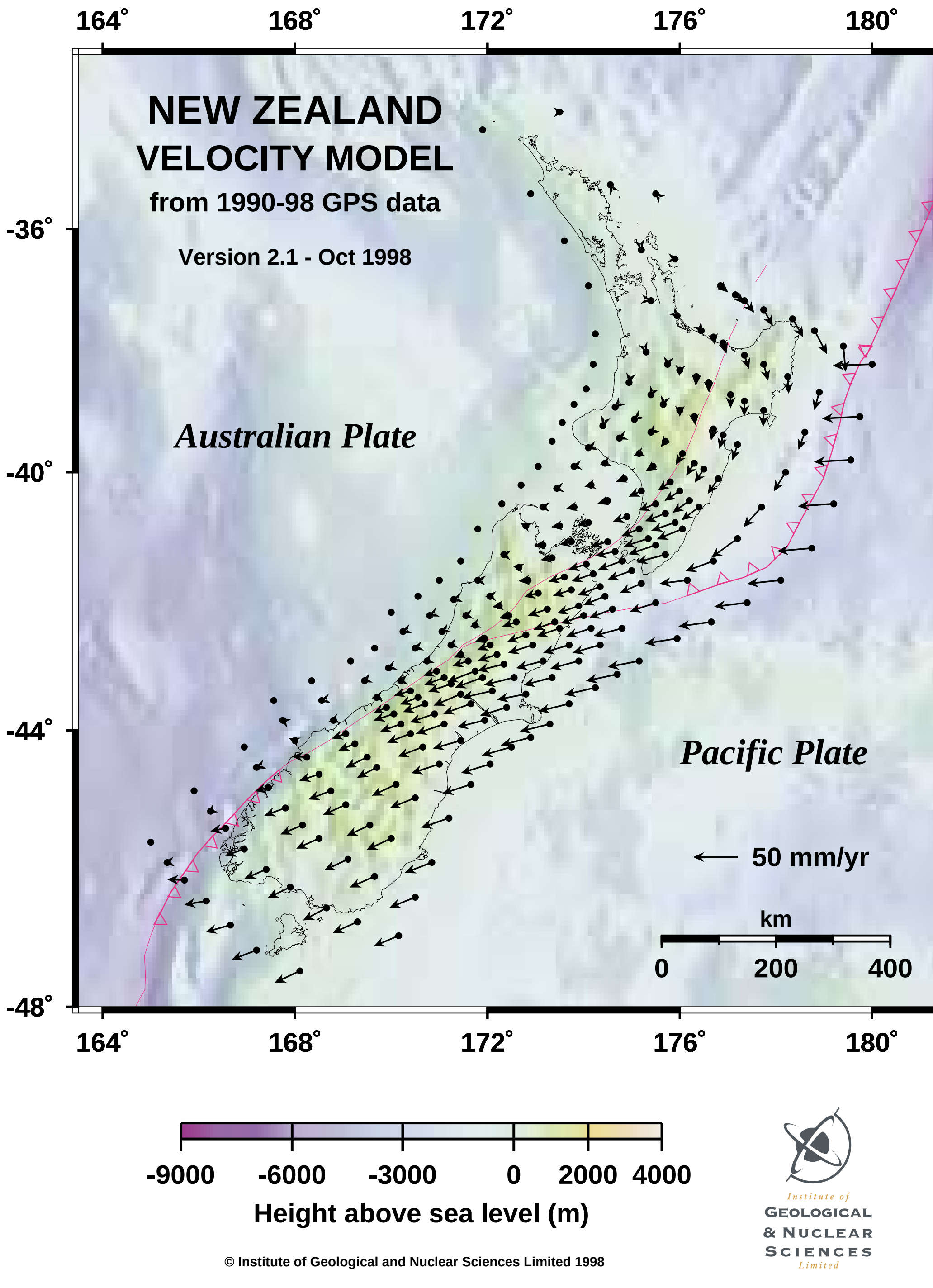
The velocity model contains only horizontal rates as there is not currently available suitable data to be able to estimate the vertical rates reliably. In the computation of the velocity model the vertical rates were not constrained and they were disregarded in the final model. The horizontal velocity model in terms of the Australian plate is shown in Figure 3.

Beavan (1998) evaluated three methods of transforming the velocity model from the Australian-fixed reference frame into ITRF96. The recommended method was to use the IGS determined ITRF96 satellite orbits to set the orientation and scale and a single IGS core station (TIDB – Tidbinbilla near Canberra on the Australian plate) to constrain the ITRF96 coordinates and velocities.

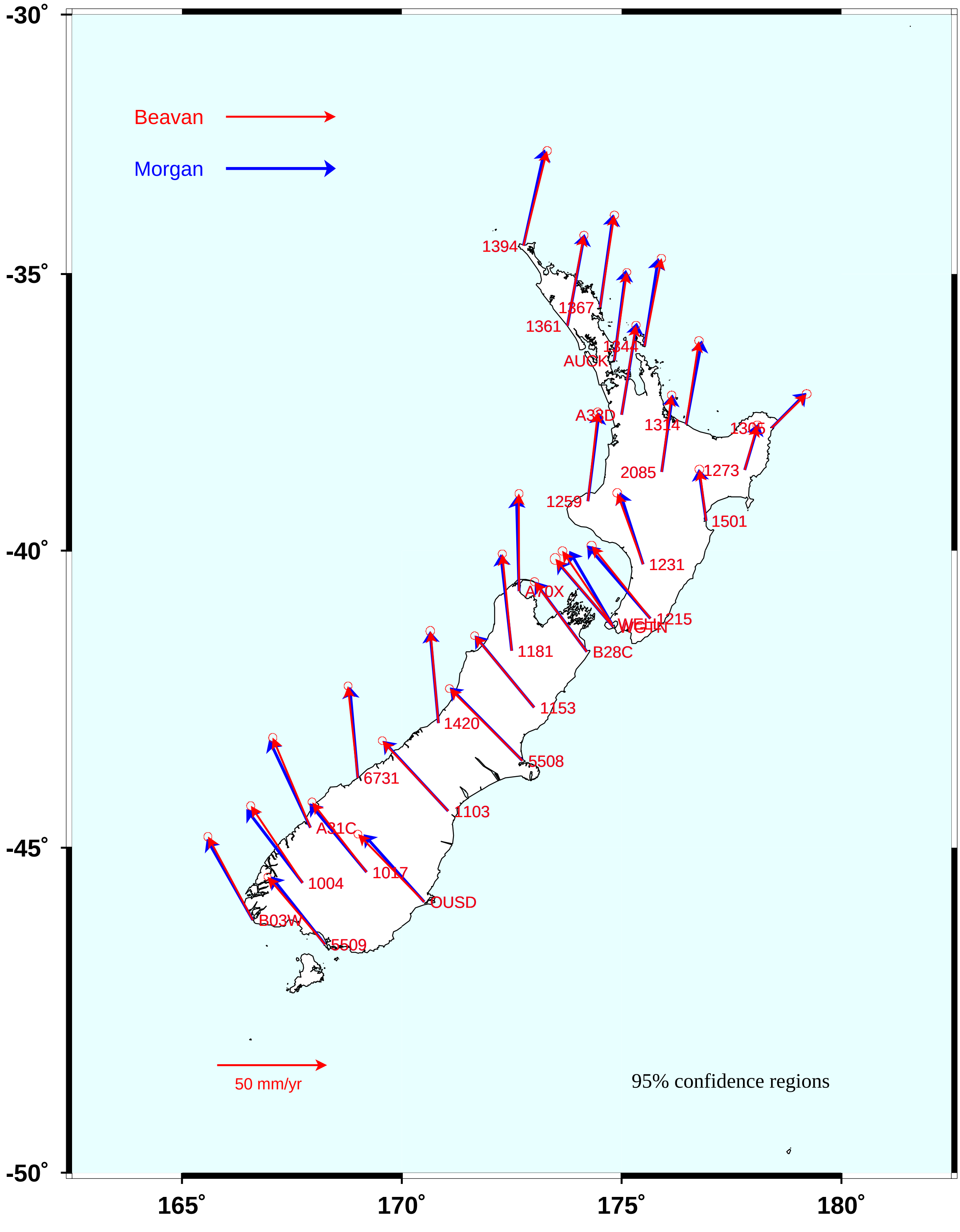
As part of the quality assurance process GNS was responsible for comparing the coordinates and velocities computed by Beavan (1998) and Morgan and Pearse (1999). This check was warranted since both groups used different processing software and strategies. The following paragraphs are a summary of the full analysis between the solutions given in Beavan (1998).

Preliminary comparisons of the ITRF96 coordinates at the epoch of 1996.5 and the associated ITRF96 velocities for the 30 Zero and First Order stations did show significant differences at some sites. Only where a specific reason was identified did either group re-run the analysis. One example of a reason was when Morgan and Pearse had initially left all the data for HB Mt Greenland (Geodetic Code 1420) in their processing without regard for the effect of the 1994 Arthur's Pass earthquake on that site.

The comparison of coordinates and velocities was carried out in terms of the WGS84 ellipsoid to separate the horizontal and vertical components. For the coordinates there were small systematic offsets of 1 mm north, 3 mm east and 7 mm vertically between the two groups results. The cause of these systematic offsets remain unknown though they were considered insignificant. The rms scatter of the coordinate differences, after removing the offsets, was 1 mm north, 2 mm east and 8 mm vertically. This was significantly better than the initial aim of 10 mm agreement in each component at the 95% confidence level. The two velocity solutions had no systematic offsets and the rms scatter was 1 mm/yr, with the two largest differences being 3.3 and 2.5 mm/yr (Figure 4). This also was significantly better than the initial aim of 3-4 mm/yr agreement at the 95% confidence level.



♦ Figure 3: Velocity Model in an Australian-fixed reference frame



♦ Figure 4: Comparison of Beavan (1998) and Morgan and Pearse (1999) ITRF96 velocity estimates from Beavan (1998). 95% Confidence regions are shown only on the Beavan estimates.

6 Computation of NZGD2000 coordinates at epoch 2000.0

In accordance with the Office of the Surveyor-General Policy 98/3 (1998c) the coordinates for NZGD2000 stations are to be published at the epoch of 2000.0 (0h0m 1 January 2000). Two different approaches have been implemented to generate the epoch 2000.0 coordinates and these are discussed in the following sub-sections.

6.1 *Zero and First Order Stations*

The epoch 2000.0 coordinates for the Zero and First Order stations were generated by applying the GNS velocity model (Beavan, 1998) to the 1996.5 epoch coordinates supplied by Morgan and Pearse (1999), except for CHAT (Chatham Island). For the Chatham Island coordinate the GNS velocity model could not be used as it does not cover the Chatham Islands, instead the NNR-Nuvel1A model (DeMets et al., 1994) was used since CHAT is on the Pacific plate and outside the plate boundary deformation zone. The rates applied to the epoch 1996.5 coordinates are contained in Table 2.

Geodetic Code	Name	Northing Rate	Easting Rate
AUCK	Whangaparaoa	40.4	4.9
CHAT	Chatham Island	31.3	-40.5
WGTN	Wellington Airport	32.6	-24.7
1004	Mt York	34.7	-22.9
1017	Hyde Rock	32.8	-25.3
1103	Mt Horrible	33.2	-30.7
1153	Isolated Hill	33.3	-27.3
1181	Mt Murchison	43.8	-5.4
1215	Eringa	31.7	-29.0
1231	Mt Stewart	33.4	-12.5
1259	Huirangi	41.4	3.8
1273	Okahuatiu	19.9	5.0
1305	Te Pohue	15.7	14.1
1314	Maketu	36.6	4.7
1344	Ruahine	40.3	6.4
1361	Mahora	41.7	6.3
1367	Pukearenga	41.8	5.7
1394	Te Paki	43.1	8.6
1420	Mt Greenland	41.9	-4.2
1501	Bluff Hill	23.9	-3.2
2085	Marotiri	34.4	2.5
5508	Windsor Castle	34.8	-31.8
5509	Three Sisters	31.8	-26.3
6731	Haast	42.4	-6.0
A31C	Milford	41.3	-17.2
A33D	Te Herunga	40.7	5.5
A70X	Parapara	44.2	-0.7
B03W	Puysegur Point	38.2	-20.1
B28C	Cape Campbell	32.3	-24.1
OUSD	Otago University	31.7	-31.1
WELL	Wellington	34.4	-23.1

◆ Table 2: Horizontal velocity rates (mm/yr) applied to epoch 1996.5 coordinates

The primary stations and coordinates that define (realise) the New Zealand Geodetic Datum 2000 (NZGD2000) are those in the Zero and First Order networks as listed in Table 3 and shown in Figure 1.

The NZGD2000 coordinates in Table 3 are in terms of the International Terrestrial Reference Frame 1996 (ITRF96) at epoch 1 January 2000 (2000.0). The 95% confidence levels on the Zero Order and First Order coordinates are 0.01m, 0.01m, 0.02m (Latitude, Longitude, Height).

Geodetic Code	Name	Order	Latitude (° ′ ″)	Longitude (° ′ ″)	Ellipsoidal Height (m)
AUCK	Whangaparaoa	Zero	36 36 10.2402 S	174 50 03.7880 E	132.711
CHAT	Chatham Island	Zero	43 57 20.8326 S	176 33 57.0227 W	57.9811
WGTN	Wellington Airport	Zero	41 19 24.4454 S	174 48 21.2186 E	26.073
1004	Mt York	First	45 33 43.6111 S	167 44 20.1266 E	411.196
1017	Hyde Rock	First	45 23 15.5209 S	169 11 51.7276 E	1680.809
1103	Mt Horrible	First	44 24 02.0503 S	171 03 26.4405 E	397.157
1153	Isolated Hill	First	42 41 14.7040 S	173 00 37.0016 E	405.505
1181	Mt Murchison	First	41 43 44.6973 S	172 29 58.2847 E	1486.646
1215	Eringa	First	41 10 48.5107 S	175 39 07.7910 E	590.791
1231	Mt Stewart	First	40 14 24.7129 S	175 29 17.9227 E	143.609
1259	Huirangi	First	39 08 02.3985 S	174 13 41.5683 E	263.041
1273	Okahuatiu	First	38 34 30.5480 S	177 48 17.4692 E	323.407
1305	Te Pohue	First	37 49 28.3511 S	178 24 25.5711 E	360.454
1314	Maketu	First	37 45 34.0792 S	176 27 59.0730 E	95.727
1344	Ruahine	First	36 19 58.9983 S	175 31 06.9717 E	438.003
1361	Mahora	First	35 57 43.5863 S	173 46 09.8974 E	164.970
1367	Pukearenga	First	35 37 02.0783 S	174 30 51.6930 E	174.403
1394	Te Paki	First	34 27 59.7095 S	172 46 17.0730 E	351.050
1420	Mt Greenland	First	42 57 11.6870 S	170 49 46.7693 E	919.307
1501	Bluff Hill	First	39 28 44.3468 S	176 55 02.0846 E	119.271
2085	Marotiri	First	38 36 57.7701 S	175 54 54.0969 E	760.272
5508	Windsor Castle	First	43 34 53.4132 S	172 44 34.9627 E	335.355
5509	Three Sisters	First	46 32 12.9470 S	168 15 12.3806 E	176.343
6731	Haast	First	43 51 38.9427 S	169 00 12.9269 E	14.412
A31C	Milford	First	44 40 24.6238 S	167 55 26.6376 E	9.546
A33D	Te Herunga	First	37 35 21.7825 S	175 00 00.0836 E	318.912
A70X	Parapara	First	40 42 46.8026 S	172 40 19.9543 E	169.539
B03W	Puysegur Point	First	46 09 23.0087 S	166 36 33.5751 E	44.265
B28C	Cape Campbell	First	41 44 56.5656 S	174 12 49.7107 E	254.535
OUSD	Otago University	First	45 52 10.2057 S	170 30 39.3147 E	26.197
WELL	Wellington	First	41 16 29.6122 S	174 46 58.6319 E	37.686

◆ Table 3: Defining NZGD2000 coordinates in ITRF96 at epoch 2000.0 using the GRS80 ellipsoid

As the velocity models do not contain vertical rates the ellipsoidal heights of the 1996.5 coordinates are the same as the 2000.0 coordinates. That is, we have assumed that there are no vertical velocities at any of the stations. The ellipsoidal heights are not the same as mean sea level heights. The ellipsoid associated with NZGD2000 is the Geodetic Reference System 1980 (GRS80) ellipsoid (Moritz, 1980).

The coordinates that realise the NZGD2000 Zero and First Order network (Figure 1) are not fixed - nor technically do they need to be in terms of ITRF96. The coordinates will be updated as required to account for new observations, earthquakes, or localised mark movement. Previous coordinate values will be available to users and via the date of the coordinate computation (as opposed to the date the coordinates are expressed in – epoch 2000.0). Users will thus be able to determine when coordinates were updated and be able to see the magnitude of the changes. Initially ITRF96 is the reference frame in which coordinates are computed though in the future this may be changed. Users will be consulted prior to any significant changes to NZGD2000.

6.2 *Second, Third, Fourth and Fifth Order Stations*

With the coordinates defined for the primary NZGD2000 Zero and First Order stations (Table 3) the in-fill (densification) stations were then able to be adjusted in terms of these defining coordinates. The in-fill adjustment was undertaken using the SNAP (Crook, 1995) adjustment software. The SNAP software was modified to enable the observation data files to be corrected for the effects of deformation using the GNS velocity model version 2.1 (Section 5). The deformation correction applied, converted the observation data from the observation epoch to epoch 2000.0 before the adjustment of the data. The least squares adjustment of the data was then performed by constraining the new observations to the 2000 coordinates of the Zero and First Order NZGD2000 stations. The SNAP software is unable to assign uncertainties to fixed stations: Therefore when subsequent data are adjusted in terms of the Zero and First Order station their coordinates are assigned zero uncertainties (held fixed).

There were two approaches adopted for the adjustment of the in-fill stations. These two approaches are described in the following sub-sections.

6.2.1 *Initial population of NZGD2000*

Prior to the official release of NZGD2000 the available observation data for the second, third and fourth Order NZGD2000 networks were adjusted in a single SNAP adjustment. The different order observation data were weighted using the *a priori* errors listed in Table 4 (OSG, 1998b).

The adjustment for the initial population of NZGD2000 contained 313 Second Order stations, 1339 Third Order stations and 1714 Fourth Order stations.

6.2.2 *Continuing In-fill of NZGD2000*

Following the official release of NZGD2000 new observation data have been collected and will continue to be collected to further densify the Second, Third, Fourth and Fifth Order NZGD2000 networks. To incorporate these data localised SNAP adjustments are performed in which the new observations are constrained by the coordinates of existing higher Order NZGD2000 stations in the area using the same *a priori* errors as in Table 4.

		Constant				Line Length Error		
		E mm	**N mm**	**U mm**		**E ppm**	**N ppm**	**U ppm**
1st Order		1.2	1.2	1.5		0.04	0.04	0.15
2nd Order		1.2	1.2	1.5		0.4	0.4	1.5
3rd Order		4	4	5		1.2	1.2	5
4th Order		4	4	5		4	4	15
5th Order		4	4	5		12	12	50

◆ Table 4: *A* priori errors of observations

7 Summary

This report has described how the coordinates for the initial NZGD2000 Zero and First stations were computed and how the Second, Third, Fourth and Fifth Order stations are adjusted in terms of these values. The coordinates within NZGD2000 are published at the epoch of 2000.0 (0h0m 1 January 2000). None of the coordinate values for any NZGD2000 Order stations are immune from the possibility being changed (unlike the NZGD49 First Order stations). Reasons for changing the coordinates of NZGD2000 stations include deformation inconsistent with the velocity model (e.g. earthquakes) or the addition of new observations.

To date the observations that have been included in the NZGD2000 network have all met their respective accuracy criteria as outlined in the OSG Standard 1 (1998b). That accuracy standard states that any order marks shall have a relative accuracy to the next higher order mark of no worse that 50 mm. Therefore Fourth Order coordinates have a relative accuracy to the Zero Order of no worse than 100 mm and are often significantly better than this.

The coordinates for NZGD2000 stations can be obtained from the Geodetic Database located on the LINZ web site (http://www.linz.govt.nz/databases/geodetic/index.html)

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