Toitu te whenua
Land Information New Zealand

Standard for New Zealand Vertical Datum 2009

LINZS25004

Effective date 14 September 2009

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TERMS AND DEFINITIONS

For the purposes of this standard, the following terms and definitions apply.

Term/abbreviation	Definition
ellipsoid	a surface formed by the rotation of an ellipse about a main axis. For the purposes of this standard, the ellipsoids used are oblate to match the general shape of the Earth. An oblate ellipsoid is one in which the semi–minor axis of the ellipse is the axis of revolution.
ellipsoidal height	the distance from a reference ellipsoid to a point along the ellipsoidal normal
equipotential surface	a surface that is always perpendicular to the force of gravity. An example is the surface of the ocean, if disturbances caused by influences such as tides, currents, seawater density, wind, and atmospheric pressure are not considered.
geoid	an equipotential surface that is approximated by sea level in the open oceans and which is the reference surface for orthometric heights
GRS67	Geodetic Reference System 1967 — a set of parameters adopted by the International Union of Geodesy and Geophysics in 1967 that includes a reference ellipsoid and a normal gravity field for the Earth (IAG 1967)
GRS80	Geodetic Reference System 1980 — a set of parameters adopted by the International Association of Geodesy that includes a reference ellipsoid and a normal gravity field for the Earth (Moritz 2000)
LVD	local vertical datum
normal height	the distance from the quasigeoid to a point along the curved normal gravity plumbline. Normal heights are calculated along levelling lines using actual gravity observations
normal–orthometric height	the distance from the quasigeoid to a point along the curved normal gravity plumbline. Normal–orthometric heights are calculated along levelling lines using a normal gravity field rather than actual gravity observations.
NZGD2000	New Zealand Geodetic Datum 2000, a three-dimensional geocentric datum based on the International Terrestrial Reference Frame 1996 with ellipsoidal heights defined in terms of the GRS80 ellipsoid
NZGeoid2009	New Zealand Quasigeoid 2009
NZGeoid2009 grid	the grid file of NZGeoid2009 values as provided on the LINZ website
NZVD2009	New Zealand Vertical Datum 2009

Term/abbreviation	Definition
orthometric height	the distance from the geoid to a point along the plumbline. Orthometric heights can not be easily realised in practice because their calculation requires knowledge of density variations inside the local topography, as well as local gravity.
quasigeoid	a non–equipotential surface that coincides reasonably closely with the geoid and which is the reference surface used for normal and normal-orthometric heights
quasigeoid height	the vertical distance from the reference ellipsoid to the quasigeoid
vertical datum	a curved or level reference surface from which to determine elevations

FOREWORD

Introduction

A national geodetic system is a fundamental component of a nation's infrastructure. The unique property of a geodetic system is its ability to allow the integration of multiple geographically dependent data sources into a single geographic reference frame.

One element of a geodetic system is a national vertical datum. Transformations are needed to enable spatial data held in terms of other vertical datums to be converted to the national vertical datum. This allows diverse spatial datasets to be correctly correlated and compared within a consistent framework.

A key benefit of the New Zealand Vertical Datum 2009 (NZVD2009) is the ability to readily determine heights in terms of it anywhere within New Zealand's territory without resorting to the cost and limitations of precise levelling.

Purpose of standard

The purpose of this standard is to specify a national vertical datum for New Zealand and to define its relationship to other commonly used height systems.

Brief history of standard

This is a new standard.

Committee responsible for standard

The expert committee responsible for reviewing this standard consisted of the following representatives.

Business Group/Company	**Name**
GNS Science	John Beavan
LINZ, Business & Regulatory Assurance	Apanui Williams
LINZ, Customer Services	Nic Donnelly
LINZ, Office of the Surveyor-General	Don Grant Matt Amos
LINZ, Regulatory Frameworks & Processes	Mel Amuimuia Michelle Gooding Ruth Willis
Local Government New Zealand	Michael Brownie
NIWA	Rob Bell
University of Otago, School of Surveying	Robert Tenzer

References

Claessens S, Hirt C, Featherstone W, Kirby J 2009 *Computation of a new gravimetric quasigeoid model for New Zealand*, technical report prepared for Land Information New Zealand by Western Australia Centre for Geodesy, Curtin University of Technology, Perth, p. 39.

Department of Survey and Land Information 1989, *Geodetic Survey Branch Manual of Instruction*, DoSLI, Wellington, p. 117.

Heck, B. 2003, *Rechenverfahren und Auswertemodelle der Landesvermessung*, 3rd edn, Wichman, Karlsruhe, p. 473.

International Association of Geodesy 1967, *Geodetic Reference System 1967,* Special Publication 3, International Association of Geodesy, Paris, p. 116.

Moritz, H. 2000, *Geodetic Reference System 1980*, Journal of Geodesy, vol. 74, no. 1, pp. 128-133.

1 Scope

(a) This standard describes the national vertical datum, New Zealand Vertical Datum 2009 (NZVD2009).

(b) This standard enables the transformation of NZVD2009 heights to and from the 13 major precise levelling–based local vertical datums (LVDs) and the New Zealand Geodetic Datum 2000 (NZGD2000).

2 Intended use of standard

Any person using or referring to NZVD2009 must comply with this standard.

COMMENTARY

Spatial extent of NZVD2009

NZVD2009 should only be used within the area defined by 160°E to 170°W and 25°S to 60°S.

3 New Zealand Vertical Datum 2009

3.1 Official reference surface

(a) NZVD2009 heights must be measured in relation to the official reference surface.

(b) The official reference surface of NZVD2009 is the New Zealand Quasigeoid 2009 (NZGeoid2009).

3.2 Official height system[1]

(a) NZVD2009 heights must be provided in the normal–orthometric height system in relation to the official reference surface.

(b) The value of the NZGeoid2009 in relation to the Geodetic Reference System 1980 (GRS80) ellipsoid at a specific location must be bi–linearly interpolated from the NZGeoid2009 grid using its NZGD2000 position.

[1] For more information about height systems, see Appendix A: Height systems.

3.3 Normal–orthometric correction

(a) NZVD2009 normal–orthometric heights must be calculated using the GRS80 normal gravity field specified in Table 1.

(b) NZVD2009 normal–orthometric heights determined by precise levelling must be reduced using the normal–orthometric correction (NOC) equation (Heck 2003) and GRS80 parameters specified in Table 1:

$$\text{NOC} = -\frac{f^*}{R} H_{avg} \sin 2\phi \cos\alpha\, \delta s \qquad \text{expressed in metres}$$

where

f^*	is the GRS80 normal gravity flattening constant
R	GRS80 mean Earth radius, expressed in metres
H_{avg}	average normal-orthometric height of benchmarks, expressed in metres
ϕ	mid–latitude between benchmarks
α	azimuth between benchmarks
δs	horizontal distance between benchmarks, expressed in metres.

Table 1: GRS80 gravity field parameters (Moritz 2000)

Parameter	Symbol	Value
normal gravity flattening constant	f^*	0.005 302 440 112
mean Earth radius	R	6 371 000 m

(c) Where NZVD2009 normal-orthometric heights are determined by precise levelling the NOC must be calculated in relation to a mark with an existing NZVD2009 height that is included in the levelling line.

COMMENTARY

Historic normal–orthometric correction

The normal–orthometric correction used for precise levelling reductions in New Zealand before this standard became effective is defined in Appendix B.

4 Local Vertical Datums

(a) The official LVDs defined in Table 2 may be used with NZVD2009.

(b) The offsets defined in Table 2 must be used to relate NZVD2009 to the official LVDs.

Table 2: Official local vertical datums and offsets from NZVD2009[2, 3]

Local vertical datum	**Offset to NZVD2009** (m)
One Tree Point 1964	0.06
Auckland 1946	0.34
Moturiki 1953	0.24
Gisborne 1926	0.34
Napier 1962	0.20
Taranaki 1970	0.32
Wellington 1953	0.44
Nelson 1955	0.29
Lyttelton 1937	0.47
Dunedin 1958	0.49
Dunedin-Bluff 1960	0.38
Bluff 1955	0.36
Stewart Island 1977	0.39

[2] For more information about the local vertical datums, see Appendix C.
[3] A description of how the offsets were computed is provided in Claessens et al. (2009)

5 Height Transformations

5.1 Introduction

The following paragraphs define the transformations between official New Zealand height systems. The transformations defined are between:

(a) NZGD2000 and NZVD2009,

(b) LVDs and NZVD2009,

(c) different LVDs, and

(d) LVDs and NZGD2000.

5.2 Transformation between NZGD2000 and NZVD2009

When transforming between NZGD2000 ellipsoidal heights and NZVD2009 normal-orthometric heights, the following equations must be used:

$$H_{NZVD} = h - N$$

$$h = H_{NZVD} + N$$

where

H_{NZVD} is the NZVD2009 normal–orthometric height in metres

h is the NZGD2000 ellipsoidal height in metres

N is the NZGeoid2009 value in metres at the NZGD2000 position of h.

5.3 Transformation between a local vertical datum and NZVD2009

When transforming between normal–orthometric heights in terms of a LVD listed in Table 2 and NZVD2009 normal–orthometric heights, the following equations must be used:

$$H_{NZVD} = H_A - o_A$$

$$H_A = H_{NZVD} + o_A$$

where

H_{NZVD} is the NZVD2009 normal–orthometric height in metres

H_A is the LVD A normal–orthometric height in metres

o_A is the LVD A offset from Table 2.

5.4 Transformation between local vertical datums

When transforming normal–orthometric heights between the LVDs listed in Table 2, the following equation must be used:

$$H_B = H_A - o_A + o_B$$

where

H_A	is the LVD A normal–orthometric height in metres
H_B	is the LVD B normal–orthometric height in metres
o_A	is the LVD A offset from Table 2
o_B	is the LVD B offset from Table 2.

5.5 Transformation between a local vertical datum and NZGD2000

When transforming between normal–orthometric heights in terms of a LVD listed in Table 2 and NZGD2000 ellipsoidal heights, the following equations must be used:

$$h = H_A + N - o_A$$

$$H_A = h - N + o_A$$

where

h	is the NZGD2000 ellipsoidal height in metres
H_A	is the LVD A normal–orthometric height in metres
N	is the NZGeoid2009 value in metres at the NZGD2000 position of h
o_A	is the LVD A offset from Table 2.

Appendix A: Height systems

A.1 Introduction

A height is a vertical distance above a reference surface. The type of reference surface used has an impact on the type of height that can be measured from it. Normal-orthometric and ellipsoidal are the two types of height that are commonly used in New Zealand.

A.2 Normal–orthometric heights

(a) Normal–orthometric heights correspond to what most users understand as heights above mean sea level.

(b) Normal-orthometric heights are approximations of true orthometric heights within the limits of approximation of the normal gravity field to the actual gravity field.

(c) The flow of fluids is more realistically predicted by normal-orthometric heights than by ellipsoidal heights.

A.3 Ellipsoidal heights

(a) Ellipsoidal heights are measured above a reference ellipsoid.

(b) The GRS80 ellipsoid is a simple geometric approximation of the shape of the geoid that varies from mean sea level by up to about ±100 m globally.

(c) Ellipsoidal heights cannot reliably predict the flow of fluids because the ellipsoid does not relate to the Earth's gravity field.

(d) Ellipsoidal heights are provided in Global Navigation Satellite System positions because of their geometrically simple definition.

(e) NZGD2000 uses ellipsoidal heights based on the GRS80 ellipsoid.

Appendix B: Historic normal–orthometric correction

Before this standard became effective, normal–orthometric heights that were established by precise levelling were reduced using the following Geodetic Reference System 1967 normal–orthometric correction (NOC_{GRS67}) equation (The Department of Survey & Land Information 1989):

$$NOC_{GRS67} = -2\eta \sin 2\phi \left[1 + \left(\eta - \frac{2\beta}{\eta}\right) \cos 2\phi\right] z \; H_{avg} \; \delta\phi \qquad \text{expressed in metres}$$

where

η	equals 0.002 506
β	equals 0.000 007
ϕ	is the mid–latitude between benchmarks
z	is one minute of arc in radians (~0.0002908882)
H_{avg}	is the average height of benchmarks, expressed in metres
$\delta\phi$	is the difference in latitude between benchmarks, expressed in arc–minutes, positive southwards.

Appendix C: Background information for local vertical datums

This appendix contains useful background information about the local vertical datums for which offsets to NZVD2009 are provided in Table 2.

Table 3: New Zealand Local Vertical Datums

Local vertical datum	**Code**	**Data used to define datum**	**Reference mark name**	**Reference mark geodetic code**	**Reference mark height in terms of LVD** (m)	**Offset to NZVD2009** (m)	**Standard deviation** (m)
One Tree Point 1964	ONTPHT1964	1960 – 1963	RNZN BM	DJM9	3.139	0.06	0.03
Auckland 1946	AUCKHT1946	1909 – 1923	98-21 SO 69501	DD1N	3.491	0.34	0.05
Moturiki 1953	MOTUHT1953	1949 – 1952	BC 84	B309	3.141	0.24	0.06
Gisborne 1926	GISBHT1926	1926	GB 01	ACVP	3.039	0.34	0.02
Napier 1962	NAPIHT1962	Unknown	H 40	B3XM	3.913	0.20	0.05
Taranaki 1970	TARAHT1970	1918 – 1921	New Plymouth Fundamental	AGMH	4.906	0.32	0.05
Wellington 1953	WELLHT1953	1909 – 1946	K 80/1	ABPB	2.087	0.44	0.04
Nelson 1955	NELSHT1955	1939 – 1942	N 1	AC4T	3.532	0.29	0.07
Lyttelton 1937	LYTTHT1937	1918 – 1933	UD 40	B40V	3.165	0.47	0.09
Dunedin 1958	DUNEHT1958	1918 – 1937	WW 83	AFEQ	2.737	0.49	0.07
Dunedin-Bluff 1960	DUBLHT1960	No sea level data used	Z 41	B3R8	112.699	0.38	0.04
Bluff 1955	BLUFHT1955	1918 – 1934	Bluff Fundamental	ABCC	7.011	0.36	0.05
Stewart Island 1977	STISHT1977	1976 – 1977 (5 tides only)	N (Paterson SD)	A017	44.10	0.39	0.15