- Map Layer Descriptions -

https://nzgd.org.nz

The New Zealand Geotechnical Database presents a large quantity of geotechnical information, which is presented in a hierarchical set of information layers that can be selectively displayed. The layer hierarchy is grouped to provide rapid access to individual layers within each map layer collection. The map layers themselves are further classified either as geotechnical investigation data (both individual and collated) or as published maps and reports.

Map Layers and their Descriptions

The Map Layers

Each map layer displays a description outlining the important information about the data being displayed when it is initially opened. These descriptions are collated here so they can all be printed out for reference while using a viewer.

Most map layers within the New Zealand Geotechnical Database are composed from a number of internal layers, which can be selectively switched on and off. These are usually arranged so only one internal layer is displayed at a time (e.g. for a particular earthquake). The map layers are numbered for reference purposes (e.g. CGD0100, CGD0200 etc.), but please use descriptions (e.g. 5 Sept 2010 Aerial Photography) rather than the mostly hidden reference numbers when referring to the internal layers (e.g. CGD0101, CGD0102 etc. within map layer CGD0100).

The map layer descriptions following this introduction should be clearer with an appreciation of how viewing software such as Google Earth operates. The satellite images forming the background are tiled to efficiently receive them from the server in small chunks. The tiles are also arranged as a pyramid, with the images that have the largest pixels sizes at the top level and the smallest at the bottom. The top image is viewed from long distances, or high eye altitudes, so the user can efficiently navigate toward detailed items in the lowest level pyramid level. Portions of the lower level images are progressively loaded as the eye altitude decreases (i.e. as the user *zooms in* toward the finest detailed images).

The tiling and creation of image pyramids are core procedures within the publication process for each map (or internal) layer, so are not explicitly included in the methodology outlined in the descriptions. The same tiling process was also used for large quantities of geometric shapes and groups of individual place marks.

Version control for the map layers is principally through their publication dates. While much of the data within each map layer is static, the display arrangements can change as additional data is added or improved arrangements are suggested.

This document is updated whenever one of the map layers is updated. If a copy of this document is printed, please check the release date beside the printed map title against the date within the citation instructions immediately above the Important Notice in each description (e.g. 1 June 2012 as highlighted in the sample excerpt below) as it is loaded. The revision history is summarised at the end of this document.

> Cite figures or other works derived from these map layers (see the Important Notice below) as:
>
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>
> **Important notice**
>
> This map and data was prepared and/or compiled for the Earthquake Commission (EQC) to assist in assessing insurance claims made under the Earthquake Commission Act 1993 and/or for the New Zealand Geotechnical Database on behalf of the Canterbury Earthquake Recovery Authority (CERA). It was not intended for any other purpose. EQC, CERA, their data suppliers and their engineers, Tonkin & Taylor, have no liability to any user of this map and data or for the consequences of any person relying on them in any way. Each New Zealand Geotechnical Database map and data is made available solely on the basis that:
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Using the Map Layers

Simultaneously overlay combinations of map layers and internal layers to synthesise an understanding of the physical meaning of the information being displayed. This is also helpful for both identifying and quantifying the noise or error within the acquired data.

A lot of the data is colour banded and/or contoured for presentation, with the bands of constant colour between contours. Jagged band boundaries (or contours) provide good indicators of the amount of noise within the information being displayed. The colour bands are often rendered as bitmap images rather than vector shapes and lines because of the quantity of information being presented. This conveniently also provides fuzzy boundary when the user zooms in to view the information more closely than the data warrants.

Some viewing software provides terrain exaggeration and background imagery with unspecified location accuracy, which can affect the apparent positions of features. Users may need to independently verify positions when using low viewing elevations. The aerial photography layer (CGD0100), particularly the high resolution 24 Feb 2011 layer, can provide better background imagery for Christchurch.

Finally, the database is frequently updated. It is therefore essential to view newly added data and avoid using superseded data by restarting the viewing software occasionally (e.g. at least daily) to refresh the internal cache.

Geotechnical Investigation Data

Map Layer and Description	Reference	
Geotechnical Investigation Data	CGD0010	
Description Shared geotechnical investigation data supplied by owners or agents of the owners		
Laboratory Test Data	CGD0020	
Description Laboratory test data and reports for investigations conducted by The Earthquake Commission		
TC3 Area wide investigations	CGD0025	
Description Area-wide geotechnical investigations being conducted by The Earthquake Commission.		

The investigation data presented in this section of map layers is most likely to vary as new investigations are both uploaded by a database user and checked in by the New Zealand Geotechnical Database Administrator for all users to view.

Geotechnical Investigation Analysis

Map Layer and Description	Reference	
Liquefaction Evaluation of CPT Investigations	CGD0050	

Description

Regional-scale maps of liquefaction vulnerability indicators calculated from CPT profiles for a range of earthquake scenarios, ground water table surfaces and soil properties.

Methodology

This analysis tool, based on the Boulanger and Idriss (2014) liquefaction triggering method, is applied to all of the CPT profiles checked in to the Geotechnical Investigation Data portion of the New Zealand Geotechnical Database (NZGD) as at 28/02/2015. The tool is only run occasionally, so there can be up to 12 months between checking in a new CPT profile and it being added to the maps.

The tool's calculation methods are described in the revised CGD Technical Specification 01 (2015).

The internal maps present CPT profiles classified with two earthquake scenarios: i) event-specific (back analysis) using the four main earthquakes in the Canterbury Earthquake Sequence (CES) and ii) SLS, ILS and ULS design earthquakes (forward analysis).

The following liquefaction vulnerability indicators are independently mapped for each earthquake scenario listed above:

Symbol and Indicator name		Description or Reference
S_{VD1}	Calculated Settlement	Base on Zhang, Robertson and Brachman (2002)
CT	Crust Thickness	Based on PGA and depth to groundwater as defined in CGD Technical Specification 01
CTL	Cumulative Thickness of Liquefying Layers	Total thickness of liquefiable layers within the CPT profile (as defined in CGD Technical Specification 01)
LPI	Liquefaction Potential Index	As defined by Iwasaki et al. (1978)
LPI_{ISH}	Liquefaction Potential Index - Ishihara	Using the Ishihara inspired LPI method developed by Maurer et al. (2014a)
LSN	Liquefaction Severity Number	As defined in Tonkin & Taylor (2013)

The indicators are also mapped for each scenario with a selection of liquefaction triggering input parameters so users can investigate the sensitivity to both the earthquake scenario and:

- The Probability of Liquefaction, P_L (P_L = 15%, P_L = 50% and P_L = 85%) which is better defined as the certainty with respect to the various cyclic resistance ratio curves; and
- The Fines Content versus I_c relationship calibration parameter, C_{FC} (C_{FC} = 0.0 and C_{FC} = 0.2).

The event-specific scenarios estimate the liquefaction vulnerability indicators for the four main earthquakes in the CES based on the best estimate of the spatially varying depth to groundwater at the time of the event and earthquake PGA shaking. The water table depths use the *Event Specific Groundwater Surface Elevations* (Map Layer CGD0800) and the Digital Elevation Models (DEM, Map Layer CGD0500). These allow the vulnerability indicators to be compared with the land damage observations in the vicinity of a specific site.

Map Layer and Description	Reference	

For the SLS, ILS and ULS design scenario earthquakes, indicators are mapped for 15th percentile, median and 85th percentile groundwater surface elevations. Only the depth to groundwater is spatially varied, based on the GNS Science Median Water Table Elevations (Map Layer CGD5160) and the most recent (Feb 2012 augmented with Sept 2011) DEM. These maps allow designers to investigate how these influence the local variation of each vulnerability indicator.

Regional-scale maps

These regional-scale maps of the liquefaction vulnerability indicators are provided for information purposes only and do not remove the obligation for designers to conduct site specific assessments and analyses. The technical specification describes the indicator calculations. Of particular note for the regional analysis maps:

- Soil properties were estimated for any **pre-drill** material removed from CPT sites.
- The **seismic loading** was based either on probabilistic adjustment to an empirical ground motion model at recording station sites or on a standard PGA and magnitude earthquake;
- The **groundwater conditions** used either the event-specific or probabilistic regional groundwater models.
- Sites were assumed to be both **flat** and **laterally confined** (i.e. no sloping ground surface or lateral spreading).
- Only the **top 10 m** was analysed for consistency between indicators.

Site specific analyses

Site specific analyses should consider the following aspects that were not explicitly incorporated in the regional analysis:

- **Soil susceptibility** assessments and appropriate **I_c cut-off profiles** based on laboratory test results.
- Specific **fines content profiles** based on laboratory test results.
- Site specific **material investigations** for the CPT investigations that had material removed above the groundwater table (pre-drill).
- **Thin layer corrections** to the CPT traces.
- Local variations in **site topography**, either existing or proposed, when the site is not flat;
- Lateral confinement that is insufficient to limit or prevent **lateral spreading**.

References

Tonkin and Taylor (2013) Liquefaction vulnerability study, Tonkin and Taylor Report 52020.0200. February 2013. 52 pages, 14 appendices and 27 references including Idriss and Boulanger (2008), Iwasaki et al. (1978), Robertson and Wride (1998) and Zhang et al. (2002) identified above.

Boulanger, R.W. and Idriss, I.M. (2014) CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering University of California Davis, California, April 2014 available http://cgm.engr.ucdavis.edu/library/reports/

New Zealand Geotechnical Database (2015) Liquefaction Evaluation of CPT Investigations CGD Technical Specification 01, July 2015

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:
New Zealand Geotechnical Database ([enter year]) "Liquefaction evaluation of CPT investigations", Map Layer CGD0050, retrieved [enter date] from https://www.nzgd.org.nz/

Map Layer and Description	Reference	
CPT Layer Analysis and Depth of Refusal	CGD0055	

Description

Depth to the upper surface of the first hard layer and the depth to refusal detected in a CPT profile, relative to the ground surface.

Methodology

This investigation analysis tool is applied to all of the CPT profiles checked in to the Geotechnical Investigation Data portion of the New Zealand Geotechnical Database.

Hard layers are those with 90% of the recorded qc greater than 20 MPa, over a selectable layer thickness of 0.1 m to 0.5 m. The hard layer suggesting refusal is where the recorded qc is greater than 20 MPa, over the selectable layer thickness. These maps only show depths for CPT profiles that have an identifiable hard layer of the nominated thickness.

As this is an automated analysis tool, this map layer should only be used to estimate effective refusal depths when planning a new site investigation based on other investigations within the general area. The original CPT investigation data should be evaluated manually for all other purposes.

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:
New Zealand Geotechnical Database ([enter year]) "CPT Layer Analysis and Depth of Refusal", Map Layer CGD0055, retrieved [enter date] from https://www.nzgd.org.nz/

Map Layer and Description	Reference	
Soil Behaviour Type Index (*Ic*)	CGD0060	

Description

Maps of the averaged Soil Behaviour Type Index (*Ic*) for 1 m thick slices of CPT profiles.

Methodology

This investigation analysis tool, based on Robertson & Wride (1998) and Youd et al. (2001), is applied to all of the CPT profiles uploaded to the Geotechnical Investigation Data portion of the New Zealand Geotechnical Database. The tool is only run fortnightly, so new CPT profiles may be mapped up to a fortnight after they are checked in.

The soil behaviour type index (Ic), with normalised tip resistance and sleeve friction for the CPT cone, indicates whether the soil behaves as a coarse grained or fine grained soil. This is calculated for each CPT profile using the Robertson & Wride (1998) method as outlined in CGD Technical Specification 01 (2013), averaged over 1 m thick slices and classified for each slice between 0 and 10 m deep within the CPT profile.

As this is an automated analysis tool, this map layer should only be used to estimate the Soil Behaviour Type Index when planning a new site investigation based on other investigations within the general area. The original CPT investigation data should be evaluated manually for all other purposes.

References

Robertson, P.K. & Wride, C.E., (1998). *Evaluating cyclic liquefaction potential using the cone penetration test*, **Canadian Geotechnical Journal**, 35:442 – 459

Youd, T.L., Idriss, I.M., Andrus, R.D., Arango, I., Castro, G., Christian, J.T., Dobry, R., Finn, W.D.L., Harder Jr., L.H., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C, Marcuson, W.F., Marting, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B, & Stokoe, K.H. (2001). *Liquefaction Resistance of Soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils*: **Journal of Geotechnical and Geoenvironmental Engineering**, 127(10):817–833, October 2001.

New Zealand Geotechnical Database (2013) Liquefaction Evaluation of CPT Investigations CGD Technical Specification 01, 21 May 2013

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:
New Zealand Geotechnical Database ([enter year]) " Soil Behaviour Type Index (Ic)", Map Layer CGD0060, retrieved [enter date] from https://www.nzgd.org.nz/

Collated Investigation Data

Map Layer and Description	Reference	Published
Aerial Photography	CGD0100	1 June 2012

Description

High resolution aerial photographs of significant areas following each of the major earthquakes

Methodology

The aerial photographs were acquired on 5 Sept 2010, 24 Feb 2011, 14-15 June 2011, 16 June 2011 and 24 Dec 2011 by NZ Aerial Mapping. They were acquired to a range of specifications and supplied as ortho-rectified, colour balanced, geo-located, tiled images that were transformed into image pyramids for efficient transfer and display.

The images were acquired soon after significant ground movements and in conditions that were not ideal for aerial photography. The locations of the reference datums used during the acquisition were not verified at the time of supply, so there are unquantified errors in the image locations. These may add to or subtract from the estimated average of 1 m residual error following the ortho-rectification process.

The acquisition dates and commissioning agencies for each photograph set are tabulated below:

Photograph Set	Acquisition Date(s)	Commissioning Agencies
Post-Sept 2010	NZAM, 5 Sept 2010	Ministry of Civil Defence and Emergency Management
Post-Feb 2011	NZAM, 24 Feb 2011	Ministry of Civil Defence and Emergency Management
Post-June 2011	NZAM, 14-15 June 2011	The Earthquake Commission
Post-Dec 2011	NZAM, 24 Dec 2011	The Earthquake Commission

Only one photograph set can be displayed at a time and users may need to zoom out for some image sets to load. Users may also need to zoom in and out slowly to minimise network problems.

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:
New Zealand Geotechnical Database (2012) "Aerial Photography",
Map Layer CGD0100 - 1 June 2012, retrieved from https://www.nzgd.org.nz/

Map Layer and Description	Reference	Published
Liquefaction Interpreted from Aerial Photography	CGD0200	11 Feb 2013

Description

A regional-scale map showing the extents of ejected liquefaction material interpreted from aerial photography

Methodology

The quantity of ejected liquefaction material deposited on the streets was visually identified using the aerial photographs. Aerial photographs taken after each of the significant earthquakes were examined using Google Earth. Regions of the city with visible evidence of ejected material were identified and digitized. The region boundaries were aligned with road centre-lines and property boundaries rather than the boundaries of the individual surface features being mapped.

Classification	Apparent Features
MODERATE to SEVERE	• Roads had either ejected material or wet patches wider than a typical vehicle width • Ejected material in grass or on roads • Groups of 2-3 ejected material 'boils' within properties or parks
MINOR	• Roads had either ejected material or wet patches narrower than a typical vehicle • Only one or two ejected material 'boils' within a property or park
NONE	• None of the above features were observed

The photographs were of varying quality and light conditions. Shadows from low sun angles in some areas and sets of photographs may have been misidentified as ejected liquefaction material. Water from burst pipes or springs could also be misidentified as ejected material. Conversely, ejected material may have been obscured from view or removed before the photographs were taken. Photographs were not available for all areas of the city and there were no observations in the Port Hills.

These maps should be used in conjunction with the associated Aerial Photograph and property-scale observations to form a complete picture of the extent and severity of the liquefaction.

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:

New Zealand Geotechnical Database (2013) "Liquefaction Interpreted from Aerial Photography",
Map Layer CGD0200 - 11 Feb 2013, retrieved [date] from https://www.nzgd.org.nz/

Revisions

01 Oct 2012 – Initial release
11 Feb 2013 – Added Interpreted Liquefaction map for 4 Sept 2010 earthquake

Map Layer and Description	Reference	Published
Liquefaction and Lateral Spreading Observations	CGD0300	11 Feb 2013

Description

Property or road scale maps showing categorised quantities of ejected material and lateral spreading observed after the 4 Sept 2010, 22 Feb 2011 and 13 June 2011 Earthquakes

Methodology

The quantities of material ejected due to liquefaction and observations of lateral spreading were collated from on-foot rapid inspection of individual properties following each significant earthquake. The observations were categorized according to the quantity of ejected material observed on the ground surface and according to the presence or absence of evidence of lateral spreading. Each of these three categories was further subdivided according to the severity.

The observations were collected for the Earthquake Commission and were only made in residential areas. The mapping only identified liquefaction and lateral spreading that was visible at the surface at the time of inspection. Liquefaction may have occurred at depth without obvious evidence at the surface and evidence of liquefaction may have been removed before the inspection. (Removed material may be identifiable within the aerial photographs that were taken within a day or two of the earthquake.)

The properties were not all inspected between each pair of consecutive earthquakes (e.g. between 4 Sept 2010 and 22 Feb 2011) so the extent of the land deformations is most likely incomplete. Also, some observations following the 22 Feb 2011 and 13 Jun 2011 earthquakes could have been induced by preceding earthquakes.

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:

New Zealand Geotechnical Database (2013) "Liquefaction and Lateral Spreading Observations", Map Layer CGD0300 - 11 Feb 2013, retrieved [date] from) from https://www.nzgd.org.nz/

Revisions

01 Oct 2012 – Initial release
11 Feb 2013 – Added Road Observations map for 22 Feb 2011 earthquake
22 Sep 2016 – Added street mapped and photo observations for 14 Feb 2016 earthquake

Map Layer and Description	Reference	Published
Observed Ground Crack Locations	CGD0400	23 July 2012

Description

Digitized Ground Crack Locations following the 4 Sept 2010 and 22 Feb 2011 Earthquakes

Methodology

Crack locations were mapped in order to infer the general direction, magnitude and extent of the lateral spreading. Field observations of crack locations were recorded using coloured pens on paper copies of aerial photographs. The marked-up photographs were later scanned and the coordinates of the coloured lines were manually digitized.

The mapping objectives changed in response to the varying situation following the two earthquakes. Observations after the 4 Sept 2010 Earthquake were principally for insurance claim settlements. The crack widths were recorded in property-by-property observations, but cracks were not tracked across property boundaries and only a portion of properties were mapped before the 22 Feb 2011 Earthquake.

Cracks were mapped at a scale of 1:5000 to 1:10000 for about two weeks following the 22 Feb 2011 Earthquake in order to rapidly identify the extent of lateral spreading following the earthquake. The individual crack widths were not recorded.

From early March 2011, cracks were generally mapped at a scale of 1:2000 and classified according to their maximum width (with many tapering to nothing at both ends). Cracks were tracked through properties in order to identify spreading regions rather than spreading within individual properties.

The crack mapping is incomplete and only observations made by the mapping teams are presented. In particular, the mapping following the 4 Sept 2010 Earthquake was incomplete before the 22 Feb 2011 Earthquake occurred and subsequent mapping remains incomplete within the residential 'red zone' areas. Also, cracks in roads were often not able to be mapped because many were filled and the roads resealed before a mapping team arrived.

The suggested viewing scale for this map is 1:3000, which is a viewing altitude of about 1 km in Google Earth. All crack locations include unquantified errors in the orthorectified aerial photographs (see Aerial Photographs map layer notes), the manual field recording method, the photograph printing and scanning equipment, manual digitization and dimensional changes within the paper.

Colours for the 50 to 200 mm crack widths are similar for both sets of data to provide an overview of the spreading rather than to provide a comparison between earthquakes. (The colours can be changed by the user if required.)

Cite figures or other works derived from these map layers (see the Important Notice, Page 3) as:
New Zealand Geotechnical Database (2012) "Observed Ground Crack Locations",
Map Layer CGD0400 - 23 July 2012, retrieved [date] from https://nzgd.org.nz

Map Layer and Description	Reference	Published
LiDAR and Digital Elevation Models	CGD0500	30 June 2015

Description

Pre and post earthquake Digital Elevation Models (DEM) created from Airborne LiDAR

Methodology

LiDAR was acquired by AAM Brisbane (AAM) and New Zealand Aerial Mapping (NZAM) following each of the significant earthquakes. The suppliers classified the acquired points allowing the creation of a bare earth or terrain model, by removing points for structures and vegetation that were judged to be higher than 0.5 m above the surrounding ground. A DEM was developed from each supplied LiDAR set by averaging the ground-return elevations within a 10 m radius of each grid point. All of these DEM's used a common 5 m grid and used either moving averages or windowed averages. Each DEM was colour banded and rendered in an image pyramid to create a viewable version of the underlying elevation model. Colours were clipped from the images around significant waterways and coastal marine areas.

The LiDAR sources and commissioning agencies for each Digital Elevation Model are tabulated below:

DEM	Source LiDAR	Commissioning Agencies
Pre-Earthquake	AAM, 6-9 Jul 2003*	Christchurch City Council
	AAM, 21-24 Jul 2005	Environment Canterbury & Waimakariri District Council
	AAM, 6-11 Feb 2008	Environment Canterbury & Selwyn District Council
Post-Sept 2010	NZAM, 5 Sep 2010	Ministry of Civil Defence and Emergency Management
Post-Feb 2011	NZAM, 8-10 Mar 2011	Ministry of Civil Defence and Emergency Management
	AAM, 20-30 May 2011	Christchurch City Council
Post-June 2011	NZAM, 18 & 20 Jul, 11 Aug, 25-27 Aug, and 2-3 Sept 2011	The Earthquake Commission
Post-Dec 2011	NZAM, 17-18 Feb 2012	The Earthquake Commission

The NZAM LiDAR was acquired using instruments and procedures that give a fundamental vertical accuracy of ±0.10 m (one sigma) for areas of open ground with hard surfaces. The accuracy is in terms of a reference network defined by field surveying data. Metadata for the AAM LiDAR indicates a vertical accuracy of ±0.07 to ±0.15 m (excluding GPS error and Geoid modelling error) and 0.40 to 0.55 m horizontal.

The pre-earthquake LiDAR has lower accuracy and sparser LiDAR point sets than the post-earthquake sets. The post-Feb 2011 DEM was created from two partially overlapping LiDAR sets, with points taken from the more accurate 20-30 May set in preference to the 8-10 Mar set wherever the two sets overlapped.

The vertical elevations were calibrated against land-based survey data supplied by the Christchurch City Council, Land Information New Zealand and Environment Canterbury from surveys of their benchmark networks. All of the LiDAR elevation measurement points within a 1 m radius of each benchmark were extracted from each of the point clouds. The elevation difference between each measurement point and its adjacent benchmark were incorporated in a separate

Map Layer and Description	Reference	Published

layer. The accuracy of the supplied survey data was not quantified. Statistics for calibration of the LiDAR point cloud sets are:

Source LiDAR:	6-9 Jul 2003	5 Sept 2010	8-10 Mar 2011	20-30 May 2011	July-Sept 2011
Average error:	-0.02 m	-0.04 m	0.03 m	0.01 m	0.05 m
Standard Deviation:	0.13 m	0.13 m	0.06 m	0.06 m	0.05 m

The flight paths for the NZAM LiDAR are only displayed clearly when either the path folders are double clicked or the limit markers are moved on the time range tool bar.

Cite figures or other works derived from these map layers (see Important Notice, Page 3) as:
New Zealand Geotechnical Database (2015) "LiDAR and Digital Elevation Models", Map Layer CGD0500 - 30 June 2015, retrieved [date] from https://www.nzgd.org.nz/

Revisions

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Revisions

23 July 2012 – Initial release
30 June 2015 – Additional colour banded ranges and contours added for Sept 2011 DEM

Map Layer and Description	Reference	Published
Vertical Ground Surface Movements	CGD0600	23 July 2012

Description

Vertical elevation changes between LiDAR sets that approximate the vertical ground movements during significant earthquakes

Methodology

Elevation changes were calculated both for individual earthquakes (and their associated aftershocks) and for sets of consecutive earthquakes as differences between pairs of Digital Elevation Models (DEM). These 'observed' elevation differences for the overlapping region of each DEM pair were colour banded and rendered in an image pyramid. Colours were clipped from the images around significant waterways and coastal marine areas.

GNS Science dislocation models of the vertical tectonic movements during each earthquake were also colour banded for a separate layer. The vertical movements were summed for sets of consecutive earthquakes and presented in other layers. Contours of the tectonic movements are also provided as overlays for other maps.

Local vertical movements were calculated as the differences between the 'observed' elevation differences and the associated tectonic models. These are presented as a third layer for each event combination.

All of the movements are differences between DEMs and are inherently less accurate than their source DEM's. The pre-earthquake source DEM is less accurate than the post-earthquake DEMs (see notes accompanying the LiDAR and Digital Elevation Models map layers), so all four sets of movements derived from that DEM have more error than the other difference sets. The post-Feb 2011 DEM was created from two partially overlapping LiDAR sets, with points taken from the more accurate set wherever the two sets overlapped. Some of the DEMs have visually distinguishable lines or ripples within the colour bands that are almost certainly artefacts from the data acquisition and subsequent processing rather than from physical vertical movements. Notable examples are several approximately NNE-SSW swathes visible in the Feb 2011 difference set and an almost E-W line at 43.48°S in the 13 Jun 2011 difference set.

The earthquake dates are abbreviated as S10, F11, J11 and D11 in the Google Earth sidebar (for 4 Sept 2010, 22 Feb 2011, 13 June 2011 and 23 Dec 2011 respectively). The time interval for each difference set is displayed graphically in the sidebar, using an "X" beneath the earthquake label for one earthquake and ">–––<" for cumulative movements during two or more earthquakes.

Cite figures or other works derived from these map layers (see the Important Notice , Page 3) as:
New Zealand Geotechnical Database (2012) "Vertical Ground Surface Movements", Map Layer CGD0600 - 23 July 2012, retrieved [date] from https://www.nzgd.org.nz/

Map Layer and Description	Reference	Published
Horizontal Ground Surface Movements	CGD0700	23 July 2012

Description

Horizontal ground surface movements between LiDAR sets that approximate the movements during significant earthquakes

Methodology

Horizontal movements were calculated for both individual earthquakes (and their associated aftershocks) and sets of consecutive earthquakes as differences between pairs of LiDAR point clouds. The horizontal movements for each earthquake combination were calculated using a sub-pixel correlation method developed by Imagin' Labs Corporation and California Institute of Technology. The movements were calculated on 4 m grids (8 m for the pre-earthquake LiDAR sets) from both ground and non-ground LiDAR points and averaged to provide Cartesian movements in a 56 m grid. The averaging distance was tailored to the noise in the two LiDAR sets.

The horizontal movements were rendered as arrows on a 56 m grid to indicate both direction and magnitude of the movement at each grid point. The arrows were scaled 56:1 so an arrow between two adjacent grid points (e.g. east-west or north-south) represents 1.0 m movement in the indicated direction. Arrows were not plotted in significant waterways, coastal marine areas and most other non-residential land where the movements were poorly correlated and produced less accurate horizontal movement estimates. The correlation process and horizontal movements are also significantly affected by elevation errors. Some of the horizontal movement are also influenced by localised changes such as new or demolished buildings, vegetation and earthworks for subdivisions.

GNS Science dislocation models of the horizontal tectonic movements during each earthquake were also colour banded and presented in a separate layer. The horizontal movements were summed for sets of consecutive earthquakes and presented in other layers. Contours of the tectonic movements are also provided as overlays for other maps.

"Local" horizontal deformations were calculated as the differences between the 'observed' movements and the associated tectonic models. These are presented as a third layer for each event combination.

The pre-earthquake source DEM is less accurate than the post-earthquake DEMs (see notes accompanying the LiDAR and Digital Elevation Models section) so all four sets of movements derived from that DEM have more error than the other difference sets. The post-Feb 2011 DEM was created from two partially overlapping LiDAR sets, with points taken from the more accurate set wherever the two sets overlapped.

The horizontal movements were calibrated against data supplied by the Christchurch City Council, Land Information New Zealand and Environment Canterbury from surveys of their benchmark networks. The horizontal movements at the benchmark locations are presented in a separate layer.

The earthquake dates are abbreviated as S10, F11, J11 and D11 in the Google Earth sidebar (for 4 Sept 2010, 22 Feb 2011, 13 June 2011 and 23 Dec 2011 respectively). The time interval for each difference set is displayed graphically in the sidebar, using an "X" beneath the earthquake label for one earthquake and ">–––<" for cumulative movements during two or more earthquakes.

Map Layer and Description	Reference	Published
The movement arrows are hidden for viewing altitudes higher than about 5 km. Reference: Beavan, J., Levick, S., Lee, J. and Jones, K. (2012) Ground displacements and dilatational strains caused by the 2010-2011 Canterbury earthquakes, GNS Science Consultancy Report 2012/67. 59 p. Cite figures or other works derived from these map layers (see Important Notice, Page 3) as: New Zealand Geotechnical Database (2012) "Horizontal Ground Movements", Map Layer CGD0700 - 23 July 2012, retrieved [date] from https://www.nzgd.org.nz/		

Map Layer and Description	Reference	Published
Event Specific Groundwater Surface Elevations	CGD0800	12 June 2014

Description

Groundwater surface elevations based on Environment Canterbury (ECan) and Tonkin & Taylor Ltd (T&T) measurements

Methodology

Water level dip measurements from wells installed for the Earthquake Commission (EQC) and ECan since Sept 2010 were used to augment measurements from existing shallow wells supplied by ECan. Water level dips were converted to free surface elevations, based on surveyed well-head levels.

Surface models were fitted to the elevations recorded at these wells and the adjacent rivers immediately prior to the 4 Sept 2010, 22 Feb 2011, 13 June 2011 and 23 Dec 2011 earthquakes. Geographically sparse well measurements for the earlier earthquakes were augmented with observations from the newly installed wells. Some predicted elevations were the elevation measured one year after the earthquake and the remainder were extrapolated back in time using the variation observed in adjacent wells. The fitted surface for each earthquake was colour banded and rendered in an image pyramid. The well locations are also plotted.

Groundwater depths were derived from the free surface elevations prior to each earthquake by subtracting the elevations from the most appropriate LiDAR-derived digital surface elevation model. The depths were colour banded and rendered.

The free surface elevations only provide mean values at the time of each earthquake and are only suitable for back analysis purposes. They are indicative only, with no allowance for extreme or seasonal fluctuations, or for localised perturbations (e.g. changes in topography or permeability) away from the measured well. They are not suitable for design.

Users should note that the free surface elevations are periodically updated using elevations recorded in new well installations and longer durations of observations within existing wells, which are both extrapolated back in time as outlined above.

The Environment Canterbury wells have links to their published ground water monitoring data.

Reference: Tonkin & Taylor (2012) Canterbury Earthquakes 2010 and 2011 Land Report as at 29 February 2012, retrieved 26 July 2012 from http://canterbury.eqc.govt.nz/news/reports

Cite figures or other works derived from these map layers (see the Important Notice, Page 1) as:
New Zealand Geotechnical Database (2014) "Event Specific Groundwater Surface Elevations", Map Layer CGD0800 – 12 June 2014, retrieved [date] from https://www.nzgd.org.nz/

Revisions

01 Oct 2012 – Initial release
20 Nov 2012 – All map layers replaced to incorporate back extrapolation of new observations
11 Feb 2013 – All layers replaced (as above). Replaced maps moved to new Superseded section
12 Jun 2014 – All layers replaced to reflect Version 2 of the CGD5160 Median Surface

<table>
<tr><th>Map Layer and Description</th><th>Reference</th><th>Published</th></tr>
<tr><td>Borehole Logs (pre Sept 2010)</td><td>CGD0035</td><td>1 June 2012</td></tr>
<tr><td colspan="3">Description
Environment Canterbury well drilling logs published before the Sept 2010 earthquake and collated for the Earthquake Commission</td></tr>
<tr><td>CBD MASW Investigations</td><td>CGD0040</td><td>12 Oct 2012</td></tr>
<tr><td colspan="3">Description
MASW investigations of roads within the Central Business District commissioned by the Christchurch City Council for the Christchurch Central Recovery Plan
Initial release 1 June 2012. Additional investigation lines added 12 Oct 2012.</td></tr>
<tr><td>Suburban MASW Investigations</td><td>CGD0045</td><td>12 Oct 2012</td></tr>
<tr><td colspan="3">Description
Suburban MASW investigations prepared for the Earthquake Commission and for the Canterbury Earthquake Recovery Authority
Initial release 1 June 2012. Additional investigation lines added 12 Oct 2012.</td></tr>
</table>

Published Maps and Reports

Map Layer and Description	Reference	Published
CERA Residential Zoning Maps	CGD5010	30 Jan 2013
Description Residential property damage zones to guide the recovery and rebuild process. First published by CERA on 23 June 2011 and updated on 5 December 2013. **This map will be updated as new information is released**. The damage zones are only for residential properties and specifically exclude all other property types, including schools, parks, commercial zones, and the central business district (CBD). Zones were initially identified from engineering assessments of residential land, building and infrastructure damage. The zone boundaries were adjusted using the criteria set by the New Zealand Government on the basis of whether it was practical to repair properties in a timely and cost effective way. New Zealand Geotechnical Database - Map Layer CGD5010 - 30/01/2014		
MBIE Residential Foundation Technical Categories	CGD5020	30 Jan 2014
Description The "Residential Foundation Technical Categories" map first published by the Ministry of Business, Innovation and Employment on 28 October 2011 and updated 5 December 2013. Technical Category 1 (TC1) Future land damage from liquefaction is unlikely, and ground settlements are expected to be within normally accepted tolerances. Standard foundations (NZS 3604) are acceptable subject to shallow geotechnical investigation. Technical Category 2 (TC2) Minor to moderate land damage from liquefaction is possible in future large earthquakes. Lightweight construction or enhanced foundations are likely to be required such as enhanced concrete raft foundations (ie, stiffer floor slabs that tie the structure together). Technical Category 3 (TC3) Moderate to significant land damage from liquefaction is possible in future large earthquakes. Foundation solutions should be based on site-specific geotechnical investigation and specific engineering foundation design. The CERA Technical Categories Map displays this map as a web service. The shapefiles for this map are available from the New Zealand Geospatial Services Portal or the CERA folder within the ArcGIS Services Directory. New Zealand Geotechnical Database - Map Layer CGD5020 - 30/01/2014		

Map Layer and Description	Reference	Published
CBD Geological Sections	CGD5030	1 June 2012
Description Geological Sections within the Central Business District commissioned by the Christchurch City Council for the Christchurch Central Recovery Plan		
Geological Sections (Outlying Suburbs)	CGD5040	1 June 2012
Description Geological sections of the outlying suburbs prepared for the Earthquake Commission		
CBD Investigative Report Areas	CGD5050	1 June 2012
Description The Christchurch Central City Geological Interpretative Report accompanying the Christchurch Central Recovery Plan		
Suburban Investigative Areas (post Feb 2011)	CGD5060	1 June 2012
Description Investigative Reports to The Earthquake Commission about land damage following the 4 Sept 2010 and 22 Feb 2011 earthquakes		
Suburban Investigative Areas (pre Feb 2011)	CGD5070	1 June 2012
Description Investigative Reports to The Earthquake Commission about land damage following the 4 Sept 2010 earthquake		

Map Layer and Description	Reference	Published
Black Maps	CGD5080	7 Oct 2012

Description

A selection of geo-referenced historical geotechnical and geological maps from Archives New Zealand and the Christchurch City Council.

Published with permission from Archives New Zealand Christchurch Office.

Christchurch – March 1850

Three sheets of Black Map 273 – Plot of Christchurch, surveyed in March 1850, covering Hagley Park (Sheet 1), the central city bounded by Salisbury, St Aseph, Antigua and Barbadoes Streets (Sheets 2 and 3).

Archives New Zealand Reference CAYN 23142 CH1031/179 273/1, 2 & 3 Retrieved 26 May 2011
http://archives.govt.nz/gallery/v/Online+Regional+Exhibitions/Chregionalofficegallery/sss/Black+Map+of+Christchurch/

Environmental Ecology – 1856

Waterways, Swamps and Vegetation Cover in 1856 Compiled from "Black Maps" approved by J Thomas and Thomas Cass, Chief Surveyors, 1856 – Christchurch City Council Information Services digitised Map Ap001725 compiled by Ken Sibley Jul 1989 and revised by G Tibble Apr 1996.

Source: Christchurch City Council Retrieved 31 May 2011
http://resources.ccc.govt.nz/files/blackmap-environmentecology.pdf

Lyttelton – September 1849

One sheet of Black Map 297 – Plan of Lyttelton; Port Victoria; September 1849

Archives New Zealand Reference CAYN 23142 CH1031/180 297 Retrieved 26 May 2011
http://archives.govt.nz/gallery/v/Online+Regional+Exhibitions/Chregionalofficegallery/sss/CH1031-180_+297_+Black+Map+Lyttelton+1849.JPG.html

Sumner Township – November 1849

Two sheets of Black Map 293 – Plan of Sumner (both sheets with identical extents) surveyed in November 1849.

Archives New Zealand Reference CAYN 23142 CH1031/180 293/1 & 2 Retrieved 26 May 2011
http://archives.govt.nz/gallery/v/Online+Regional+Exhibitions/Chregionalofficegallery/sss/Black+Map+of+Sumner+Township

Map Layer and Description	Reference	Published
Cadastral Boundaries (2010)	CGD5090	27 Sept 2012

Description

Property, Suburb, Ward and Territorial Authority Boundaries

Methodology

The ward and Territorial Authority boundaries were supplied by Land Information NZ (LINZ). The suburb and property boundaries were supplied by CCC, SDC, and WDC in December 2010. The line segments of some suburb boundaries were adjusted so they were coincident with their ward boundary lines.

The boundaries are only supplied to provide a visual indication of their approximate locations in December 2010.

The property boundaries are only visible at viewing eye altitudes below 5 km. Some properties are split between two or more tiles.

Map Layer and Description	Reference	Published
Cadastral Maps (Historical)	CGD5100	27 Sept 2012

Description

A geo-referenced historical cadastral map of Christchurch and Sumner from the Alexander Turnbull Library. Crown Copyright Reserved.

Christchurch and Sumner Survey Districts – June 1892

One sheet. Reproduced with permission from the Alexander Turnbull Library, National Library of New Zealand.

Christchurch and Sumner survey districts, NZMS 13, CB 67 (Wellington: Lands and Survey Dept., 1892). MapColl 830bje/1914-/Acc.3142.

Retrieved 2 June 2011 from the National Digital Heritage Archive - http://ndhadeliver.natlib.govt.nz/content-aggregator/getIEs?system=ilsdb&id=1256851

Map Layer and Description	Reference	Published
Conditional PGA for Liquefaction Assessment	CGD5110	30 June 2015

Description

Conditional Peak Ground Accelerations (PGA) developed for conventional liquefaction assessments by Bradley Seismic Ltd. and the University of Canterbury

Methodology

Peak Ground Accelerations were estimated for the site-specific assessment of liquefaction due to significant earthquakes throughout the greater Christchurch region. The PGA at each location within the region was calculated for each earthquake by combining the prediction from an empirical ground motion model of the fault rupture with the PGA recorded at any adjacent strong motion stations. Locations far from any strong motion station were predominantly influenced by the predicted, log-normally distributed, PGA (termed unconditional) whereas those at a station were the (conditional) recorded PGA. The conditional PGA at each location is defined probabilistically in terms of its median value and its uncertainty or (lognormal) standard deviation.

The conditional median PGA was contoured and the standard deviation was colour banded so the two can be displayed simultaneously. (Click on a median contour or uncertainty band to display its value.) Contours are also provided for the standard deviations.

These map layers only provide median and standard deviation PGA values for each earthquake. They are only suitable for estimating the PGA at a particular location, during a historic earthquake. They are not suitable for design.

The Ministry of Business, Innovation and Employment's Sept 2012 *Guidelines for the investigation and assessment of subdivisions on the flat in Canterbury* suggest using these map layers to decide whether sites have been "sufficiently tested at the serviceability limit state" during recent seismic events. (see http://www.dbh.govt.nz/subdivisions-assessment-guide)

Strong-motion station locations were extracted from the GeoNet DELTA database in 2015.

References

Bradley and Hughes (2012a) Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment, Technical Report for the Ministry of Business, Innovation and Employment, April 2012. 22p.

Bradley and Hughes (2012b) Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment: Part 2, Technical Report for the Ministry of Business, Innovation and Employment, December 2012. 19p.

GeoNet DELTA application, accessed 5 June 2015, https://magma.geonet.org.nz/delta/app

Cite figures or other works derived from these map layers (see Important Notice, Page 3) as:
New Zealand Geotechnical Database (2015) "Conditional PGA for Liquefaction Assessment", Map Layer CGD5110 – 30 June 2015, retrieved [date] from https://www.nzgd.org.nz/

Revisions

27 Sep 2012 – Initial release
11 Feb 2013 – All layers corrected and layers added for additional significant earthquakes
19 Feb 2013 – Revised 11 Feb 2013 corrections for 22 Feb 2011 earthquake
30 Jun 2015 – Added PGA observations at GeoNet strong-motion recording stations

Map Layer and Description	Reference	Published
22 Sep 2016 – Added PGA and standard deviation contours for 14 Feb 2016 earthquake		

Map Layer and Description	Reference	Published
Geological Maps	CGD5120	1 Nov 2012

Description

A selection of published geo-referenced geological maps

Christchurch Geology – 2008

The 1:250 000 scale GNS Science map *Geology of the Christchurch Area* compiled by Forsyth, Barrell, and Jongens. Approximately centred on Christchurch, this map includes a comprehensive geological legend and cross-sections.

Reference: Forsyth, P.J., Barrell, D.J.A., Jongens, R. (2008) (compilers), Geology of the Christchurch Area, Institute of Geological and Nuclear Sciences 1:250 000 geological map 16. 1 sheet. Lower Hutt, New Zealand. GNS Science. ISBN 987-0-478-19649-8

Christchurch Geology – 1992

The 1:25 000 scale GNS Science map *Geology of the Christchurch Urban Area*, compiled by Brown & Weeber. Map includes a cross-section and overview maps of the Northern Canterbury Plains and the Waimakariri River floodplain sector.

Reference: Brown, L.J. & Weeber, J.H. (1992), Geology of the Christchurch urban area. Scale 1:25000. Institute of Geological and Nuclear Sciences geological map 1. One sheet. Institute of Geological and Nuclear Sciences Limited, Lower Hutt, New Zealand.

1:250 000 Geological Map of New Zealand (QMAP)

The QMAP project completed the last of 21 new 1:250 000 geological maps in 2012. The maps cover all of New Zealand and their accompanying texts describe each area's geomorphology, stratigraphy, tectonic history, geological resources, geological hazards and engineering geology in general terms.

See https://www.gns.cri.nz/Home/Our-Science/Earth-Science/Regional-Geology/Geological-Maps/1-250-000-Geological-Map-of-New-Zealand-QMAP/QMAP-text-maps Use of the geological map image is licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) Licence http://creativecommons.org/licenses/by/4.0/.

GNS Christchurch Urban Geological Units

See https://www.gns.cri.nz/Home/Our-Science/Earth-Science/Regional-Geology/Urban-Geological-Mapping

Revisions

24 Oct 2017 - Removed Canterbury and Westland Geology – 1866 (replaced by QMAP)
24 Oct 2017 - Added GNS Geological Map of New Zealand (QMAP)
24 Oct 2017 - Added GNS Christchurch Urban Geological Units

Map Layer and Description	Reference	Published
Geotechnical Maps	CGD5130	20 Nov 2012

Description

A selection of published geo-referenced geotechnical maps

Subsoil Strata - 1960 - Christchurch Drainage Board

Christchurch Subsoil Strata (from Borehole Logs) - Christchurch Drainage Board - April 1960. Three sheets identifying regions of Christchurch City (9 km x 9 km) with predominantly Sand, Clay & Pug, Peat and Gravel. From the surface to 4 feet (Sheet 1), from 4 to 7 feet (Sheet 2) and from 7 to 10 feet (Sheet 3) below the surface

Reference: Scott, E.F. (1963) "Christchurch Data: Notes and comments on the Christchurch. Drainage and Sewerage Systems". Unpublished report. Christchurch Drainage Board

Shallow Foundation Hazard Map - 1990

This map of Christchurch identifies regions of Low, Moderate and High Potential Risk and nominates the foundation investigation required for each region. Soils are identified in each region. The low risk areas have gravel. Moderate risk areas have Silt and Sand. High risk areas are those with Peat, old Swamps or Lakes or Filled Ground. Hill areas (on account of their landslide and erosion potential) and areas with Flood of Erosion Hazard are also nominated as high risk areas.

The map is reproduced with permission from MWH New Zealand Ltd.

Reference: Elder, D.M., McCahon, I.F. and Yetton, M.D. (1991) Earthquake hazard in Christchurch: a detailed evaluation" Research Report to the Earthquake Commission. (available http://www.eqc.govt.nz/research/research-papers/earthquake-hazard-in-christchurch-a-detailed-evaluation)

Map Layer and Description	Reference	Published
Hazard Maps	CGD5140	30 Oct 2014

Description

A selection of published geo-referenced hazard maps

ECan Timaru Liquefaction Susceptibility – 2013

Updated liquefaction susceptibility maps for Timaru District, developed as part of a 2001 earthquake hazard assessment for engineering lifelines. The 2001 maps were based primarily on geological information and some limited borehole data. The 2013 study (see reference) incorporates additional borehole data, data collected from test pits in Geraldine and Washdyke, and cone penetration tests (CPTs) in three parts of Timaru township.

Geotech Consulting Ltd (2013) Liquefaction Hazard in Timaru District, Environment Canterbury report number R13/29, June 2013 ISBN: 978-1-927234-84-6 Accessed 26 Sept 2014 from http://ecan.govt.nz/advice/emergencies-and-hazard/earthquakes/Pages/liquefaction-information.aspx#timaru

Environment Canterbury Liquefaction Assessment Area Map – 2012

The Environment Canterbury "Liquefaction assessment area map for the eastern Canterbury project area" released in January 2013. (See reference below.)

Review of liquefaction hazard information in eastern Canterbury, including Christchurch City and parts of Selwyn, Waimakariri and Hurunui Districts. Environment Canterbury Report R12/83. December 2012. accessed 19 Feb 2013 from http://ecan.govt.nz/advice/emergencies-and-hazard/earthquakes/Pages/liquefaction-information.aspx#review

GNS Science Post 4 Sept 2010 Observations

Observations of liquefaction in digital satellite images and aerial photography following the 4 Sept 2010 Earthquake, compiled by GNS Science. From Appendix A3.2 of the reference above.

GNS Science Post 22 Feb 2011 Observations

Observations of liquefaction in digital satellite images and aerial photography following the 22 Feb 2011 Earthquake, compiled by GNS Science. From Appendix A3.2 of the reference above.

ECan Liquefaction Hazard Maps - 2004

Two (historic) hazard maps showing "liquefaction potential" and another showing "liquefaction ground damage potential", developed by BECA for Environment Canterbury and published in the poster "The Solid Facts on Christchurch Liquefaction".

Source: Environment Canterbury - Geological Hazard Information
http://ecan.govt.nz/services/online-services/property-information/explanatory-information/pages/earthquakes-hazards.aspx#geological-hazard-information-ecan

Revisions

27 Sep 2012 – Initial release

21 Feb 2013 – Added Environment Canterbury Liquefaction Assessment Area Map and the two accompanying liquefaction observations maps

30 Oct 2014 – Added the 2013 liquefaction susceptibility map for the Timaru District

Map Layer and Description	Reference	Published
Topographic Maps	CGD5150	9 Oct 2012

Description

A selection of published geo-referenced historical topographical maps

Christchurch-Mandeville – 1850

One sheet showing 40 numbered trig stations between Ashley River and Lake Ellesmere, Native and European reserves and indicates nature of ground and ground cover. Reproduced with permission from the National Library of New Zealand. Crown Copyright Reserved.

Trigonometrical [sic] ***and topographical survey of the districts of Mandeville and Christchurch: shewing*** [sic] ***the trigonometrical stations***, 1850. MapColl 834.44cba/1850/Acc. 1270 and 27187

Retrieved 2 June 2011 from the National Digital Heritage Archive – http://ndhadeliver.natlib.govt.nz/content-aggregator/getIEs?system=ilsdb&id=700004

Canterbury 1849

On sheet covering "Sketch Map of the country intended for the Settlement of Canterbury" between the Ashley and Ashburton rivers traced from original map of J. Thomas, dated 1849.

Reproduced with permission from Archives New Zealand Christchurch Office

Archives New Zealand Reference CAIX CH765 1/21(b) Retrieved 26 May 2011 http://archives.govt.nz/gallery/v/Online+Regional+Exhibitions/Chregionalofficegallery/sss/Map+of+Canterbury+by+Thomas/

Map Layer and Description	Reference	Published
GNS Science Median Water Table Elevations (Version 2)	CGD5160	10 June 2014

Description

Maps of the median water table, as both elevation and depth below ground, across Christchurch City and surrounding area, representing the period since the 4 September 2010 M_w 7.1 Darfield Earthquake. These version 2 (2014) maps are based on monitoring from Sept 2010 to Nov 2013.

Groundwater Protection Zones

Three broad land-surface groundwater protection zones proposed by Weeber (2008) for the Christchurch-West Melton groundwater system. The zone boundaries are defined by the 3 m thickness contour of near-surface, fine-grained sediments and the boundary between the upward and downward hydraulic gradients in the shallow aquifers (Riccarton, Springston and Christchurch formations).

This map provides an indirect outline of areas characterised by upward and downward hydraulic gradients, and places where superficial fine-grained deposits that act as aquifer confining layers in the Eastern/Coastal Zone.

Post Darfield Earthquake Median Water Table Elevation

Two median water table elevation surfaces developed from observation records for 967 shallow monitoring wells, modelled elevations of surface water along the river centre-lines and the coast. The slope of the surface was allowed to break perpendicular to rivers. Drawdown points were used to correct the model for local aberrations where the methodology produces a water table above the ground surface.

A representative median water table elevation was calculated for each well. Only short term records (< 12 monthly records) were available for 310 wells, so surrogate medians were estimated using data from nearby wells with long-term records, to account for seasonal variation. One map of surface contours is provided for well observations with longer-term records (≥ 12 records) and the other contour map includes the surrogate short-term medians (< 12 records). The differences between the two surfaces are subtle, and in most places less than ± 0.5 m. Users need to decide which surface is more appropriate based on specific engineering requirements and match their own local site observations.

These map layers and their background report were re-issued in May 2014 (version 2) and may be re-issued periodically to reflect ongoing groundwater monitoring within both existing wells and additional wells installed during the rebuilding of Christchurch City.

85th and 15th Percentile Water Table Elevations

Post-Darfield earthquake 85th and 15th percentile surfaces were created from the 85th and 15th percentile surface elevation observations at each site. The 85th percentile surface was created by calculating the difference between the 85th percentile and the median water level observed at each site, spatially interpolating these relative differences, then adding the interpolated differences to the median water table surface. The same method was used to create the 15th percentile surface. Expected groundwater variation at rivers and along the coastline were included in the calculations, based on observed surface water fluctuations. At drawdown points, 85th percentile values were set at ground level.

These maps (new in version 2) provide context for the median water table surface, showing the variations of the water table in different parts of Christchurch City between 2010 and 2013. On

Map Layer and Description	Reference	Published

average, the water table is below the 85th percentile surface for 85% of the observations at each monitoring well. Fifteen percent of observations should be below the 15th percentile surface.

Post Darfield Earthquake Depth to Water Table – Median, 85th and 15th Percentile Elevations

Maps of the depth of the median water table surface beneath a 25m-grid Digital Elevation Model (DEM) of the ground surface. This 25 m DEM was derived from 5m-grid DEMs, using the most recent, Feb 2012, augmented with additional extent from Sept 2011 (both in Map Layer CGD0500).

These map layers and their background report were re-issued in May 2014 (Version 2) and may be re-issued periodically to reflect ongoing groundwater monitoring within both existing wells and additional wells installed during the rebuilding of Christchurch City.

Median and 85th and 15th Percentile Grids for 1990-2010

Fluctuations in groundwater between 1990 and 2010 were also considered best represented by the 85th percentile, median and 15th percentile elevations at 55 CCC and ECan shallow monitoring wells with long-term records. However, these three grid maps were independently interpolated using ordinary kriging. Surfaces for height above and depth below the median were then created from the interpolated surfaces. Between 1990 and 2010 there were inter-annual water table variations (around 2 m in the west and 1.2 m in the east) that were twice the scale of seasonal variations (around 1 m in the west, 0.5 m in the east). Natural fluctuations of groundwater occur at time-scales longer than post-Darfield Earthquake monitoring. The pre-Darfield Earthquake variations between 1990 and 2010 provide the best proxy of the likely scales of future water table fluctuations until more data is available.

Confidence Index for All Records

A qualitative confidence index (for all well records), that accounts for the density of monitoring wells and the duration of the recordings, indicating where there is a lower, medium or higher confidence in the median water table elevation map. Indicative precision reflects modelling experience and the local slope (hydraulic gradient) of the water table surface.

References

GNS Science (2013) *Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake*, GNS Science Report 2013/01, March 2013, 66p and 8 Appendices (Superseded)

van Ballegooy, S.; Cox, S. C.; Thurlow, C.; Rutter, H. K.; Reynolds, T.; Harrington, G.; Fraser, J.; Smith, T. (2014) Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake: Version 2, GNS Science Report 2014/18, April 2014. ISBN 978-1-927278-41-3. 79 p and 8 Appendices.

Weeber, J.H. (2008) *Christchurch groundwater protection: A hydrogeological basis for zone boundaries, Variation 6 to the Proposed Natural Resources Regional Plan*. Environment Canterbury. Report No.U08/21. ISBN 978-1-86937-802-8, 60 p.

Revisions

07 Mar 2013 – Initial release

12 Jun 2014 – Map layers rearranged and new Version 2 maps added. Version 1 layers and description moved to a Superseded section.

Map Layer and Description	Reference	Published
Ground Motion	CGD5170	30 June 2015

Description

Spatial distributions of Peak Ground Acceleration estimated from recorded ground motion records.

PGA Contours by O'Rourke et al.

Contours of PGA developed by O'Rourke et al. for the significant earthquakes within the Canterbury earthquake sequence.

For each earthquake, the geometric mean was calculated from the two horizontal PGAs at each recording station. The spatial distribution of the geometric mean values was estimated for each earthquake using ordinary kriging and the spherical variogram developed and verified by Jeon and O'Rourke (2005) for spatial analysis of PGV from the 1994 Northridge earthquake.

GeoNet Strong-Motion Stations

Locations of the GeoNet strong-motion stations, extracted from the GeoNet DELTA database in June 2015.

References

Jeon, S.-S. and O'Rourke, T.D. (2005). Northridge earthquake effects on pipelines and residential buildings. *Bulletin of the Seismological Society of America*. 95(1):294-318

O'Rourke, T.D., Jeon, S.-S., Toprak, S., Cubrinovski, M. and Jung, J.K. (2012). Underground Lifeline System Performance during the Canterbury Earthquake Sequence, Proceedings of the 15th World Congress on Earthquake Engineering (15WCEE), Lisbon, Portugal, 24-28 Sep 2012

GeoNet DELTA application, accessed 5 June 2015, https://magma.geonet.org.nz/delta/app

Revisions

30 May 2013 – Initial release
30 June 2015 – Added GeoNet strong-motion station locations

Map Layer and Description	Reference	Published
Port Hills Mass Movements and Surface Deformations	CGD5180	30 October 2014

Description

Relative hazard exposure categories for slope stability and surface deformations for the GNS Science mapped mass movements within the Port Hills, Christchurch.

Methodology

The two map layers were created by the Christchurch City Council from an interpretation of the mass movement maps provided within the GNS Science series of reports on Port Hills Slope Stability and the report on the findings from investigations into areas of significant ground damage (see references below).

Final: Mass Movement Relative Hazard Exposure Categories

Boundaries for Class I and II mass movement areas derived from the GNS Science report series on Port Hills Slope Stability and from the Class II and III mass movement areas identified by GNS Science based on field mapping. These final versions of the superseded Stage 1 areas (described below) are based on detailed studies that considered what could trigger a landslide, how big it could be, where and how the land is likely to move and, crucially, the level of risk to people.

Stage 1: Mass Movement Surface Deformations

Cracks related to subsurface movement at 34 potential mass movement areas associated with the Canterbury Earthquake sequence were collected during fieldwork between 4 December 2010 and January 2013. Cracks were mapped during site walkover inspections, with an approximate accuracy of ±5 m. Both cracking (extension) and localised uplift (compression) were recorded in the field at all sites where safe, owner agreed, access was possible. Where crack extension was observed, the relative vertical and horizontal displacement across the crack was estimated to the nearest 0.01 m. Crack widths often varied spatially so the estimates are those considered as most representative of the entire crack length. Only the spatial extents were recorded for compression features. Only cracking considered to be related to subsurface ground movement was recorded in order to minimise the contribution of features such as localised foundation damage etc within the mass movement deformations.

Stage 1: (Superseded) Mass Movement Relative Hazard Exposure Categories

Superseded boundaries for mass movement areas identified by GNS Science based on field mapping and the combined areal extent of tensions cracks, compression zones and other mass-movement landforms. The total displacement of these areas was estimated to be greater than 0.1 m relative to its surrounding land. The boundaries have an approximate accuracy of ±10 m and only encompass areas where ground movement was identified during the mapping (October 2012 to January 2013). They do not include areas where debris could run-out down-slope (where the hazard would be debris inundation) or areas where movement and cracking could retrogress up-slope from the currently mapped limits.

Use limitations (all map layers)

The Stage 1 dataset was prepared by the Institute of Geological and Nuclear Sciences Limited (GNS Science) exclusively for and under contract to Christchurch City Council as part of GNS Science Consultancy Report 2012/317. That report considers the risk associated with geological hazards. As there is always uncertainty inherent within the nature of natural events, GNS Science gives no warranties of any kind concerning its assessment and estimates, including accuracy, completeness,

Map Layer and Description	Reference	Published

timeliness or fitness for purpose and accepts no responsibility for any actions taken based on, or reliance placed on them by any person or organisation other than Christchurch City Council. GNS Science excludes to the full extent permitted by law any liability to any person or organisation other than Christchurch City Council for any loss, damage or expense, direct or indirect, and however caused, whether through negligence or otherwise, resulting from any person or organisation's use of, or reliance on that report.

The information shown on the map layers is based on field mapping (with accuracy as indicated above). Some viewing software provides terrain exaggeration and background imagery with unspecified location accuracy, which can affect the apparent positions of features.

Only features apparent during the fieldwork were mapped and it should be noted that these features may change over time. For example, new cracks and areas of subsidence may appear and some cracks may disappear.

The cracking data presented represents all the available data from the site at the time of collection, which may be subject to change through time. Additional data may be collected during the on-going studies so the source database may change in the future as data is added or updated. It is strongly recommended that any future studies undertaken in these areas should include both a detailed site inspection to ensure an adequate understanding of the ground conditions and an assessment of potential change since the database mapping.

The mapped data should be used for information only.

References

C. I. Massey et al. (2014) Canterbury Earthquakes 2010/11 Port Hills Slope Stability, GNS Science Consultancy Reports 2014/34, 2014/67, 2014/73 and 2014/75 to 2014/79, August 2014, accessed 28 October 2014 from http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/porthillsgeotech/porthillsmassmovement.aspx

C.I. Massey, M.D. Yetton, J. Carey, B. Lukovic, N. Litchfield, W. Ries, G. McVerry (2012). Canterbury Earthquakes 2010/11 Port Hills Slope Stability: Stage 1 report on the findings from investigations into areas of significant ground damage (mass movements). GNS Science Consultancy Report 2012/317, 1 August 2012 FINAL accessed 29 May 2014 from http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/porthillsgeotech/porthillsgnsreports.aspx

Revisions

12 Jun 2014 – Initial release

30 Oct 2014 – Updated Port Hills Mass Movement Exposure category areas

Other Maps

Map Layer and Description	Reference	Published
Kiwirail chainage	NZGD6010	March 2015

Description

Network

Railway Locations/Stations (**Locations**): Railway network locations, stopping points, stations or yards. Active location points functioning on the rail network. Does not represent the actual location of any physical structure.

Bridges: Railway bridges, including structures over/under track. Represents centreline of bridge structure, represented as trace along MainLof track centreline (or centre of bridge for an overbridge)

Railway tunnels (**Tunnels**): Represents centreline of tunnel structure, represented as trace along MainLof track centreline.

KMPEGS: Kilometre posts or pegs depicting every full and half km (half km pegs are in Auckland and Wellington only). Represents Kilometre pegs located on Main Left track centreline, parallel to actual peg location

Track Asset

Track: All railway track, each segment representing an asset record in KiwiRails asset management database (Maximo), includes MainR, MainL, yards, sidings, loops, links and crossovers. Represents centreline of all track.

New Zealand Geotechnical Database - Map Layer NZGD6010 – 19/02/2018

Map Layer Revision History

Revision	Layer	Description of Change
01 Oct 2012	All	Initial Release
28 Sep 2012	CGD5090	Initial Release of Cadastral Boundaries (2010)
	CGD5100	Initial Release of Cadastral Maps (Historical)
	CGD5110	Initial Release of Conditional PGA for Liquefaction Assessment
	CGD5120	Initial Release of Geological Maps
	CGD5140	Initial Release of Hazard Maps
	CGD5150	Initial Release of Topographic Maps
20 Nov 2012	CGD0400	Revised line colours to provide better distinction between crack widths and added note indicating intention of colouring.

	CGD0040 CGD0045	Added additional MASW investigation lines to both CBD and suburban data sets
	CGD0800	Updated the free surface elevations using additional well observation data
	CGD5010 CGD5020	Updated zones and categories to reflect changes announced on 12 November
	CGD5080	Initial Release of Geotechnical map layers
	CGD5120	Added the "Canterbury and Westland Geology – 1866" layer
	CGD5150	Corrected the source attribution for the map
11 Feb 2013	CGD0200	Add a new layer showing liquefaction interpreted from the 4 Sept 2010 aerial photography
	CGD0300	Add a new layer showing the liquefaction and lateral spreading observed on roads following the 22 Feb 2011 earthquake
	CGD0800	Updated the free surface elevations using additional well observation data
	CGD5110	All PGA layers corrected and layers added for additional significant earthquakes
19 Feb 2013	CGD5110	Revised 11 Feb 2013 corrections for 22 Feb 2011 earthquake
21 Feb 2013	CGD5140	Added Environment Canterbury "Liquefaction Assessment Area Map" and two accompanying liquefaction observations maps
07 Mar 2013	CGD5160	Initial release of GNS Science Median Water Table Elevations
30 May 2013	CGD0050 CGD0055 CGD0060	Initial release of Geotechnical Investigation Analysis tools for Liquefaction Evaluation of CPT Investigations, CPT Layer Analysis and Depth of Refusal and Soil Behaviour Type Index (Ic)
	CGD5170	Initial release of Ground Motion maps
31 Jan 2014	CGD5010 CGD5020	Updated maps of CERA Residential Zoning and MBIE Residential Foundation Technical Categories resulting from zoning changes announced on 5 Dec 2013
12 Jun 2014	CGD5160 CGD0800 CGD5180	Added Version 2 of GNS Science Median Water Table Elevation map layers Updated Event Specific Surface Elevations to use revised CGD5160 Medians Initial release of Port Hills Mass Movements and Surface Deformations
30 Oct 2014	CGD5140 CGD5180	Added the 2013 liquefaction susceptibility map for the Timaru District Updated Port Hills Mass Movement Exposure category areas
30 Jun 2015	CGD0020 CGD0050 CGD0500 CGD5110 CGD5170	Added Laboratory test data and reports for EQC site investigations Improved the Geotechnical Investigation Analysis tools for Liquefaction Additional colour banded ranges and contours added for Sept 2011 DEM Added PGA observations at GeoNet strong-motion recording stations Added GeoNet strong-motion station locations
22 Sep 2016	CGD0300 CGD5110	Added observations from 14 Feb 2016 earthquake Added PGA and standard deviation contours from 14 Feb 2016 earthquake
24 Oct 2017	CGD5120 CGD5120 CGD5120	Removed Canterbury and Westland Geology – 1866 (replaced by QMAP) Added GNS Geological Map of New Zealand (QMAP) Added GNS Christchurch Urban Geological Units
19 Feb 2018	NZGD6010	Added Kiwirail chainage to supplementary data