Appendix A: Map outputs and descriptions

For maps sourced from the CGD, the accompanying descriptions and methodology have been copied from the CGD Map Layer Descriptions report (CGD, 2014).

List of maps:

Map 1 – LiDAR and digital elevation models

Map 2a – Vertical ground movements – Total ground movements

Map 2b – Vertical ground movement – deep-seated (tectonic) movements only

Map 2c – Vertical ground movements – Local (shallow) ground movements only

Map 3 – Port Hills mass movement and surface deformations

Map 4a – EQC liquefaction and lateral spreading observations – September 2010

Map 4b – EQC liquefaction and lateral spreading observations – February 2011

Map 4c – EQC liquefaction and lateral spreading observations – June 2011

Map 5 – MBIE residential foundation technical categories

Map 6 – MBIE Guidance areas of lateral ground movement

Map 7 – EQC observed ground crack locations

Map 8a – Horizontal ground movements – Total ground movements

Map 8b – Horizontal ground movements – deep-seated (tectonic) movements only

Map 8c – Horizontal ground movements – Local (shallow) ground movements only

- **Map 1 - LiDAR and digital elevation models**

Canterbury Geotechnical Database - Map Layer CGD0500 – 23/07/2012

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 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 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

Reference:

Canterbury Geotechnical Database (2012) "LiDAR and Digital Elevation Models", Map Layer CGD0500 - 23 July 2012, retrieved 10/02/15 from: https://canterburygeotechnicaldatabase.projectorbit.com/

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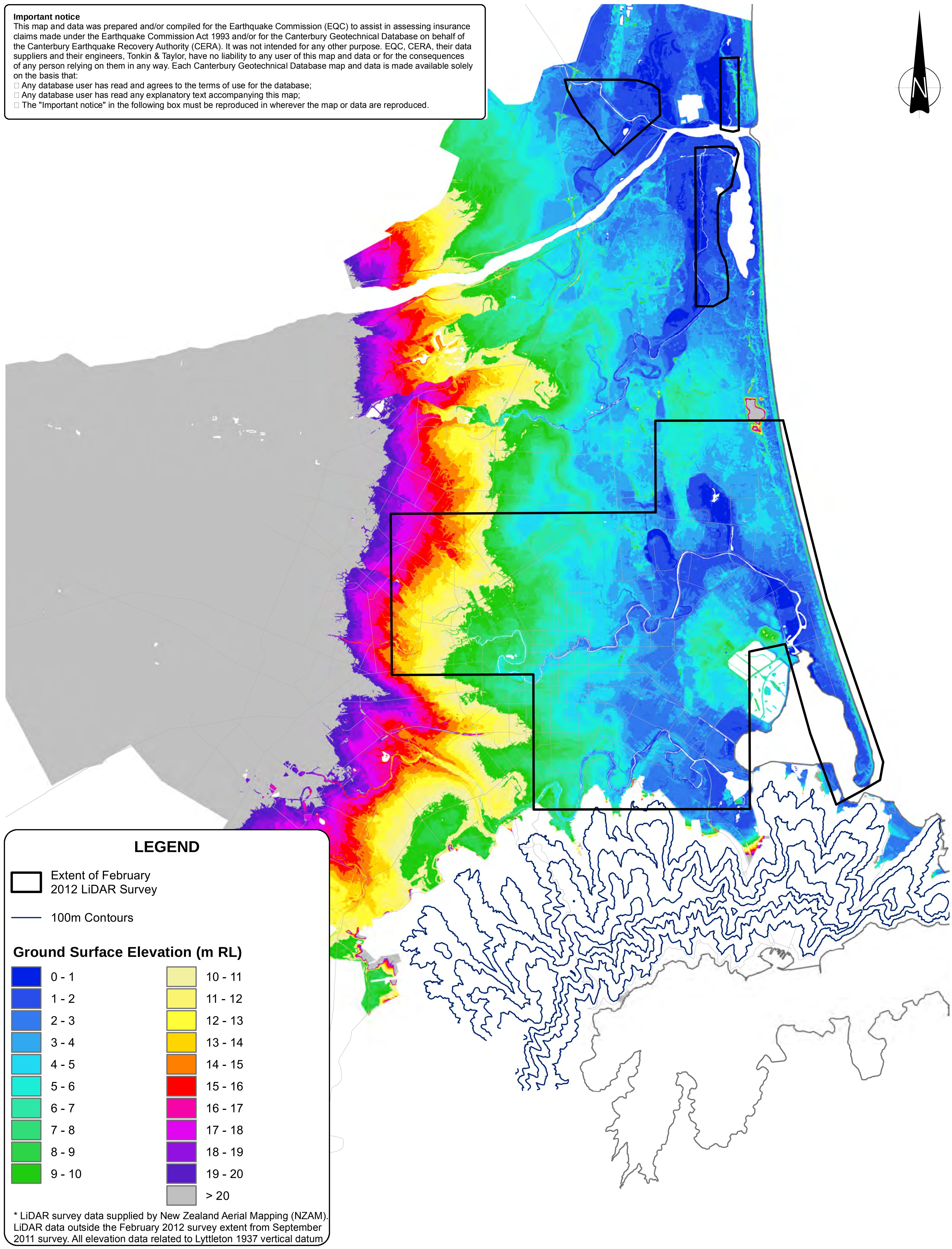

* LiDAR survey data supplied by New Zealand Aerial Mapping (NZAM). LiDAR data outside the February 2012 survey extent from September 2011 survey. All elevation data related to Lyttleton 1937 vertical datum

Notes: Road centerlines, Rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000
0 1 2 3 4 5 (km)

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ARCFILE Map Layer CGD0500		
SCALE (AT A3 SIZE) 1:100,000		
PROJECT No. 53708-000		

CANTERBURY GEOTECHNICAL DATABASE
EQC LiDAR and Digital Elevation Models
Pre September 2010 to Post December 2011

FIGURE No. Appendix A - Map 1

Rev. 0

- **Map 2 - Vertical ground movements (Map 2a, Map 2b, Map 2c)**

Canterbury Geotechnical Database - Map Layer CGD0600 – 23/07/2012

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.

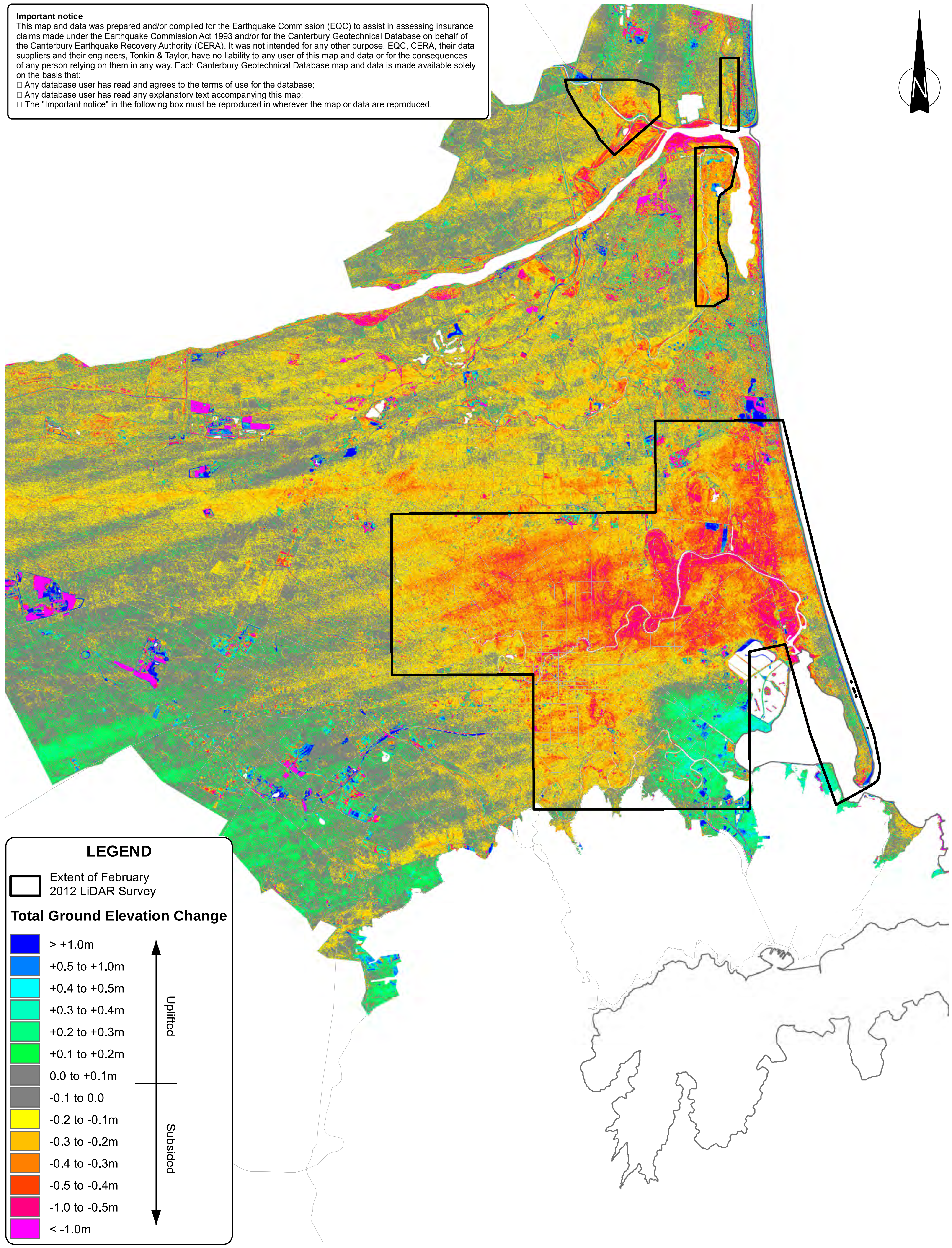
Local vertical movements were calculated as the differences between the 'observed' elevation differences and the associated tectonic models. These are presented as a third layer for each event combination.

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.

Reference:

Canterbury Geotechnical Database (2012) "Vertical Ground Surface Movements",
Map Layer CGD0600 - 23 July 2012, retrieved 10/02/15 from:

https://canterburygeotechnicaldatabase.projectorbit.com/



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000
0 1 2 3 4 5 (km)

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ARCFILE
Map Layer CGD0601
SCALE (AT A3 SIZE)
1:100,000
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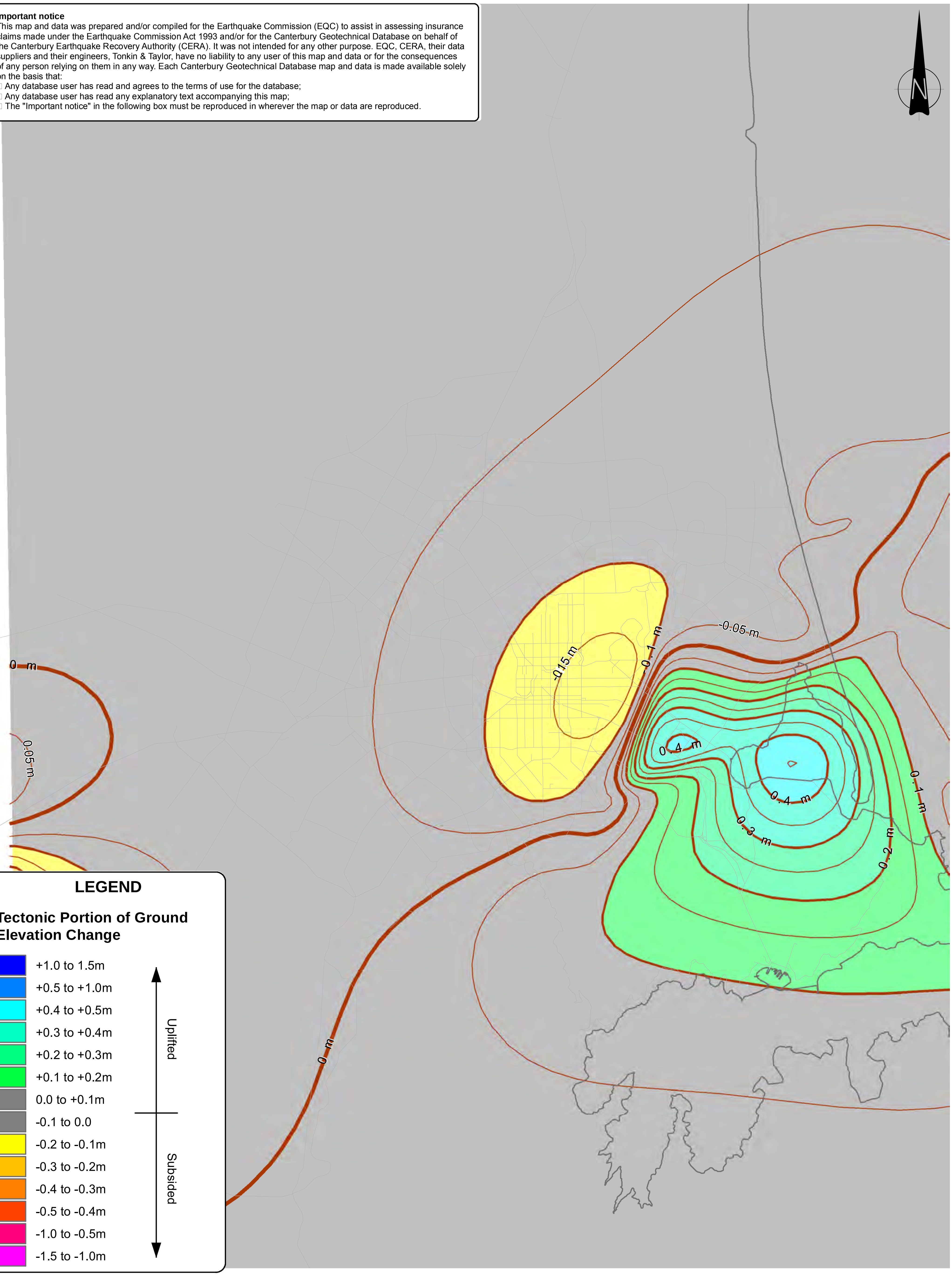
53708-000

CANTERBURY GEOTECHNICAL DATABASE
EQC Vertical Ground Movements
Total Cumulative Ground Elevation Change Due to the Canterbury Earthquakes

FIGURE No. Appendix A - Map 2a

Rev. 0

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD007.mxd Date: 24/03/2015 Time: 5:00:21 p.m.



LEGEND

Tectonic Portion of Ground Elevation Change

- +1.0 to 1.5m
- +0.5 to +1.0m
- +0.4 to +0.5m
- +0.3 to +0.4m
- +0.2 to +0.3m
- +0.1 to +0.2m
- 0.0 to +0.1m
- -0.1 to 0.0
- -0.2 to -0.1m
- -0.3 to -0.2m
- -0.4 to -0.3m
- -0.5 to -0.4m
- -1.0 to -0.5m
- -1.5 to -1.0m

Uplifted

Subsided

Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE Map Layer CGD0602

SCALE (AT A3 SIZE) 1:100,000

PROJECT No. 53708-000

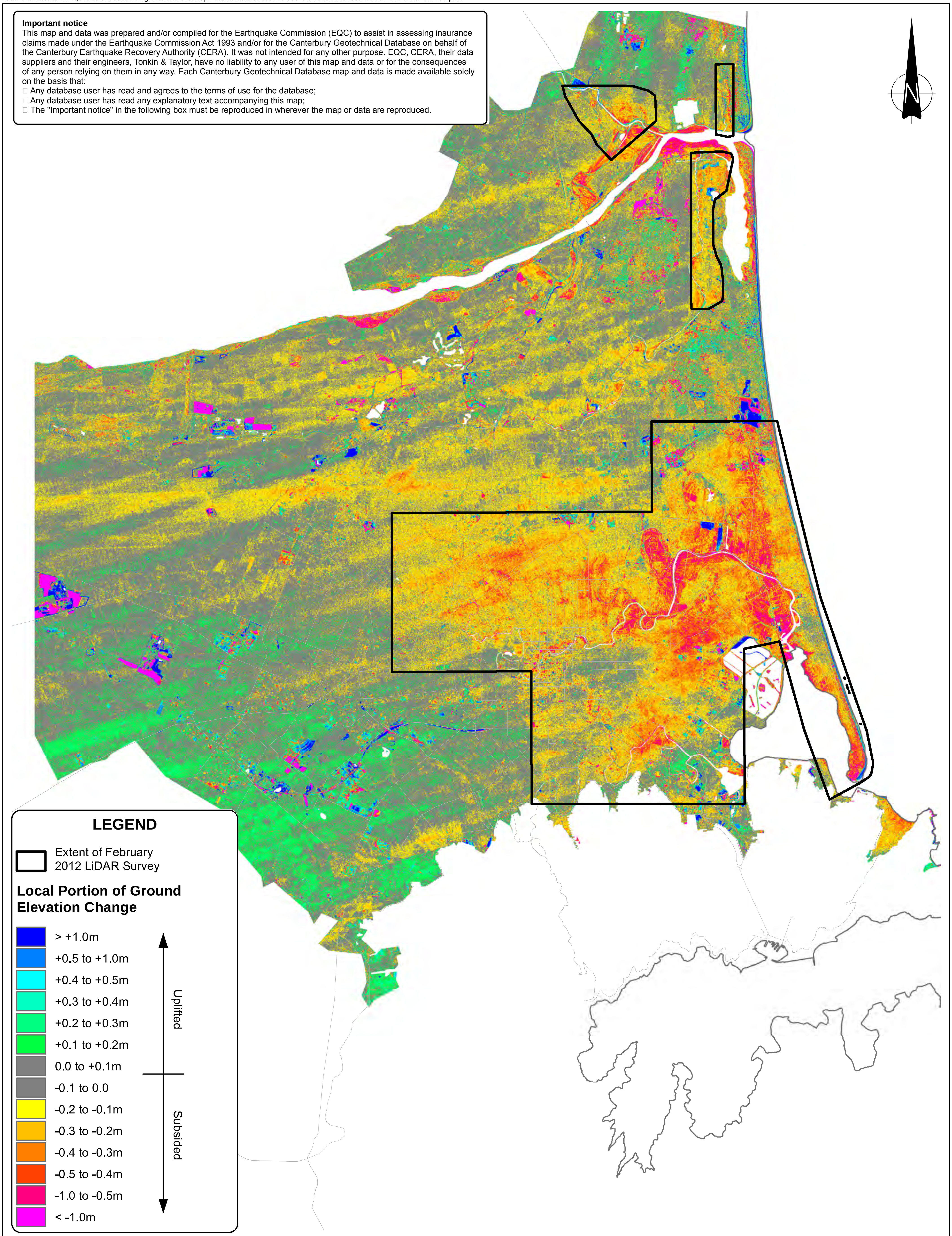
CANTERBURY GEOTECHNICAL DATABASE

EQC Vertical Ground Movements

Deep-seated (Tectonic) Portion of Cumulative Ground Elevation Change Due to the Canterbury Earthquakes

FIGURE No. Appendix A - Map 2b

Rev. 0



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD0603

SCALE (AT A3 SIZE): 1:100,000

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CANTERBURY GEOTECHNICAL DATABASE

EQC Vertical Ground Movements
Local (shallow) Portion of Cumulative Ground Elevation Due to the Canterbury Earthquakes

FIGURE No.: Appendix A - Map 2c

Rev. 0

- **Map 3 - Port Hills mass movement and surface deformations**

Canterbury Geotechnical Database - Map Layer CGD5180 - 30/10/2014

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 ground 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 location accuracy of ±5 m. Both cracking (extension) and localised uplift (contraction) were recorded in the field at all sites where safe, owner agreed, access was possible. Where crack extension was observed, the maximum 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 contraction 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 within the mass movement deformations.

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

Superseded boundaries for mass movement areas that were identified by GNS Science based on field mapping and the combined areal extent of tensions cracks, contraction zones and other mass-movement landforms. The total movement of these areas was estimated to be greater than 0.1 m relative to its surrounding ground. 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, 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

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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

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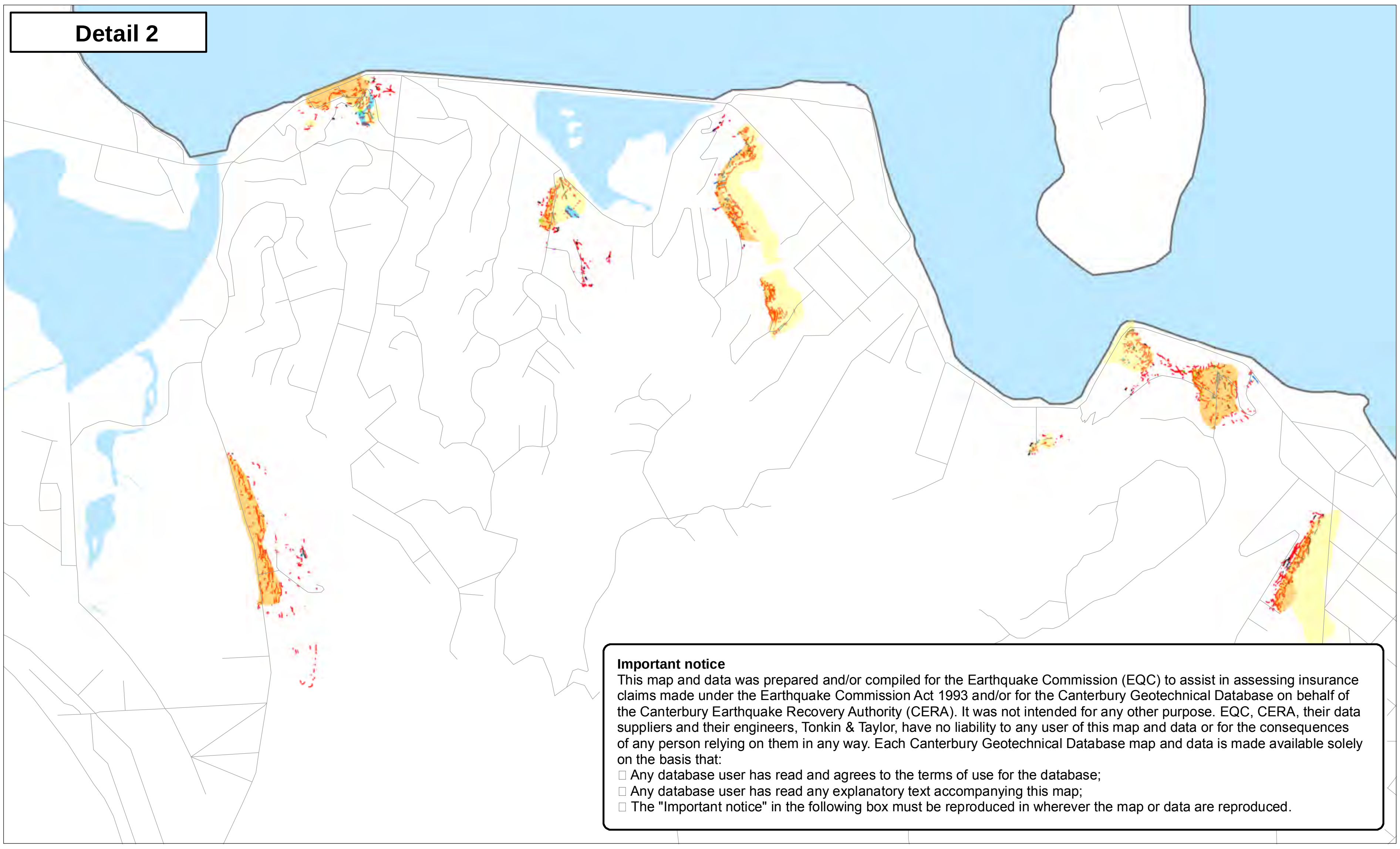

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LEGEND

Relative Hazard Exposure Categories

- CLASS I
- CLASS II
- CLASS III

Surface Deformations

- Tension crack
- Complex zone of cracking
- Subsidence
- Compression zone
- Tunnel gully
- Tilted or deformed retaining wall/fence
- Spring

Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:20,000

0 0.2 0.4 0.6 0.8 1 (km)

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ARCFILE Map Layer CGD5180

SCALE (AT A3 SIZE) 1:20,000

PROJECT No. 53708-000

CANTERBURY GEOTECHNICAL DATABASE
Port Hills Mass Movements and Surface Deformations

FIGURE No. Appendix A - Map 3

Rev. 0

- **Map 4 – EQC liquefaction and lateral spreading observations (Map 4a, Map 4b, Map 4c)**

Canterbury Geotechnical Database - Map Layer CGD0300 – 11/02/2013

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 ground 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.

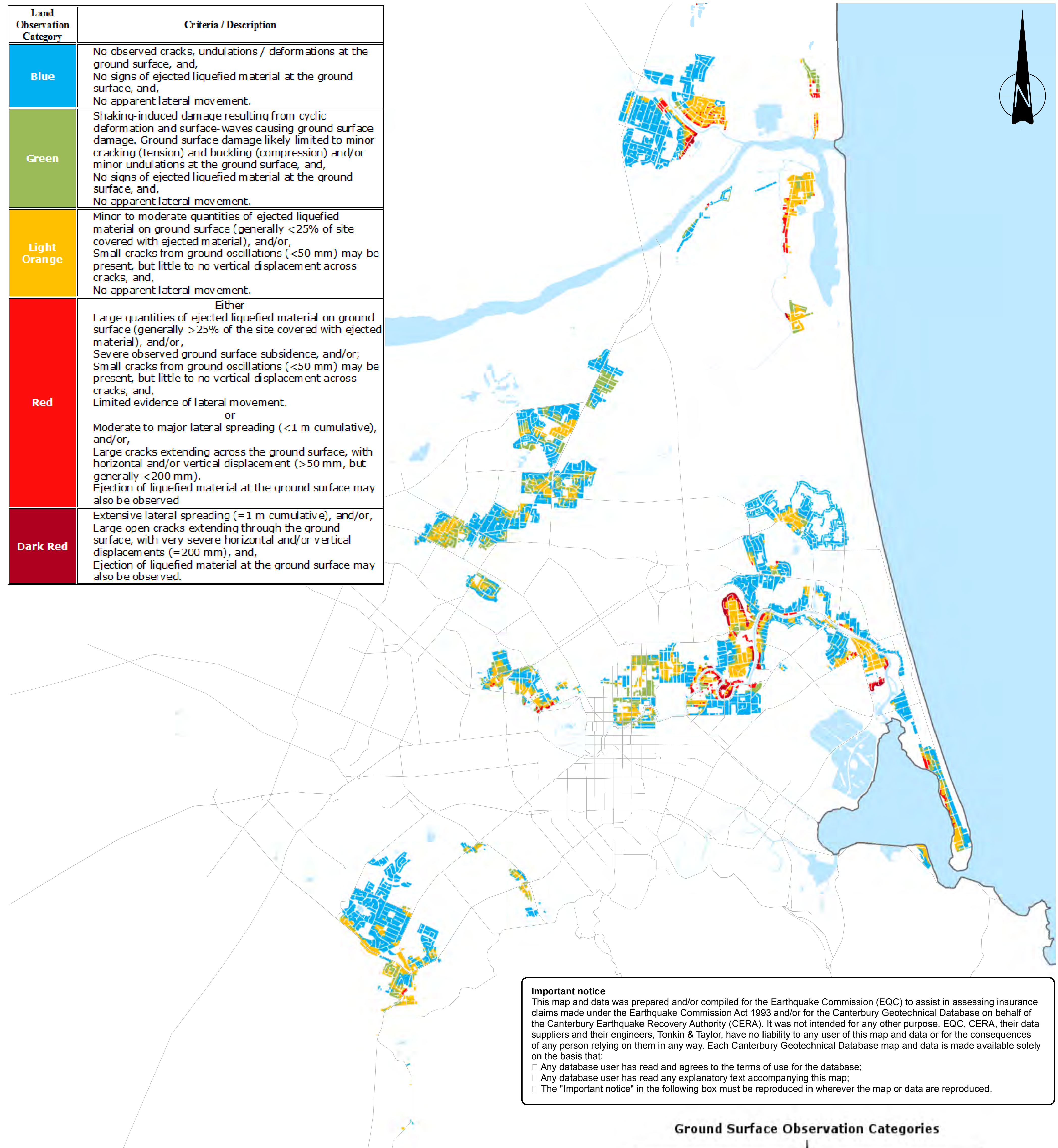
Revisions

01 Oct 2012 – Initial release

Reference:

Canterbury Geotechnical Database (2013) "Liquefaction and Lateral Spreading Observations", Map Layer CGD0300 - 11 Feb 2013, retrieved 10/02/12 from: https://canterburygeotechnicaldatabase.projectorbit.com/

Land Observation Category	Criteria / Description
Blue	No observed cracks, undulations / deformations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Green	Shaking-induced damage resulting from cyclic deformation and surface-waves causing ground surface damage. Ground surface damage likely limited to minor cracking (tension) and buckling (compression) and/or minor undulations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Light Orange	Minor to moderate quantities of ejected liquefied material on ground surface (generally <25% of site covered with ejected material), and/or, Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, No apparent lateral movement.
Red	Either Large quantities of ejected liquefied material on ground surface (generally >25% of the site covered with ejected material), and/or, Severe observed ground surface subsidence, and/or; Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, Limited evidence of lateral movement. or Moderate to major lateral spreading (<1 m cumulative), and/or, Large cracks extending across the ground surface, with horizontal and/or vertical displacement (>50 mm, but generally <200 mm). Ejection of liquefied material at the ground surface may also be observed
Dark Red	Extensive lateral spreading (=1 m cumulative), and/or, Large open cracks extending through the ground surface, with very severe horizontal and/or vertical displacements (=200 mm), and, Ejection of liquefied material at the ground surface may also be observed.



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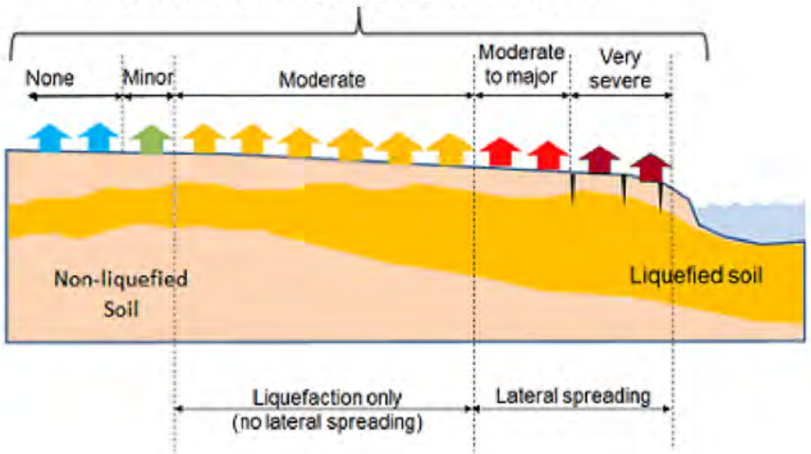
Ground Surface Observation Categories



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE Map Layer CGD0301		
SCALE (AT A3 SIZE) 1:100,000		
PROJECT No. 53708-000		

CANTERBURY GEOTECHNICAL DATABASE

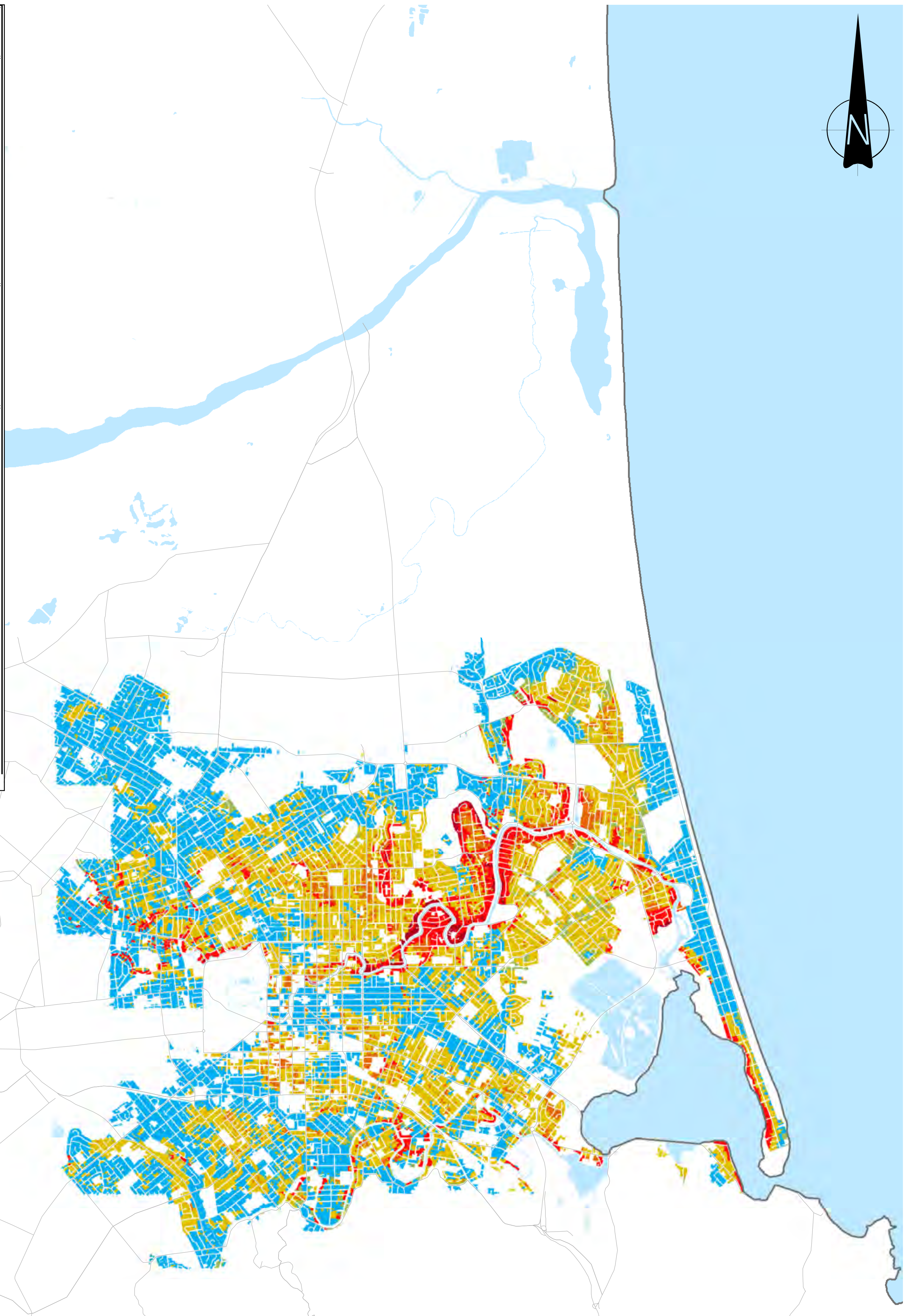
EQC Liquefaction and Lateral Spreading Observations September 2010 Property Observations

FIGURE No. Appendix A - Map 4a

Rev. 0

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD003.mxd Date: 24/03/2015 Time: 5:07:29 p.m.

Land Observation Category	Criteria / Description
Blue	No observed cracks, undulations / deformations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Green	Shaking-induced damage resulting from cyclic deformation and surface-waves causing ground surface damage. Ground surface damage likely limited to minor cracking (tension) and buckling (compression) and/or minor undulations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Light Orange	Minor to moderate quantities of ejected liquefied material on ground surface (generally <25% of site covered with ejected material), and/or, Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, No apparent lateral movement.
Dark Orange	Large quantities of ejected liquefied material on ground surface (generally >25% of the site covered with ejected material), and/or, Severe observed ground surface subsidence, and/or; Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, Limited evidence of lateral movement.
Red	Moderate to major lateral spreading (<1 m cumulative), and/or, Large cracks extending across the ground surface, with horizontal and/or vertical displacement (>50 mm, but generally <200 mm). Ejection of liquefied material at the ground surface may also be observed
Dark Red	Extensive lateral spreading (=1 m cumulative), and/or, Large open cracks extending through the ground surface, with very severe horizontal and/or vertical displacements (=200 mm), and, Ejection of liquefied material at the ground surface may also be observed



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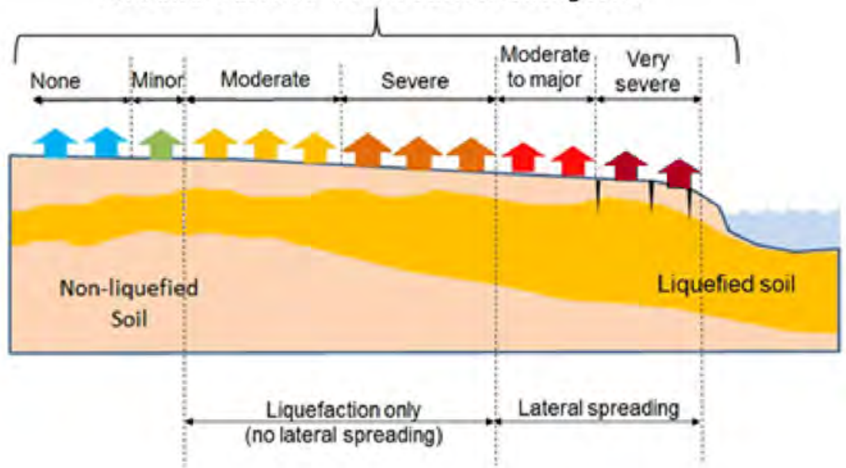
Ground Surface Observation Categories



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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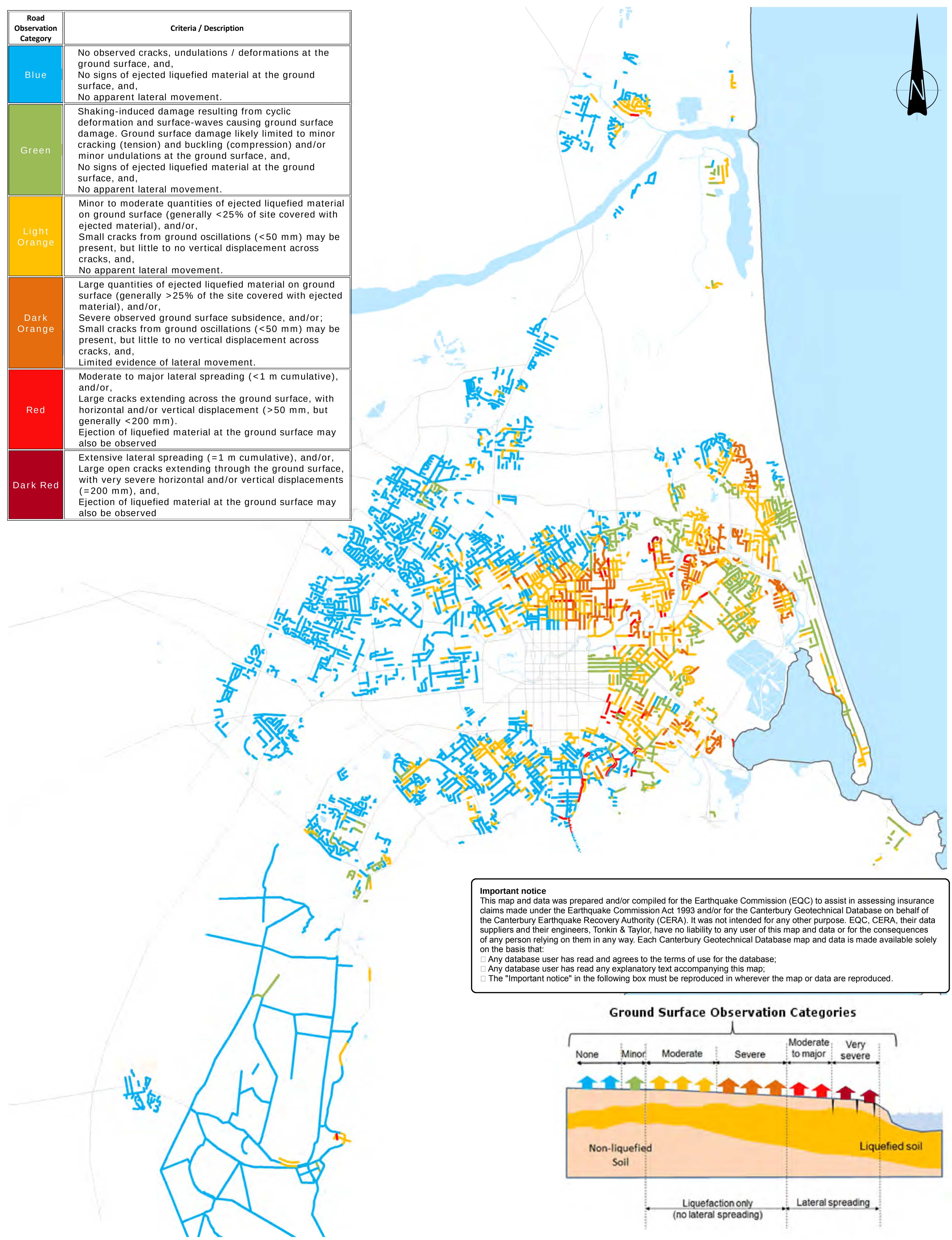
ARCFILE Map Layer CGD0302		
SCALE (AT A3 SIZE) 1:100,000		
PROJECT No. 53708-000		

CANTERBURY GEOTECHNICAL DATABASE
EQC Liquefaction and Lateral Spreading Observations
February 2011 Property Observations

FIGURE No. Appendix A - Map 4b

Rev. 0

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD004.mxd Date: 24/03/2015 Time: 5:08:46 p.m.



Road Observation Category	Criteria / Description
Blue	No observed cracks, undulations / deformations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Green	Shaking-induced damage resulting from cyclic deformation and surface-waves causing ground surface damage. Ground surface damage likely limited to minor cracking (tension) and buckling (compression) and/or minor undulations at the ground surface, and, No signs of ejected liquefied material at the ground surface, and, No apparent lateral movement.
Light Orange	Minor to moderate quantities of ejected liquefied material on ground surface (generally <25% of site covered with ejected material), and/or, Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, No apparent lateral movement.
Dark Orange	Large quantities of ejected liquefied material on ground surface (generally >25% of the site covered with ejected material), and/or, Severe observed ground surface subsidence, and/or; Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, Limited evidence of lateral movement.
Red	Moderate to major lateral spreading (<1 m cumulative), and/or, Large cracks extending across the ground surface, with horizontal and/or vertical displacement (>50 mm, but generally <200 mm). Ejection of liquefied material at the ground surface may also be observed
Dark Red	Extensive lateral spreading (=1 m cumulative), and/or, Large open cracks extending through the ground surface, with very severe horizontal and/or vertical displacements (=200 mm), and, Ejection of liquefied material at the ground surface may also be observed

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Ground Surface Observation Categories

Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD0303
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CANTERBURY GEOTECHNICAL DATABASE
EQC Liquefaction and Lateral Spreading Observations
June 2011 Road Observations

FIGURE No.: Appendix A - Map 4c

Rev. 0

- **Map 5 - MBIE residential foundation technical categories**

Canterbury Geotechnical Database - Map Layer CGD5020 - 30/01/2014

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 from liquefaction effects are expected to be within normally accepted tolerances. Once the TC is confirmed, shallow geotechnical investigations may be required (depending on the degree of damage, and in particular for a rebuild). If the 'good ground' test is met, NZS 3604 foundations (as modified by B1/AS1) can be used.

Technical Category 2 (TC2)

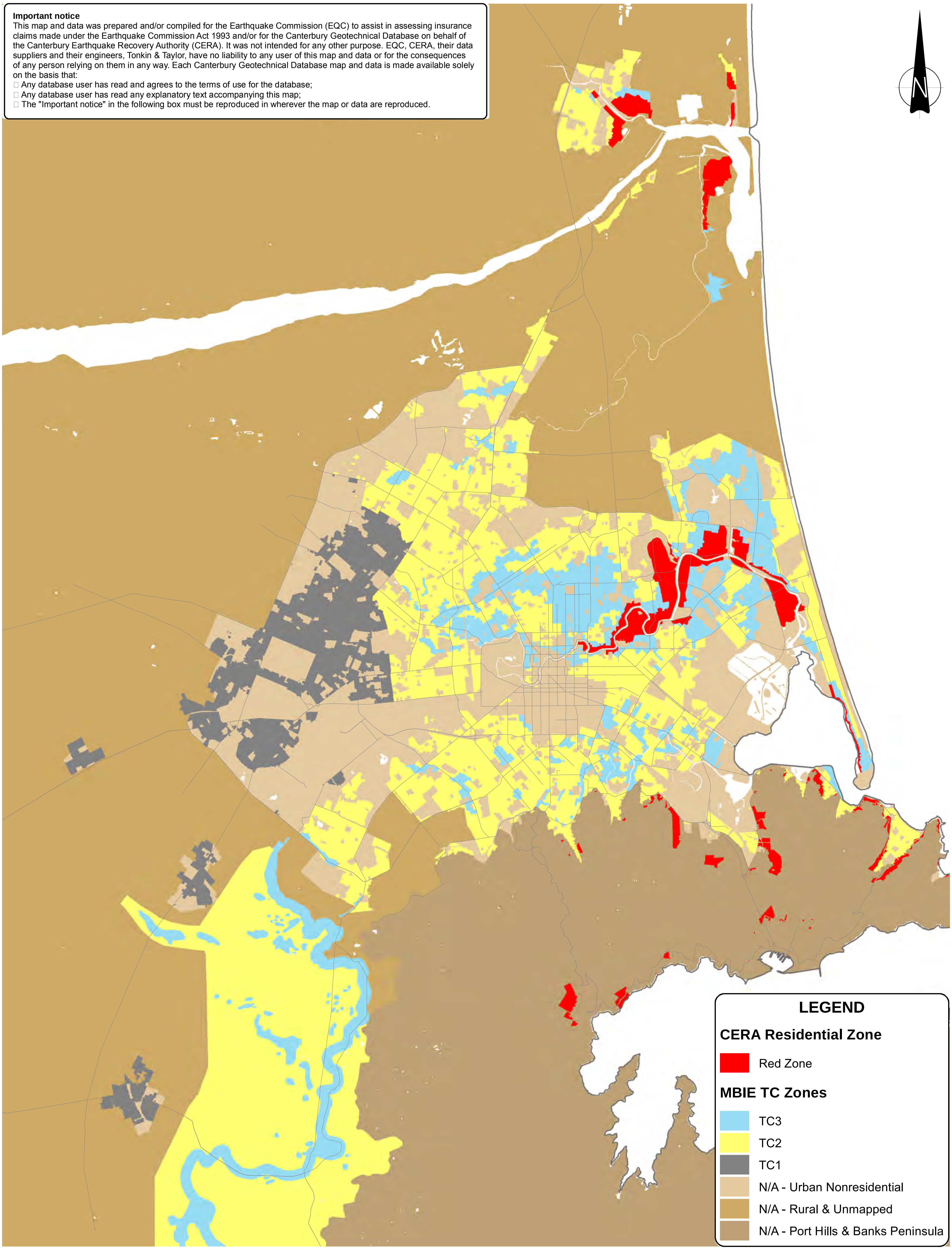
Liquefaction damage is possible in future large earthquakes. Once the TC is confirmed, shallow geotechnical investigations may be required (depending on the degree of damage, and in particular for a rebuild) and, subject to establishing minimum bearing capacities, suspended timber floor or enhanced slab foundation options per section 5 can be used.

Technical Category 3 (TC3)

Liquefaction damage is possible in future large earthquakes. Deep geotechnical investigation (or assessment of existing information) may be required (depending on the degree of damage, and in particular for a rebuild) and depending on the geotechnical assessment, might require specific engineering input for foundations.

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.



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY. MBIE TC Zones supplied by MBIE, last updated 5 December 2013

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD5020

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PROJECT No.: 53708-000

CANTERBURY GEOTECHNICAL DATABASE

MBIE Residential Foundation Technical Categories

Updated 5 December 2013

FIGURE No.: Appendix A - Map 5

Rev. 0

- **Map 6 - MBIE areas of lateral ground movement & CCC Rivers and Catchments**

This map output was created based directly on Section 12.2 of the MBIE Residential Foundation Guidelines (MBIE, 2012).

As part of the MBIE guidance, advice was provided to engineers to assist in the assessment of whether a site was likely to have experienced a major degree of lateral ground movement or ground stretching in the CES. Section 12.2 of the MBIE guidance provides an initial screening tool for two different horizontal movement mechanisms:

- **Lateral spreading adjacent to rivers**: The guidance defines setback distances from the main rivers and waterways across greater Christchurch.
- **Area-wide ground stretching**: The guidance defines two geographical areas within New Brighton and Wainoni, where evidence of area-wide ground stretching was observed due to the CES.

For properties beyond these defined areas, the guidance indicates that only "Minor to Moderate" lateral spreading is likely to have occurred during the CES, unless there is visible evidence to the contrary. "Minor to Moderate" is defined in the guidance as global lateral movement less than 300mm, and lateral stretch of the ground across a building footprint of less than 200mm.

The MBIE guidance does not suggest that all properties within the defined area have experienced major lateral spreading or ground stretching – indeed many will have experienced none at all. The guidance simply requires that engineers designing new foundations within this area undertake a more detailed assessment to consider the potential for lateral ground movements in future.

The light purple areas on the map illustrate the setback distances from the main rivers and waterways defined in the MBIE guidance, as reproduced in Table A1 below. This only covers the main waterways – there are other smaller waterways and steep changes in ground level not identified on this map which should also be considered when assessing the potential for lateral ground movements to occur.

The dark purple areas on the map illustrate the areas of area-wide ground stretching defined in the MBIE guidance, as reproduced in Table A2 below.

Table A1: Distance from free edge beyond which minor to moderate global lateral ground movement can be assumed in TC3 (excluding areas in Table A2), in the absence of any evidence to the contrary (from MBIE, 2012 - Table 12.3, pg. 12.4).

Location	Distance
Avon River, downstream of Banks Ave (including estuary)	200 m
Avon River, between Barbadoes St and Banks Ave	150 m
Avon River, between Mona Vale and Barbadoes St	100 m
Heathcote River, downstream of Colombo St	100 m
Dudley Creek and tributaries, east of Hills Rd	100 m
All other significant waterways and steep changes in ground level	50 m

Table A2: Areas of major global lateral ground movements identified within TC3 to date (from MBIE, 2012 - Table 12.2, pg. 12.4)

North New Brighton – All TC3 properties east of Anzac Drive, South of Queenspark Drive, and North of New Brighton Rd.
Wainoni – All TC3 properties within the area bounded by Wainoni Rd, Shortland St, Pages Rd, Kearneys Rd, Cypress St, Ruru Rd, McGregors Rd, Pages Rd and Cuffs Rd.

References

MBIE (2012) Repairing and rebuilding houses affected by the Canterbury earthquakes. Version 3, December 2012.

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD008.mxd Date: 24/03/2015 Time: 5:13:21 p.m.

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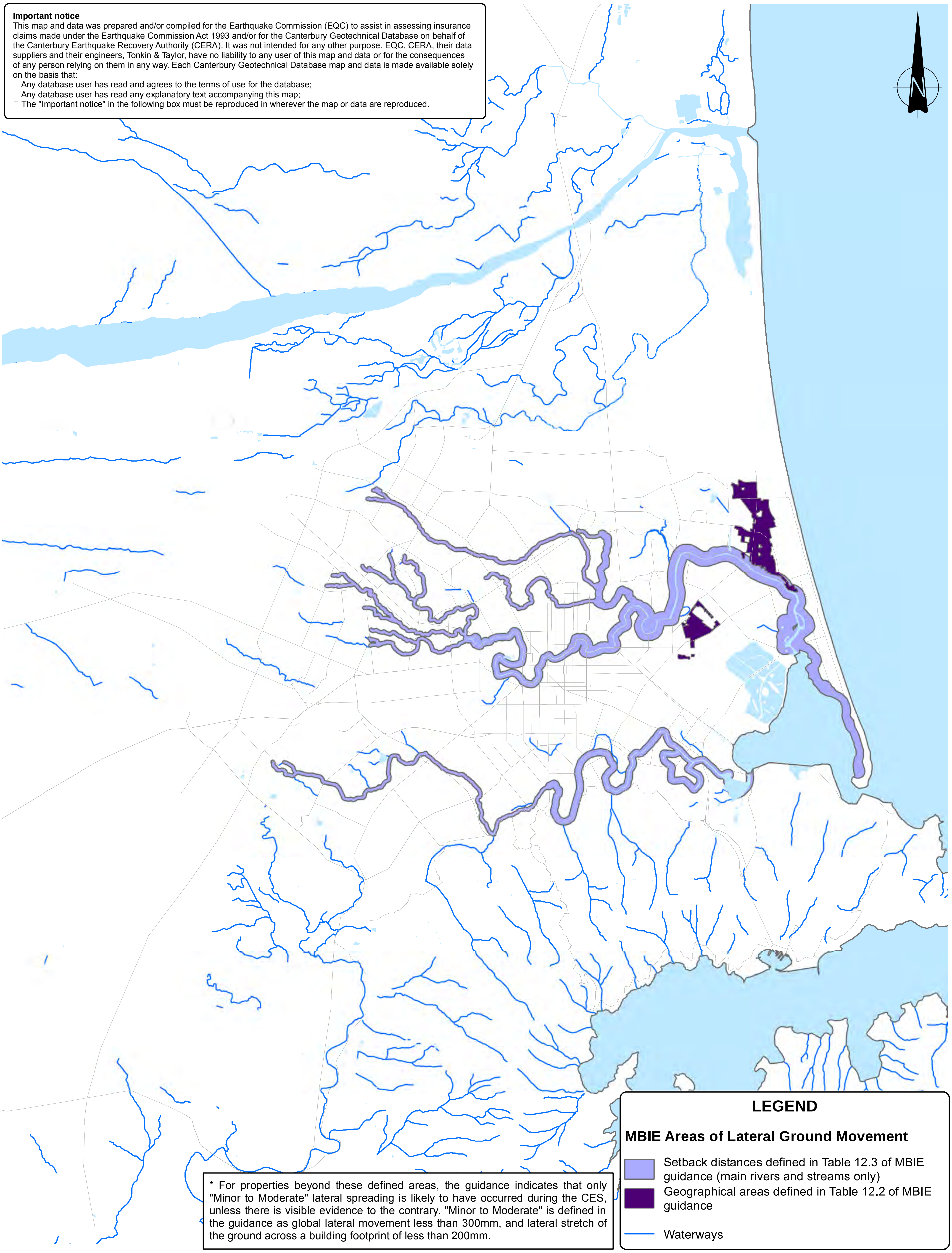

LEGEND

MBIE Areas of Lateral Ground Movement

- Setback distances defined in Table 12.3 of MBIE guidance (main rivers and streams only)
- Geographical areas defined in Table 12.2 of MBIE guidance
- Waterways

* For properties beyond these defined areas, the guidance indicates that only "Minor to Moderate" lateral spreading is likely to have occurred during the CES, unless there is visible evidence to the contrary. "Minor to Moderate" is defined in the guidance as global lateral movement less than 300mm, and lateral stretch of the ground across a building footprint of less than 200mm.

Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY. Indicative lateral ground movement defined as described within Tables 12.2 and 12.3 of the MBIE Guidance: Repairing and rebuilding houses affected by the Canterbury earthquakes. Waterways data sourced from Christchurch City Council.

A3 SCALE 1:100,000
0 1 2 3 4 5 (km)

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CANTERBURY GEOTECHNICAL DATABASE
MBIE Guidance Areas of Lateral Ground Movement
Tables 12.2 and 12.3 of the MBIE Guidance: Repairing and Rebuilding Houses Affected by the Canterbury Earthquakes

FIGURE No. Appendix A - Map 6
Rev. 0

- ## Map 7 - EQC observed ground crack locations

Canterbury Geotechnical Database - Map Layer CGD0400 – 23/07/2012

Description

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

Methodology

Crack locations were mapped in order to infer the general direction, scale 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 caused by 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.

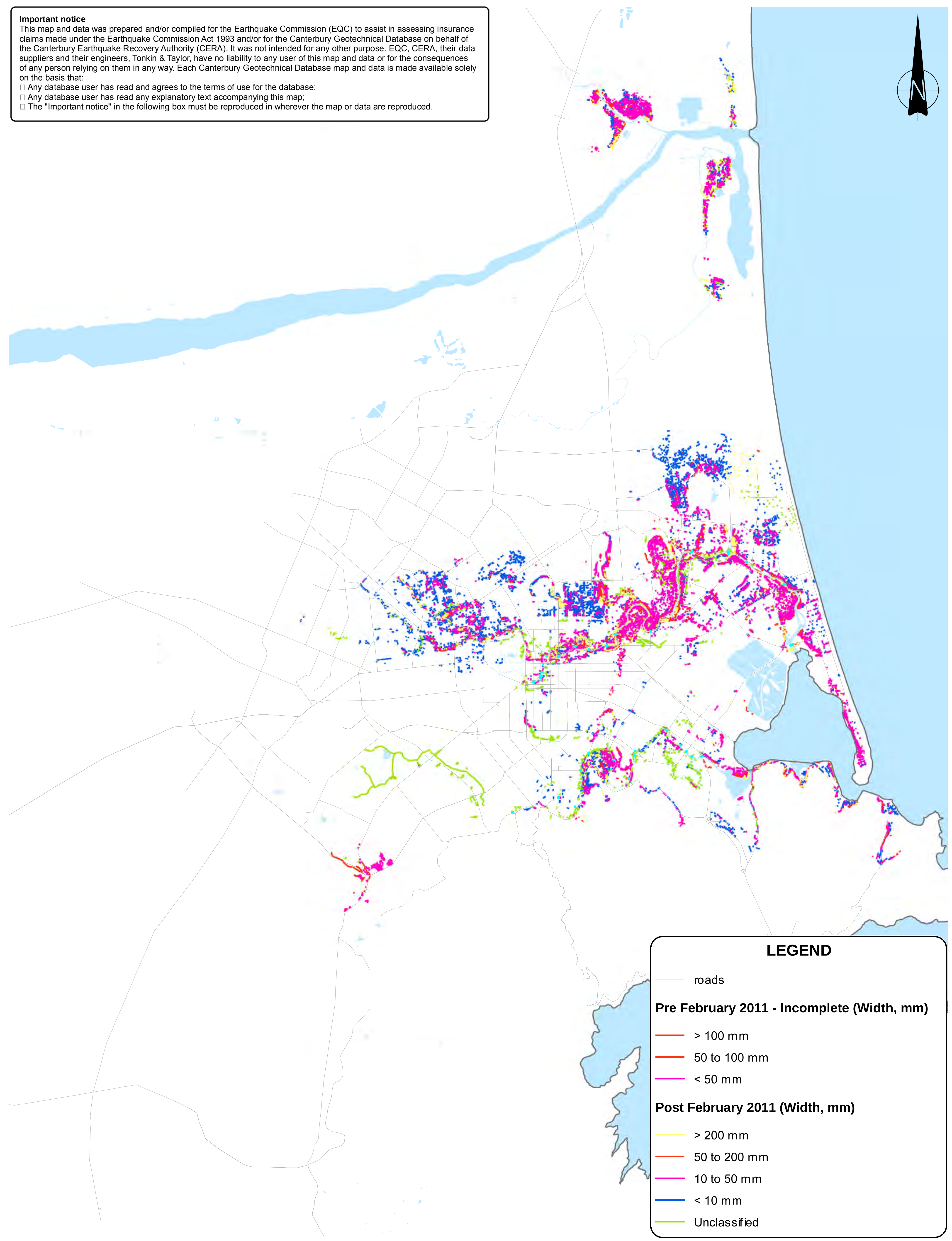
Colours for the 50 to 200 mm crack widths are similar for both sets of data to provide an overview of the spreading rather than to provide a comparison between earthquakes. (The colours can be changed by the user if required.)

Reference:

Canterbury Geotechnical Database (2012) "Observed Ground Crack Locations",
Map Layer CGD0400 - 23 July 2012, retrieved 10/02/15 from:

https://canterburygeotechnicaldatabase.projectorbit.com/

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD009.mxd Date: 24/03/2015 Time: 5:14:53 p.m.



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD0400
SCALE (AT A3 SIZE): 1:100,000
PROJECT No.: 53708-000

CANTERBURY GEOTECHNICAL DATABASE
EQC Observed Ground Crack Locations
Post 4th September 2010 and 22nd February 2011

FIGURE No.: Appendix A - Map 7

Rev. 0

- **Map 8 – Horizontal ground movements (Map 8a, Map 8b, Map 8c)**

Canterbury Geotechnical Database - Map Layer CGD0700 – 23/07/2012

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 extent 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.

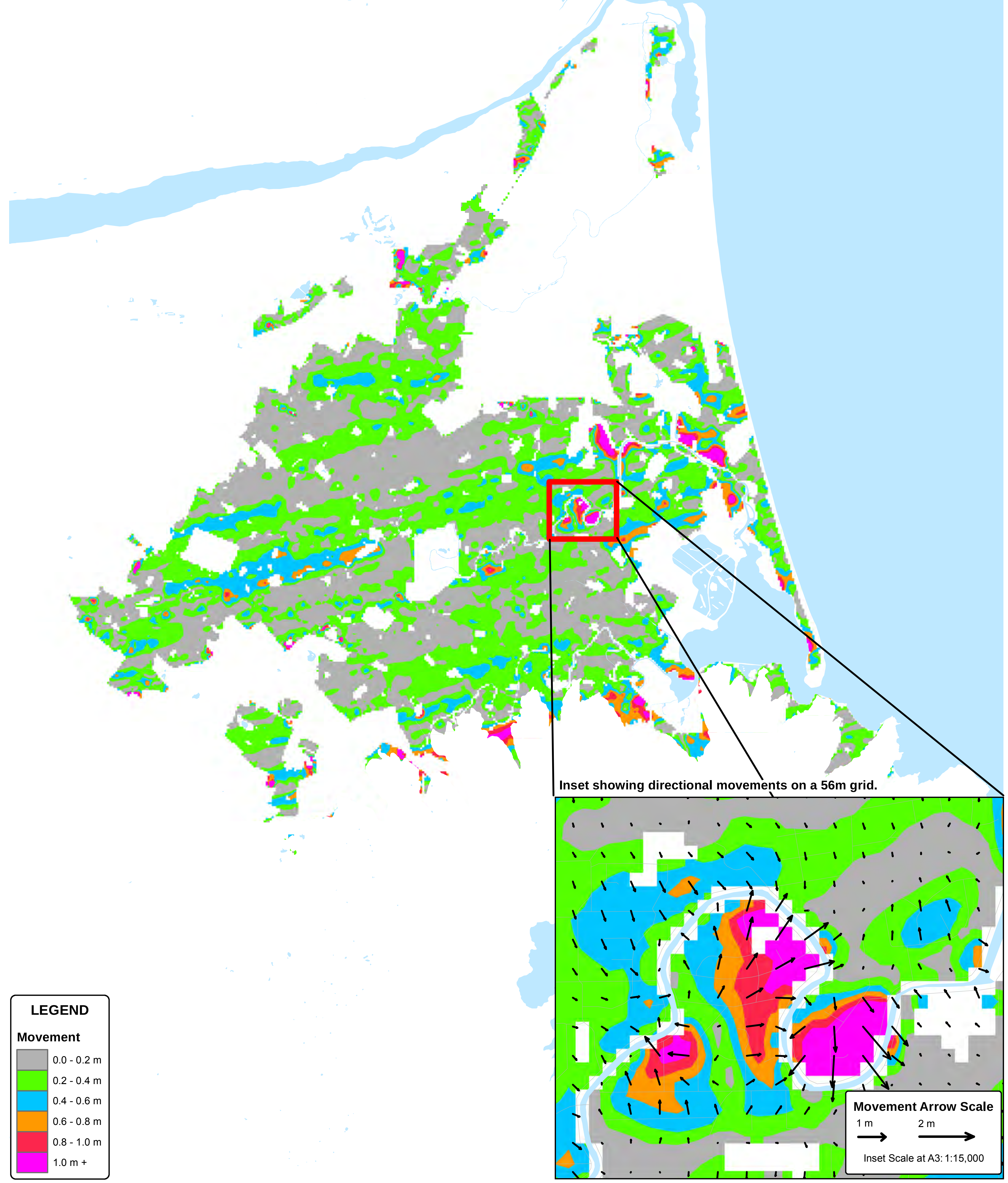
"Local" horizontal deformations were calculated as the differences between the 'observed' movements and the associated tectonic models. These are presented as a third layer for each event combination.

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.

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.

Canterbury Geotechnical Database (2012) "Horizontal Ground Movements", Map Layer CGD0700 - 23 July 2012, retrieved 10/02/15 from: https://canterburygeotechnicaldatabase.projectorbit.com/



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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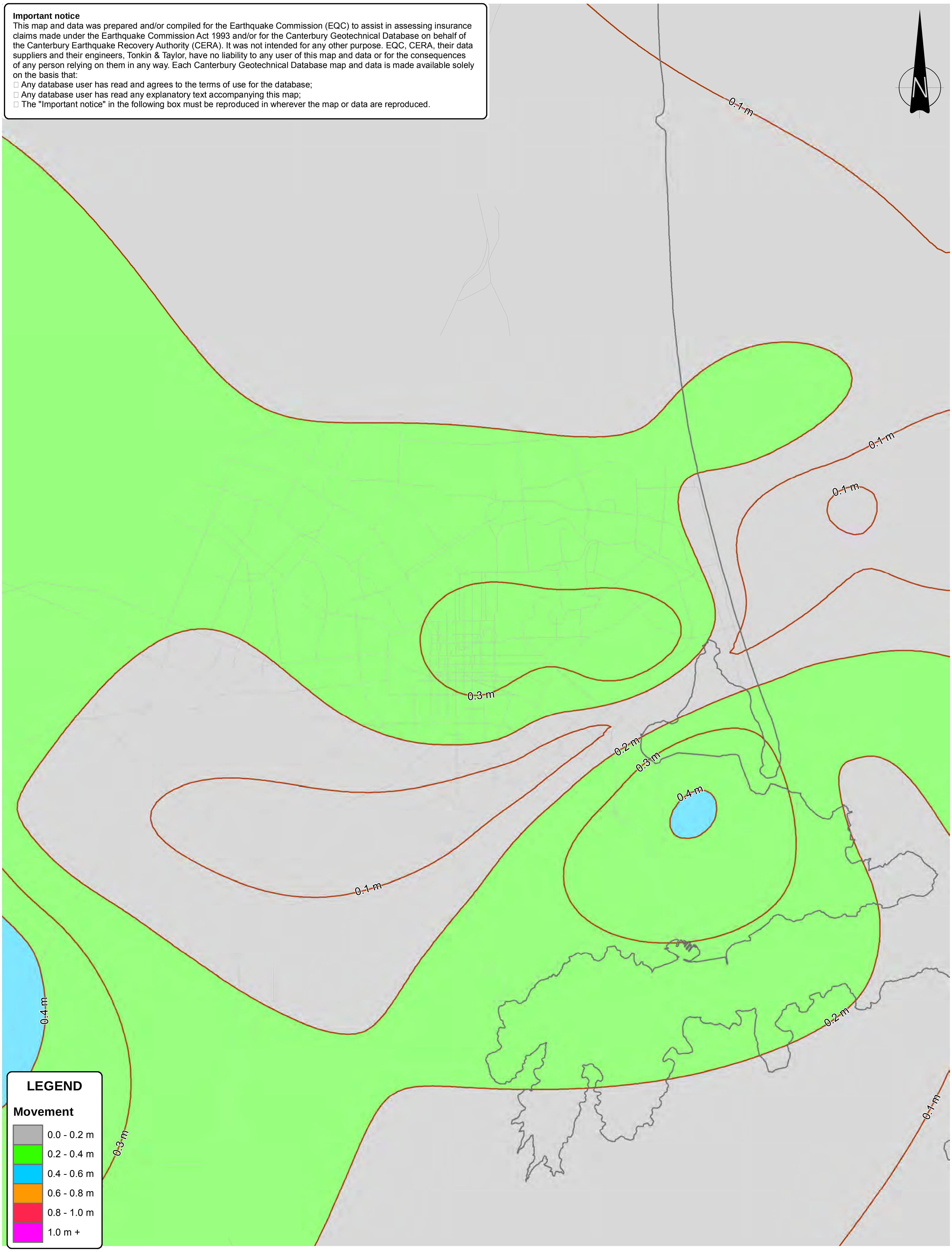
CANTERBURY GEOTECHNICAL DATABASE

EQC Horizontal Ground Surface Movements

Total Cumulative Horizontal Ground Displacement Between Jul-2003 and Sep-2011 (Inferred from LiDAR Analysis)

FIGURE No. Appendix A - Map 8a

Rev.



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD0702

SCALE (AT A3 SIZE): 1:100,000

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CANTERBURY GEOTECHNICAL DATABASE

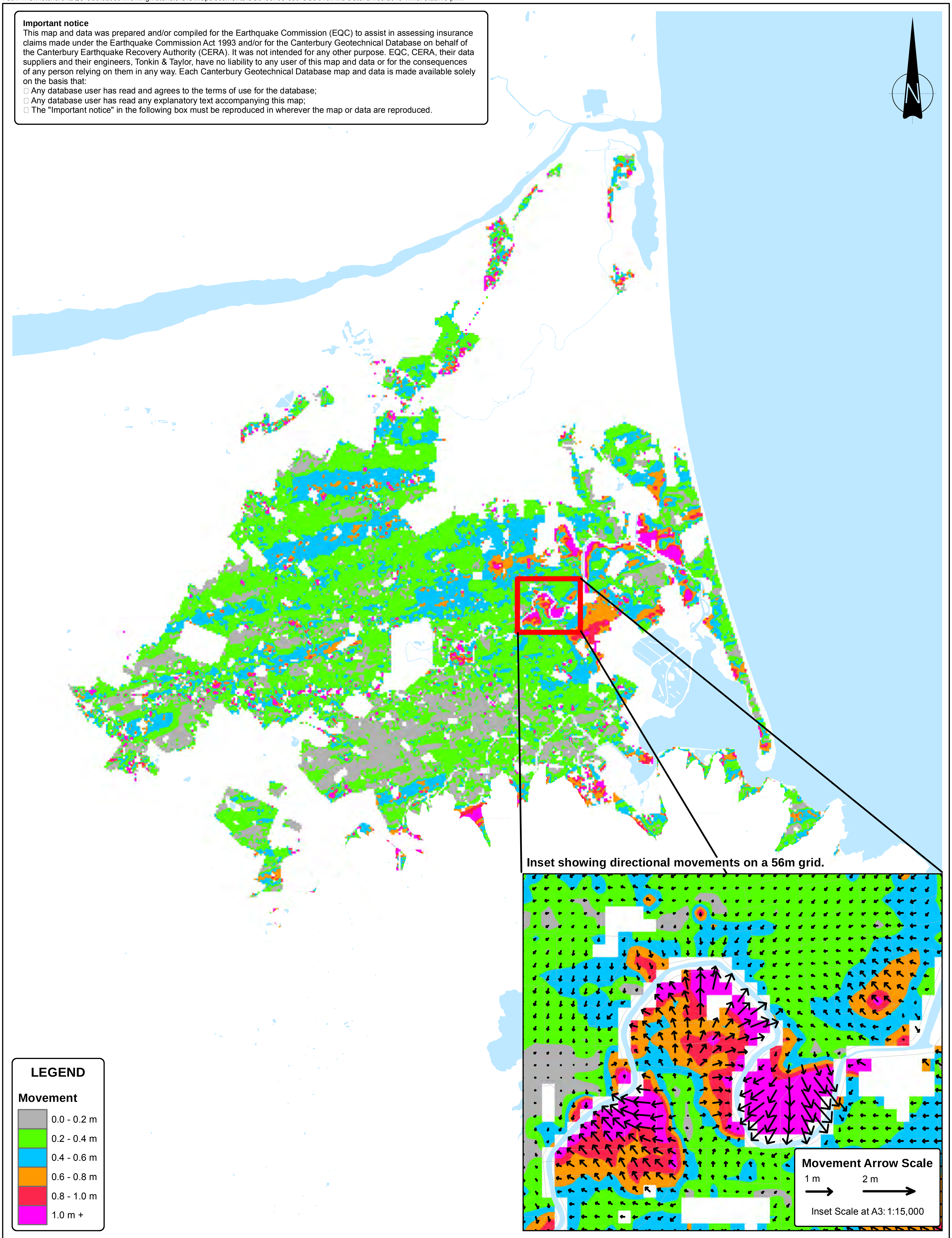
EQC Horizontal Ground Surface Movements

Deep-seated (Tectonic) Portion of Cumulative Ground Displacement Between Jul-2003 and Sep-2011 (from GNS Tectonic Model)

FIGURE No.: Appendix A - Map 8b

Rev.

Path: T:\ChristchurchEQC\Cad\52000\WorkingMaterials\GIS\MapDocuments\CGD\53708-000-CGD015.mxd Date: 24/03/2015 Time: 5:22:15 p.m.



Notes: Road centerlines, rivers, lagoons and coastline sourced from Land Information New Zealand under CC-BY.

A3 SCALE 1:100,000

0 1 2 3 4 5 (km)

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ARCFILE: Map Layer CGD0703

SCALE (AT A3 SIZE): 1:100,000

PROJECT No.: 53708-000

CANTERBURY GEOTECHNICAL DATABASE

EQC Horizontal Ground Surface Movements

Local (Shallow) Portion of Ground Movement Due to the CES (Inferred from LiDAR Survey and GNS Tectonic Model)

FIGURE No.: Appendix A - Map 8c

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