Risk Frontiers

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22 February 2011 Lyttelton earthquake, Briefing 3

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During survey day five the epicentral area of Lyttelton was assessed along with accessible suburbs on the northern side of the Port Hills (Ferrymead, Heathcote Valley etc). Unfortunately the area between Redcliffs and Sumner was closed at the time of visiting due to potential rock falls. On day six the city cordon was surveyed to (very broadly) estimate the extent of visible liquefaction into the city. Liquefaction categories reported in the previous briefing note can be supplemented with those given in Table 1 (note that Phillipstown has been updated). This briefing note also discusses updated seismological understandings of the Lyttelton earthquake.

Comparison of shaking levels with those for the September 2010 Darfield event

The extent of shaking damage to buildings during the February 22 tremor was far greater than experienced during the 2010 event. This reality was, to some extent, driven by the fact that many of the city's buildings were weakened by the first quake, but in large part was due to larger ground acceleration and velocities in the CBD region. As discussed in our first briefing note, these were in many areas greater than those prescribed in current design standards.

Figure 1 shows interpolated peak ground acceleration surfaces for the 2010 and 2011 earthquakes. Although the Darfield event had a higher magnitude, the focal area of high accelerations was well west of the CBD and much of the city's housing stock. In contrast, during the 2011 earthquake the area of greatest accelerations was directly under the city and its southern suburbs. Peak ground accelerations up to 8 times larger than those experienced during the 2010 event (lower image) were felt in densely populated areas of the city.

Lyttelton and surrounds

Damage to buildings in Lyttelton was extensive. As after the 2010 event, historic pubs and hotels were hit hard. Almost all buildings in the first two blocks off the port were "red stickered", with many looking well beyond repair. Failure of unreinforced masonry parapets, facades, chimneys and veneers were common (Figure 2) on both residential and commercial buildings. Where reinforcing (or at least restraining) work had been done after last year's quake, buildings, in some cases, appeared to avoid total façade collapse but in others did not. In all instances failure of unrestrained portions of the façade were observed. A common sight was for timber-framed, partially brick-veneered buildings to have lost part or all of their brickwork, but for adjacent walls clad in timber to outwardly appear intact. Given the much greater ductility of timber this was probably an inevitability.

Cracking was noted on a few newer buildings (Figure 3), but structural integrity appeared in all cases to be maintained. With ground accelerations in the area greater than specified in the earthquake standard, this performance is a good reflection of the stringent application of the building code in New Zealand.

We were fortunate to have the opportunity to thoroughly inspect (roof and sub-floor cavities included) a timber framed and stumped home on the western hills of the city. Despite the house displaying little evidence of stress to any major structural elements, extensive cracking to internal walls and glass windows and doors was extensive (Figure 4). Again, given the greater ductility of framing compared with wall sheeting this is expected. Discussion with the owners – over a cup of tea and a sandwich – suggest the extent of damage they experienced was common around the town, with everyone they'd spoken to having at least extensive internal cracking and breakage. As a point of interest, two neighboring concrete block homes were red-stickered and slated for demolition.

Given the mountainous terrain of the Lyttelton area rock retaining walls are common. A large number of failed walls were noted with damage to roads common and damage to homes reported. In the neighboring town of Rapaki major boulder impact damage was seen (Figure 5). Fortunately for the town other large boulders had stopped part way down the slope before reaching it.

Port Hills suburbs

Shaking damage to the accessible suburbs on the northern face of the Port Hills and valleys (Ferrymead, St Andrews Hill, Mt Pleasant, Heathcote Valley) was extensive. The Heathcote Valley School recorded the highest peak ground acceleration for the event at greater than 200% g. Cracking was common on block and brick homes, with veneer failures regularly noted. Failure of double brick walls was also common, but no complete home collapses were sighted. Dislodgement and loss of tiles on steep sloping roofs appeared to be an issue, with even newish housing suffering (Figure 6). Loss of tiling was noted in other areas of Christchurch also – the higher the pitch the more prone to failure they appear to be.

In the lower lying valley regions near Ferrymead liquefaction was an issue. Much of Main Road was damaged and the Ferrymead shops were severely affected.

Christchurch CBD

Unfortunately we were unable to gain access to the CBD. Inspecting damage from the city cordon though, extensive damage was obvious. Now well reported, damage to many of the city's iconic buildings (Figure 7) was such that a number will be brought down (Figure 8). The poor performance of unreinforced masonry buildings was again highlighted, but the impact of failures in the city was far greater than in the suburbs because the density of buildings and people (at the time) was much higher. A historic reluctance to retrofit older buildings left them under-prepared for resisting earthquake forces; this was a costly mistake (socially and financially).

Radio reports suggest around 20 – 30 % of buildings within the CBD will be demolished. A/Prof. Jason Ingham from the University of Auckland, after conducting an assessment of a portion of the city's buildings (300 buildings) reported that approximately 50% of all unreinforced masonry buildings, which make up about 50% of the city's building stock, were likely to be demolished (Figure 9). As expected, unreinforced masonry (URM) buildings performed worse than other building types, but poor performance of some reinforced concrete (RC) and timber (T) structures was also noted. Ingham believes up to 35% of the city's buildings will need to be demolished.

Liquefaction was evident on a number of streets and around many shops heading into the CBD (Figure 10). Refer to Table 1 for a description of affected streets.

Possible causes of strong ground shaking in Christchurch (Paul)

At present, the orientation of the fault that caused the earthquake is not well known. GNS Science (Figure 11) infer that the earthquake may have occurred on the dashed yellow line striking east-northeast just south of Christchurch, based on aftershocks, not on any mapped fault or surface feature. The global seismic moment tensor solutions by Harvard and the USGS both show that one of the fault planes may have been a plane dipping down to the southeast at about 57 degrees on a plane striking northeast, perhaps consistent with the dashed yellow line in the map but striking more northeast. If that is the case, then the rupture began at a depth of about 10 km southeast of Christchurch and propagated updip and to the northwest directly toward Christchurch, causing a strong pulse of ground motion due to rupture directivity effects. The rupture directivity pulse recorded at Lyttelton (LPCC) is shown in the top panel of Figure 12. Lyttelton is located on Tertiary volcanic rock (Figure 13).

The three-dimensional structure of Christchurch may have caused localised amplification of the ground motions in Christchurch, which is located on a sedimentary basin (Figure 13). The seismic body waves from the earthquake entered the basin through its thickening edge, becoming trapped within the basin and generating a long train of surface waves. These surface waves are seen following the rupture directivity pulse in the recording at Christchurch Hospital, shown in the bottom panel of Figure 12.

Damage survey images

For a full catalogue of geo-located damage survey images please follow the link here. Use images as desired with appropriate acknowledgement to Risk Frontiers. If you would like higher resolution copies please contact us.

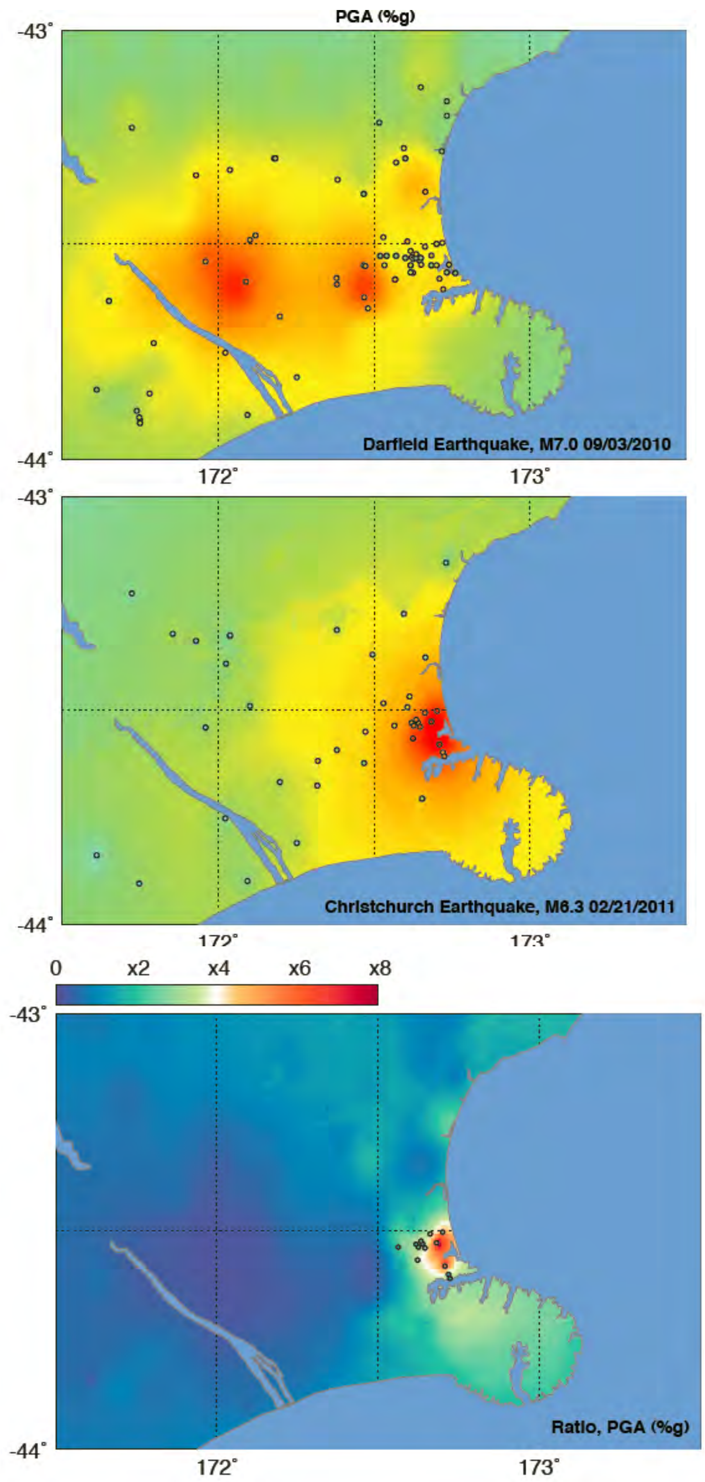

Figure 1. Comparison of peak ground accelerations for the two Christchurch earthquakes. The top panel is the 2010 Darfield (Canterbury Plain) earthquake, the centre panel is the 2011 Christchurch (Lyttelton) earthquake, and the bottom panel is the ratio of peak acceleration (Christchurch/Darfield). Source: David Wald, personal communication.

Figure 2. Failure of gable end and upper storey facade. Note the unfortunately parked car on the street below.

Figure 3. Cracking from edges of door and window frames, but no failure of newer buildings.

Figure 4. Extensive internal cracking of timber framed home.

Figure 5. Damage to home due to falling boulder.

Figure 6. Damage to newer tiled roof.

Figure 7. Loss of gables on the Presbyterian Church.

Figure 8. The noticeable lean and kink of the Grand Chancellor Hotel.

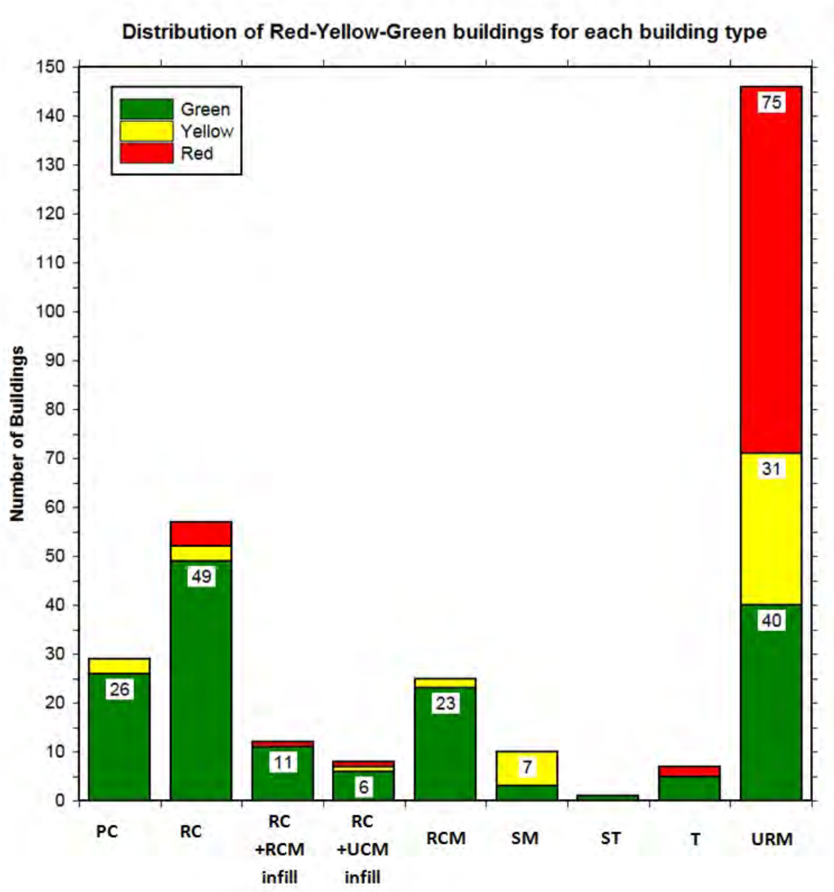

Figure 9. Damage levels to a transect of buildings in the Christchurch CBD (Jason Ingham, available here). Green signifies minimal if any damage, yellow, major but repairable damage, and red, extensive damage likely requiring demolition.

Figure 10. Liquefaction around shop entrance on city cordon. Note also cracking to parapets.

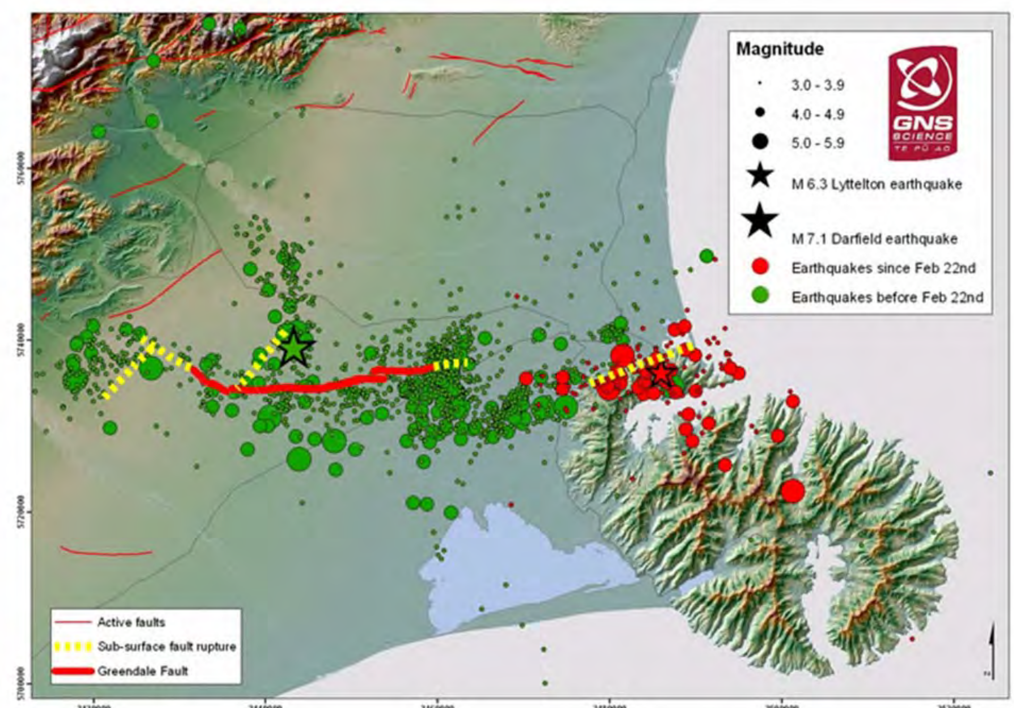

Figure 11. Map of surface faulting (red line) observed in the September 4 2010 event, and subsurface faulting inferred in the same event (western four segments) and the February 22 2011 event (eastern segment). Source: GNS Science.

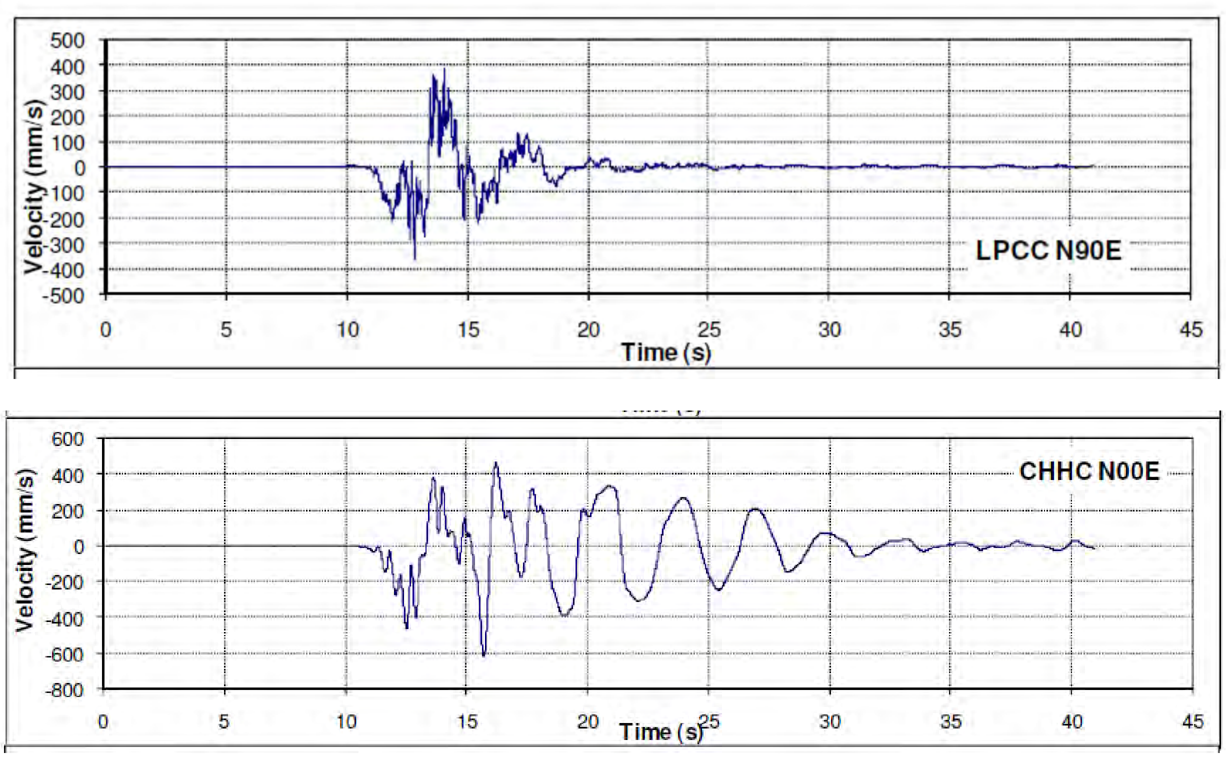

Figure 12. Ground velocity recorded at Lyttelton (LPCC, top) and Christchurch Hospital (CHHC, bottom). The Lyttelton record shows a brief but strong rupture directivity pulse, while the Christchurch record shows that pulse followed by surface waves generated at the basin edge. The records were processed by John Zhao of GNS.

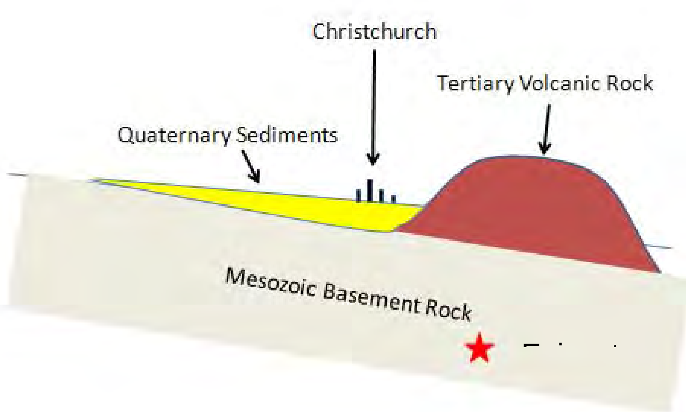

Figure 13. Schematic North – South geological cross section of Christchurch. Source: George Walker

Table 1. Additional and updated liquefaction indices for Christchurch suburbs.

Suburb	Extent of liquefaction	Comments
Phillipstown	Minor	Only a few small silt piles noted. More common near Fitzgerald Avenue. Large number of shake damage homes observed - limited to chimneys and brick buildings.
Ferrymead and Heathcote Valley	Minor	Most shops on Ferrymead Rd affected by liquefaction. Low lying areas and housing to the north of Ferrymead Road worst affected. Significant levels of shaking damage noted – this area had the highest recorded pga. Loss of brick veneers, tile damage.
St Andrews Hill	Minimal	Liquefaction focused around Main Rd. Significant shaking damage to homes, particularly heading up the hill. Cracking to block homes, failure of brick veneers, failure of double brick, loss of tiles. Failure of some newer tile roofs seen, but less extensive than damage to older ones. Cracking to a few newer style rendered brick/block homes - could just be the rendered facade. Settlement of some roads towards marshes.
Mt Pleasant	Minmal	As for St Andrews Hill
Redcliffs to Scarborough	Minimal	Access to Redcliffs and south was closed due to potential rockfalls at the time of visiting. My feeling is that these will be similar to St Andrews Hill and Mt Pleasant with possible liquefaction near the low lying Main Rd, but with the added problem of rockfall.
Lyttelton	None evident	Spreading evident on the main road and up the hills - expect this has a lot to do with unstable slopes, but could potentially be liquefaction near the harbour. Heard on radio that 1 in 10 homes were red stickered - observation suggests this is probably correct. Almost all of Norwich St severely damaged. Discussions with residents suggest almost all homes have suffered some level of damage (at least everyone they'd spoken with). Brick veneer failures on timber frames very common. Rockfalls observed to be a continued problem. Residents felt homes on the western slopes were worse affected. John McAneney's favorite bar, Wunderbar, closed!
City cordon	Varied	Reports of liquefaction in the city itself. Evident at some points around the cordon. Cordon loop notes: Beginning at Papanui and Bealey moving east. Little evidence of liquefaction until Manchester St. Common east of there. Moved south down Perth St, major liquefaction in the Richmond area. West to Fitzgerald Ave via Harvey. Severe lateral spreading along the Avon River where Harvey Street joins Fitzgerald Av. No liquefaction noted looking west down Armagh St. Liquefaction seen down Litchfield St. Businesses south of Litchfield on Fitzgerald Avenue affected badly by liquefaction. Liquefaction noted on St Asaph St. Turned west down Moorehouse, little sign of liquefaction. No liquefaction seen looking north up Madras. Liquefaction, and liquefaction damage seen on Manchester. Signs of liquefaction up Cambridge. Decreasing level of liquefaction noted as moving north up Stewart St. No signs of liquefaction in the northern part of Hagley Park. Major liquefaction on Hagley Park golf course - looks to be lower-lying than the park. Aerial photos suggest liquefaction may have occurred in southern part of park.