Tonkin & Taylor

T&T Ref: 52118
14 June 2012

Structure Smith Ltd
P O Box 26-502
Epsom
Auckland 1344

Attention: Ashley Smith

Dear Sirs

CTV Building Geotechnical Advice - Addendum 2

This addendum presents further additional information in relation to the geotechnical advice given in our letter report [1] of 11th July 2011, relating to our assessment of ground conditions at the GeoNet strong motion measurement site REHS.

1. Previous geotechnical advice

i. Section 5.0 our report of 11th July 2011 discusses the ground conditions at the GeoNet strong motion recording station REHS. It was noted that the general soil profile expected in the vicinity of this site includes a significant thickness of near-surface soft soils. It was concluded that the shallow ground conditions at the REHS site were somewhat different to the CTV Building site and the three other GeoNet stations in the CBD being considered.

ii. It was noted that shallow ground conditions are only one aspect which influence the dynamic response of a site. However, the presence of this softer soil, in conjunction with the greater amplification effects which appear to be present in the records from this site, raised questions regarding the applicability of records from the REHS site for use in analysis of the CTV Building site.

iii. At the time of our initial report, there was no additional information readily available which would allow these questions regarding the applicability of the REHS site to be resolved. Therefore my advice was that analysis for the CTV Building site should consider the 3 records from the GeoNet sites with substantially similar ground conditions (CGBS, CCCC, CHHC), and not include the record from REHS where there was unresolved uncertainty regarding applicability.

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[1] Tonkin & Taylor letter report to Structure Smith Ltd., "CTV Building Geotechnical Advice", Tonkin & Taylor, Ref 52118, 11-July-2011.

2. Area-wide assessment of subsoil ground conditions

i. Since our initial letter report of 11th July 2011, Tonkin & Taylor has completed area-wide subsurface geotechnical investigations across the Christchurch CBD area on behalf of the Christchurch City Council [2]. This ground investigation included 48 machine boreholes, 151 cone penetration tests, approximately 45km of geophysical surveys, groundwater level monitoring and laboratory testing of soil samples to identify the nature of the deposits present to depths of up to 30m below ground level.

ii. The soil profile data collected from this investigation, supplemented with existing historic borelog data held by Environment Canterbury, was compiled and interpreted to produce a generalised three-dimensional model of the simplified soil profile across the CBD. This model provides an indication for regular depth intervals of the predominant soil types which are present. An example generalised geological plan is shown in the attached Figure 1, showing predominant soil types across the city between a depth of 5m and 6m. The dark brown shading across much of the CBD on this map represents medium-dense to dense sandy gravels.

iii. While the spacing between investigation points (typically 150 – 250m) means that this CBD-wide model lacks some precision in areas away from investigation locations, it provides a useful area-wide appreciation of the geological patterns in the subsurface soil profile. The investigations used to generate this model included specific CPT and/or borehole investigations as close to as readily practical (within 50m). The sites of the CTV Building and GeoNet stations CHHC, CCCC and REHS (CBGS was outside the designated study area so was not tested as part of the CBD investigations).

iv. In our initial report of 11th July 2011, the ground conditions at each site of interest were considered based on the individual logs closest to each specific location. While this allows fine detail in the soil profile to be considered, an individual log does not necessarily fully capture the general trends and variations within the wider geological environment. With the CBD-wide investigations now available, we have therefore undertaken an assessment of the wider geological trends in the general vicinity of each recording station of interest, to complement the previous assessment based on specific logs.

v. The area-wide assessment of ground conditions in the vicinity of each site of interest is summarised in the attached Figures 2 and 3. These figures have been compiled by taking a local snapshot of the generalised geological map for each depth interval. At the centre of each snapshot square is the location of each site of interest. The width of the snapshot square is 20m for Figure 2, so for the most part this figure can be interpreted as a simplified soil profile log for each site. For Figure 3 the width of the snapshot square is 500m, so this enables the area-wide geological trends to be inspected for each depth interval across the various sites. This provides a sense of the general nature and variation of the wider geological environment.

vi. These generalised area-wide soil profiles show that soils in the vicinity of the REHS site appear to be generally softer than in the vicinity of the other GeoNet sites and the CTV building. Between the surface and about 5m depth at REHS the predominant soil types are soft organic or silty soils, whereas at the other sites there is predominantly loose to medium dense silty sand or sandy silt over this depth range. Between about 5m and 9m depth at REHS there are predominantly loose to medium dense sands and silts, whereas at the other sites much of this

[2] Tonkin & Taylor report to Christchurch City Council, "Christchurch Central City Geological Interpretative Report", Dec-2011 V1.1, available at http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/centralcityplan.aspx

depth range predominantly comprises stiffer gravelly soils. Below about 9m depth, down to the Riccarton gravels all the sites appear to have reasonably similar predominant soil types.

vii. In our initial letter report of 11th July 2011, it was noted that the dynamic response characteristics of a site are generally governed by the soil profile to rock, with thin soil layers near the surface likely to have only minor effects unless significant thickness of soft soil is present. Since this initial report, further information has become available regarding the rock-head profile beneath the CBD. Geophysical testing using deep seismic reflection techniques was undertaken by the Natural Hazards Research Platform [3] along a section line running from one side of the CBD to the other along Barbadoes St.

viii. From this deep geophysical testing, the research team working on this project has been able to infer the location of the buried profile of the Lyttelton Volcano – i.e. the top of rock. This is shown in Figure 4. This indicates that there is a potentially significant variation in the depth to rock across the CBD along this section. The estimated depth to rock increases from about 500m in the southern part of Barbadoes St (in the vicinity of the CCCC and CTV sites) to about 600m at the northern end near Bealey Ave (in the vicinity of the REHS site).

ix. Based on these differences between both the shallow soil profile and depth to rock at REHS compared to the other sites, it could be expected that there would be at least some degree of difference in the dynamic response of these sites.

x. However it is not clear from inspection of the soil profile alone exactly how significant this difference in response would be, and whether the difference is important in the frequency range of interest for the CTV building and for the intended purpose of the analysis. Fortunately, seismological analysis work recently undertaken by others provides additional information which can assist in the consideration of these questions, as discussed in Section 3.

3. Additional seismological analysis results

i. Since our initial letter report of 11th July 2011, additional seismological data has been collected and analysed, as summarised in Bradley (2012)[4]. The recent ground motion recordings taken specifically at the CTV site, and the recently-completed conditional spectral analysis work, help to answer the questions of whether the differences in soil profile at the REHS site result in a difference in the site response which is significant for this specific case.

ii. The records from REHS appear to often show higher accelerations across parts of the spectra compared to the CTV site and the other GeoNet sites, and this may be related at least in part to the particular ground conditions at the REHS site. However, the spectral analysis of the recordings from the CTV site shows that the response is of the REHS site is not unreasonably greater than measured at the CTV site. Inclusion of REHS does seem to provide an upper bound which helps to balance the suite of records across the range between the 16th and 84th percentile conditional spectra predicted for the CTV site.

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[3] Briefing by Natural Hazards Research Platform to elected and community representatives, "Progress in understanding the Canterbury Earthquakes" by Berryman, Gerstenberger, Barnes & Pettinga, 6-Jan-2012, available at http://resources.ccc.govt.nz/files/AllCommsStuff/GNSSeismicBriefing/KelvinBerrymanPresentation6January2011.ppt

[4] Bradley, B.A. (2012). "Ground motion aspects of the 22 February 2011 Christchurch Earthquake related to the Canterbury Television (CTV) Building", *Technical report prepared for the Canterbury Earthquakes Royal Commission,* 22-May-2012, WIT.BRADLEY.0003, Part D, 26pp.

4. Conclusions

i. I consider that additional assessment of general geological trends in the vicinity of the sites of interest supports the conclusion of our report of 11th July 2011 that the ground conditions at the CGBS, CCCC and CHHC sites are generally more representative of conditions at the CTV site than is the case for the REHS site.

ii. However, the additional seismological information which is now available allows the potential significance of this difference in ground conditions to be assessed. This suggests that the difference in ground conditions does not appear to have affected the dynamic performance of the REHS site in an unreasonably significant manner, compared to the range of response which is possible at the CTV site.

iii. On the basis of this additional information I am satisfied that it is appropriate to include the REHS record in the suite for structural analysis at the CTV site, effectively representing an upper bound of likely ground response.

Tonkin & Taylor Ltd
T J E Sinclair
Technical Director

Figure 1: Example generalised area-wide geological map used to compile soil profiles. This map shows predominant soil types between 5m and 6m depth. Maps available for a range of depths in T&T Appx B at http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/centralcityplan.aspx

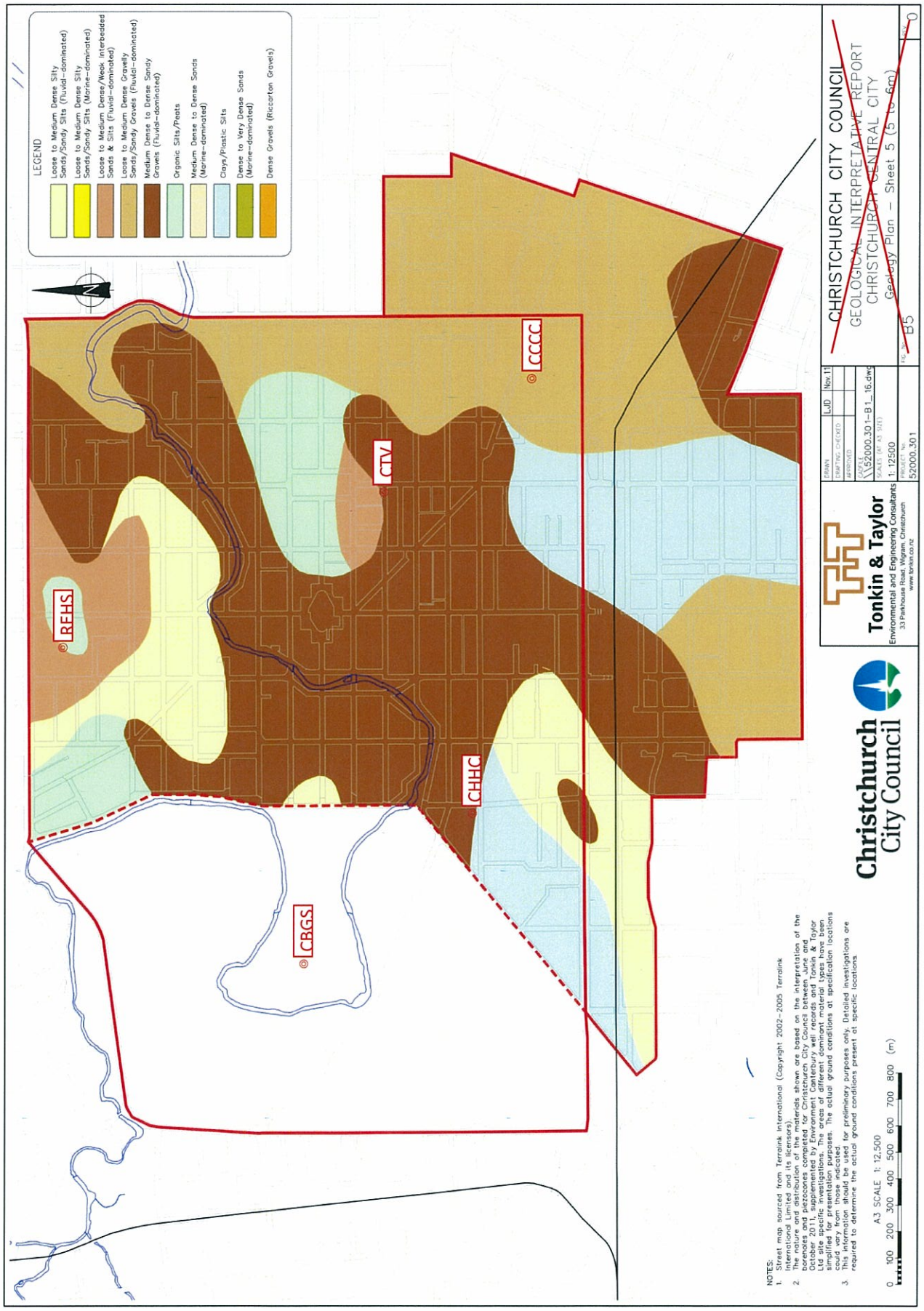

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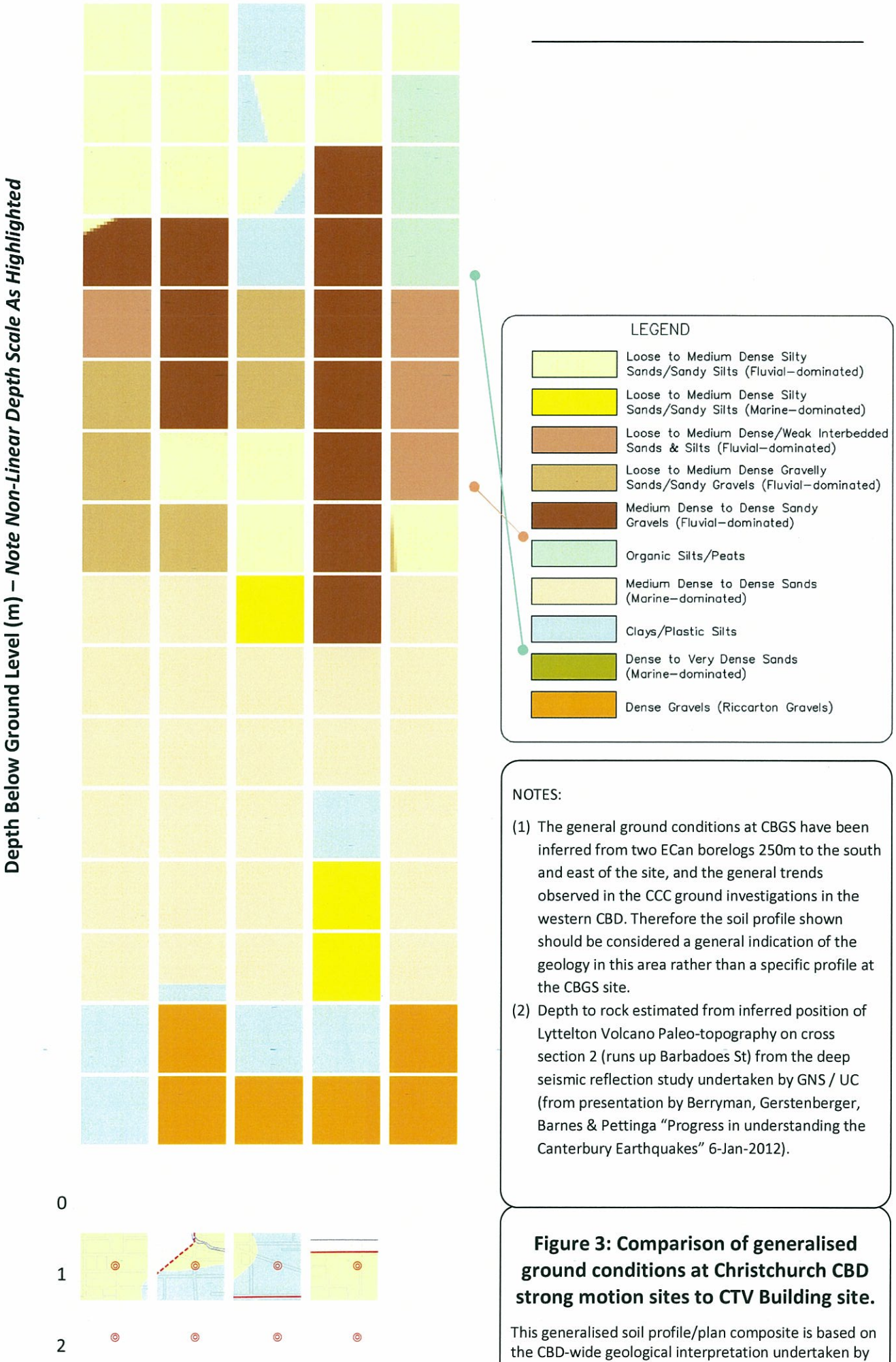
Figure 2: Comparison of generalised ground conditions at Christchurch CBD strong motion sites to CTV Building site.

This generalised soil profile/plan composite is based on



NOTES:

(1) The general ground conditions at CBGS have been inferred from two ECan borelogs 250m to the south and east of the site, and the general trends observed in the CCC ground investigations in the western CBD. Therefore the soil profile shown should be considered a general indication of the geology in this area rather than a specific profile at the CBGS site.

(2) Depth to rock estimated from inferred position of Lyttelton Volcano Paleo-topography on cross section 2 (runs up Barbadoes St) from the deep seismic reflection study undertaken by GNS / UC (from presentation by Berryman, Gerstenberger, Barnes & Pettinga "Progress in understanding the Canterbury Earthquakes" 6-Jan-2012).

Figure 3: Comparison of generalised ground conditions at Christchurch CBD strong motion sites to CTV Building site.

This generalised soil profile/plan composite is based on the CBD-wide geological interpretation undertaken by T&T for the Chch City Council ("Christchurch Central City Geological Interpretative Report", Appendix B, Fig

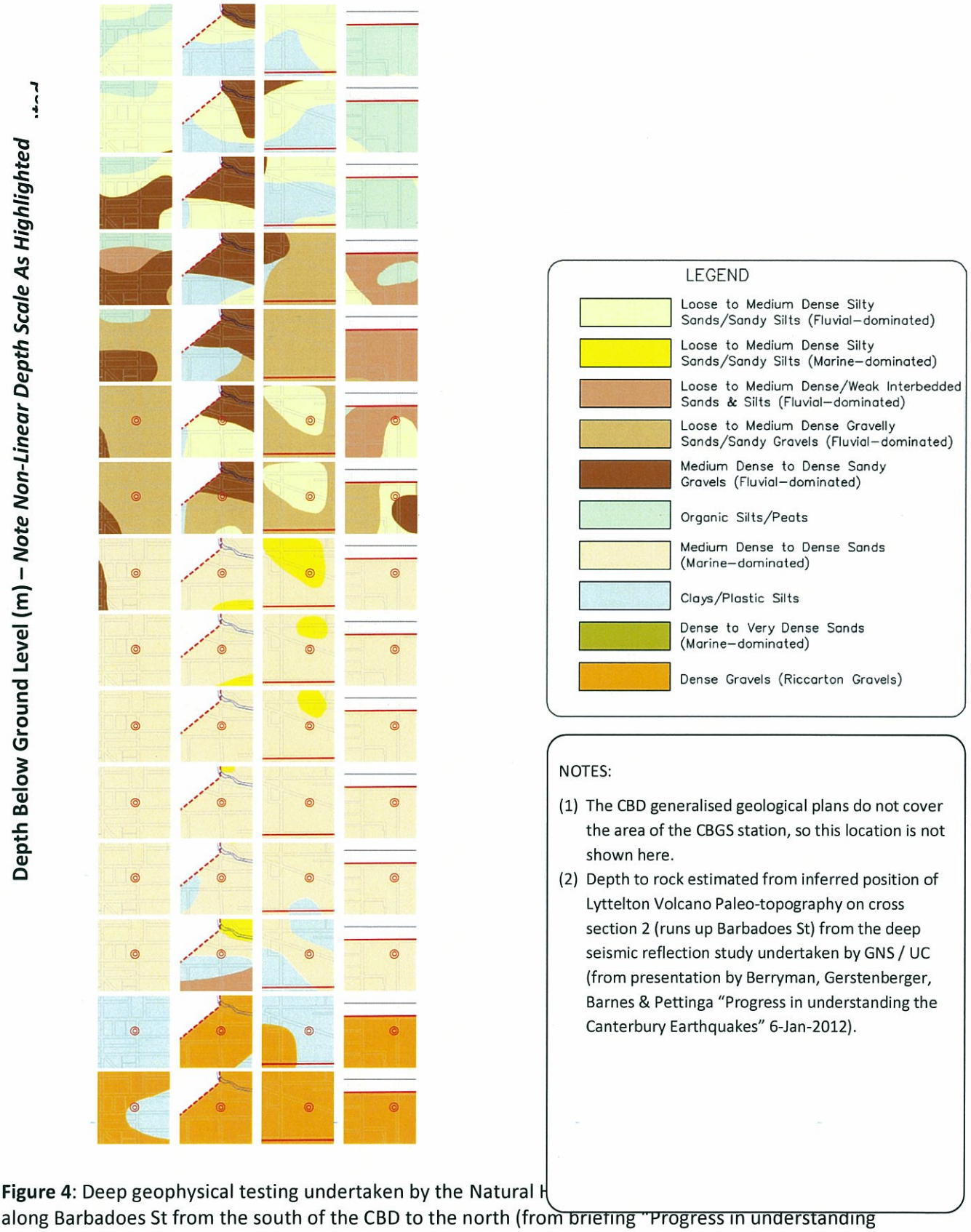
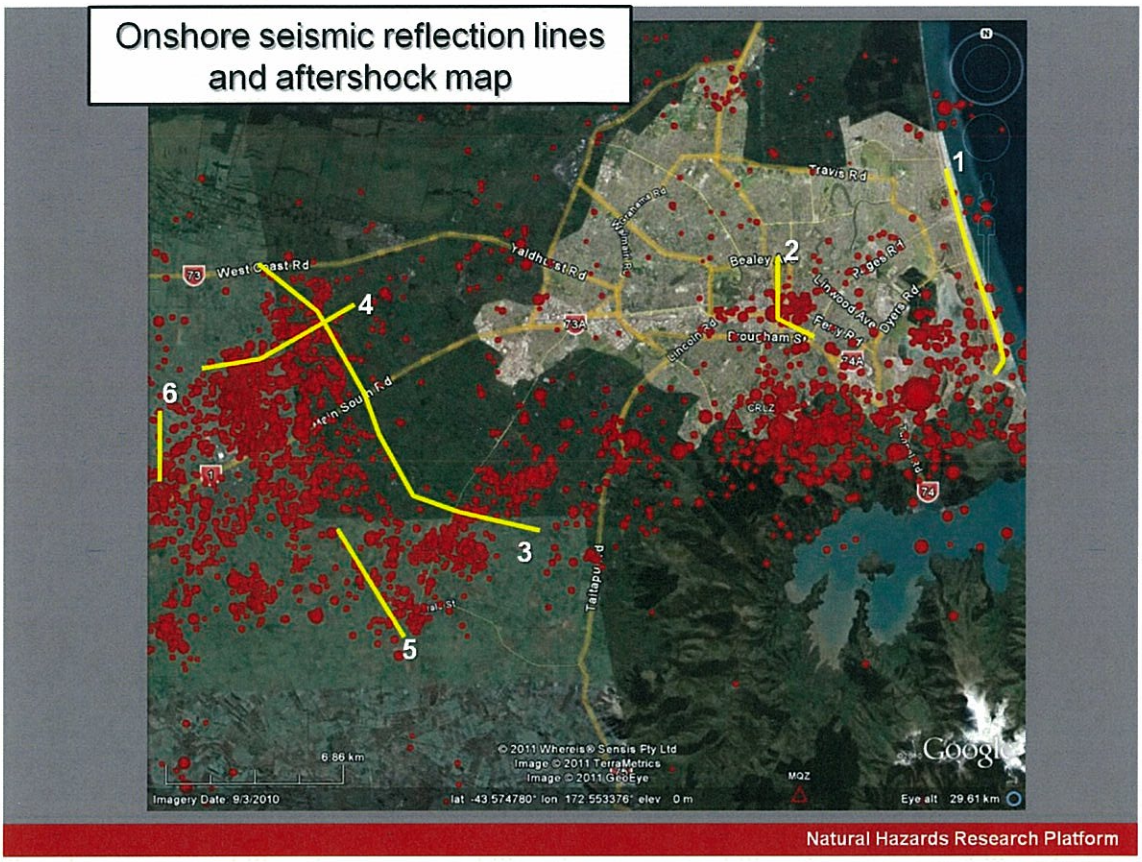
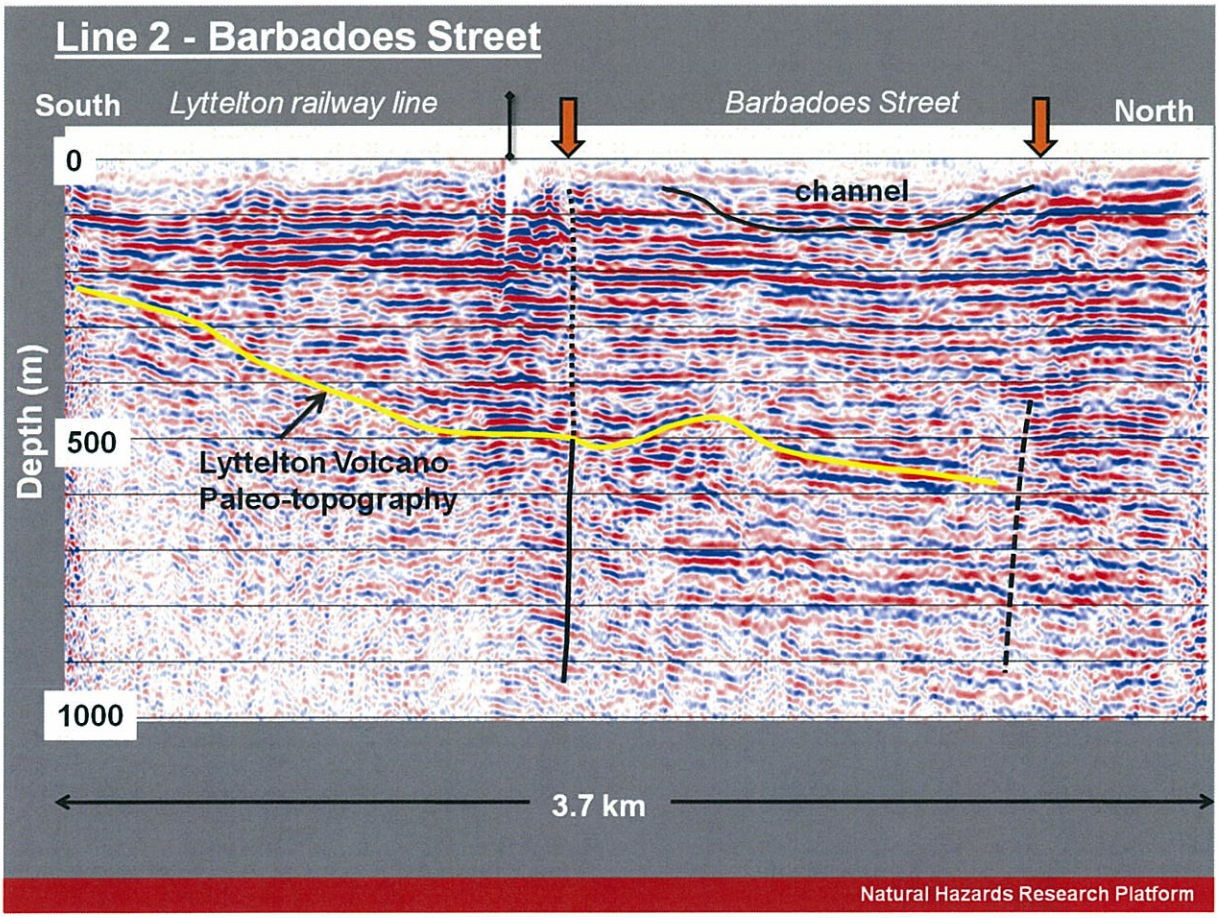


Figure 4: Deep geophysical testing undertaken by the Natural H
along Barbadoes St from the south of the CBD to the north (from briefing "Progress in understanding the Canterbury Earthquakes" by Berryman, Gerstenberger, Barnes & Pettinga, 6-Jan-2012.


Onshore seismic reflection lines and aftershock map
1
2
3
4
5
6
Travis Rd
Bealey
Yaldhurst Rd
West Coast Rd
Main South Rd
Lincoln Rd
Linwood Ave
Ferry Rd
Dyers Rd
Pages Rd
Brougham St
Taitapu Rd
73
73A
74
74A
1
6.86 km
Imagery Date 9/3/2010
© 2011 Whereis® Sensis Pty Ltd
Image © 2011 TerraMetrics
Image © 2011 GeoEye
lat -43.574780° lon 172.553376° elev 0 m
MQZ
Eye alt 29.61 km
Google
Natural Hazards Research Platform


Line 2 - Barbadoes Street
South
Lyttelton railway line
Barbadoes Street
North
0
channel
Depth (m)
500
Lyttelton Volcano
Paleo-topography
1000
3.7 km
Natural Hazards Research Platform