GEOLOGIC, GEOMORPHIC, GEOTECHNICAL, AND DISPLACEMENT MAPS OF LAND AND BUILDINGS AT SELECTED SITES OF CHRISTCHURCH CITY COUNCIL OWNED REINFORCED CONCRETE STRUCTURES DAMAGED DURING THE 2010-2011 CANTERBURY EARTHQUAKES

MANCHESTER ST CARPARK STUDY

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EXECUTIVE SUMMARY

The 2010-2011 Canterbury earthquake sequence (CES) in New Zealand's South Island caused extensive and recurrent damage to land and infrastructure within the Central Business District (CBD) of Christchurch. In this report we consider the effects of the CES on ground deformations and building deformations at the Manchester St Carpark site. We present geologic, geotechnical, geophysical and geomorphic data in the form of series of interpreted maps. Minimal land and building surface subsidence occurred at this site through the CES. This is consistent with the near-absence of liquefaction surface ejecta at the site and the scarcity of liquefiable sediments at depth beneath the site as revealed from geologic cross-sections and CPT data. However, large (>20-40 cm) west-to-southwest directed cumulative lateral displacements are suggested from differential air photo analysis. We speculate that these lateral displacements, if they can be validated, could reflect a mixture of gravitational creep in southward dipping shallow (<10 m below surface) strata and westward dip in deeper strata (~15 m below surface). This hypothesis requires further testing. A larger component of the observed damage at the Manchester St Carpark and surrounding buildings is likely to relate to transient strong ground motions, rather than liquefaction-induced differential land damage.

1. SCOPE

The University of Canterbury (Dr. Mark Quigley) was commissioned by Christchurch City Council to (1) Produce detailed geologic, geomorphic, and geotechnical site maps for Council key assets, and (2) Produce earthquake-induced horizontal and vertical displacement maps for ground surface surrounding CCC key assets.

The seven key asset sites to be considered in this suite of reports are listed in Table 1, along with their approximate WGS84 coordinates and completion dates for the significant structures at each site.

Table 1 Key Christchurch City Council Assets

ASSET	LATITUDE	LONGITUDE	COMPLETION DATE
Christchurch Art Gallery	-43.530385	172.631448	2003
Manchester street carpark	-43.529597	172.640192	1964
Christchurch City Library	-43.529633	172.635131	1979
Lichfield Street carpark	-43.533845	172.635077	1965/1986 3 floors added to 1965 bldg in 1970's
Old Bus Exchange	-43.53387	172.637407	1999
Old Civic Building	-43.53503	172.637896	1939
Lancaster Park	-43.542031	172.654145	Dean's Stand 2010; Hadlee and Tui Stands 1995; Paul Kelly Stand 2002
Christchurch South Library	-43.561394	172.63805	2002

This work required the attainment and reproduction of a suite of previously produced maps (Geology Maps, Black Maps, DEMs), reinterpretation of a variety of datasets (CPT data, boreholes, auger data, differential LiDAR data, survey data), and production of a new suite of annotated maps and cross-sections for the CCC key assets.

The purpose of these studies was to (1) document geologic setting of council assets, document heterogeneity of surface and near-surface materials with variable engineering properties, and (2) document 2010-2011 earthquake-induced land elevation and position changes at CCC asset sites to document severity of ground deformation and document geologic/geotechnical controls on ground deformation. The primary purpose of these reports is to synthesize geologic, geomorphic, geotechnical, and geophysical data into a unified model that best explains the patterns and origin of land and building deformation in the 2010-2011 Canterbury earthquake sequence.

The focus of this report is MANCHESTER ST CARPARK.

2. LOCATION AND PRIOR WORK

Manchester Street Carpark is located in central Christchurch (Fig. 1). The central lat-long of the site is -43.529597, 172.640192.

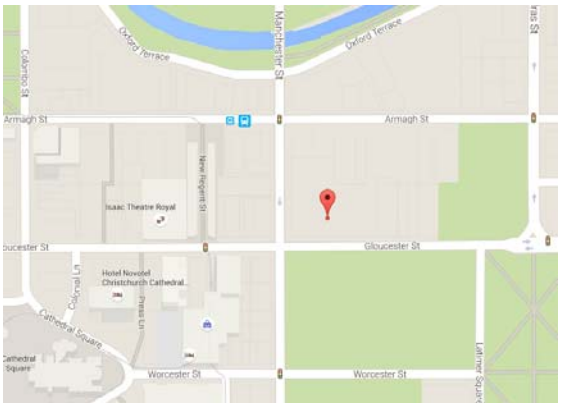

Figure 1. Location of Manchester St Carpark shown on Google Maps.

T&T conducted mapping (Fig. 2), and CPT investigations (Fig. 3) in close proximity to this site.

Horizontal and vertical displacement data was derived using differential lidar and airphoto interpretations throughout the Canterbury earthquake sequence (Fig. 4,5) and plotted on digital elevation model underlays. From these data, the tectonic component of displacement was removed (using tectonic displacements inferred geodetic seismic source models presented in Beavan et al., 2012), with the residual displacements interpreted to reflect shaking-induced permanent ground displacements relating to liquefaction and ground failure. See "Evaluation of Building Settlements during the Canterbury Earthquake Sequence using LiDAR" (T&T Ref # 53841) (see References) for further detail on how horizontal and vertical land displacements were obtained from differential LiDAR. A map showing pre-development waterways from historic "Black Maps" is shown in Fig. 6.

A series of MASW surveys were conducted by T&T in the vicinity of the Manchester St Carpark (Fig. 7,8). By combining topographic data, borehole data, CPT data, and MASW data, T&T constructed a suite of geologic cross-sections in this area (Fig. 9,10). Please see Christchurch Central City Geologic Interpretative Report" (T&T Ref REP-CCC-INT) for details including location of geotechnical sampling sites, raw and interpreted data, complete cross-sections, and preliminary geologic interpretations.

The richness of data obtained from these prior investigations provides the basis for our integrated geologic and geomorphic models for the Manchester St Carpark and our interpretations of how seismic loading and geology influenced the patterns of deformation.

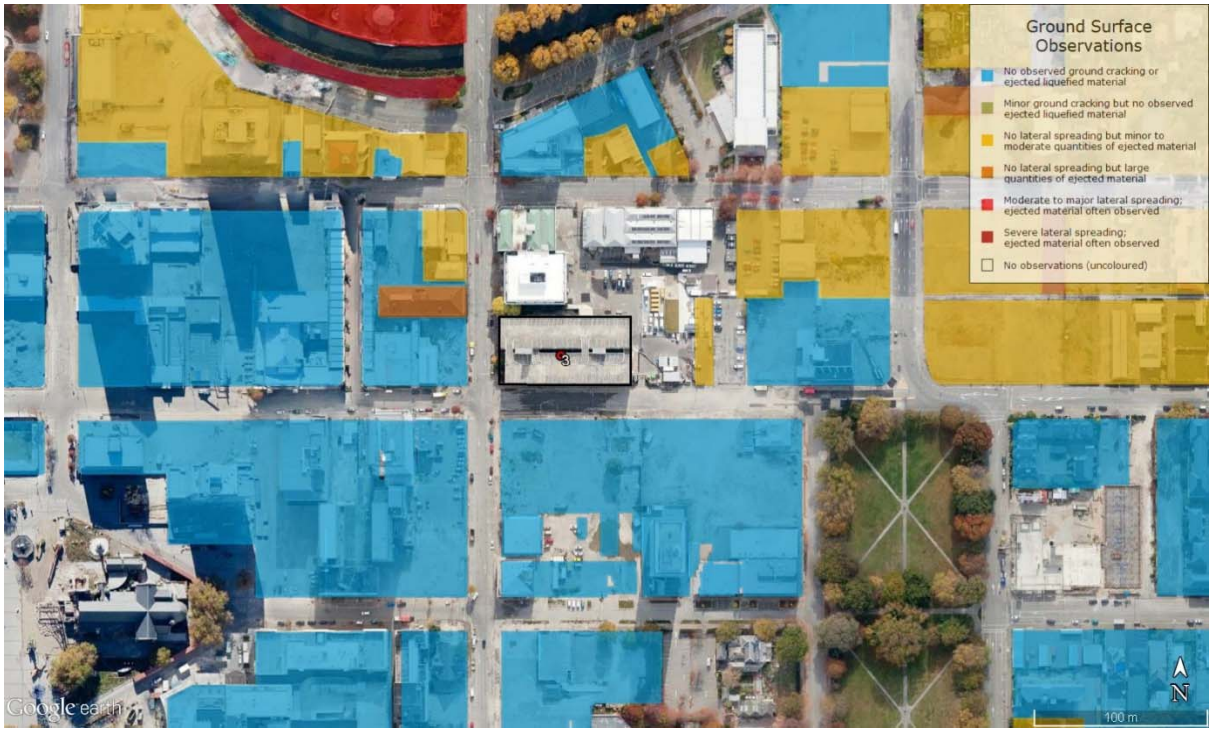

Figure 2: Area reconnaissance mapping of liquefaction and lateral spreading in the vicinity of Manchester St Carpark following the 22 Feb 2011 Christchurch Mw 6.2 earthquake (mapping by Tonkin and Taylor Ltd). More detailed mapping (this report) is presented in Fig. 11

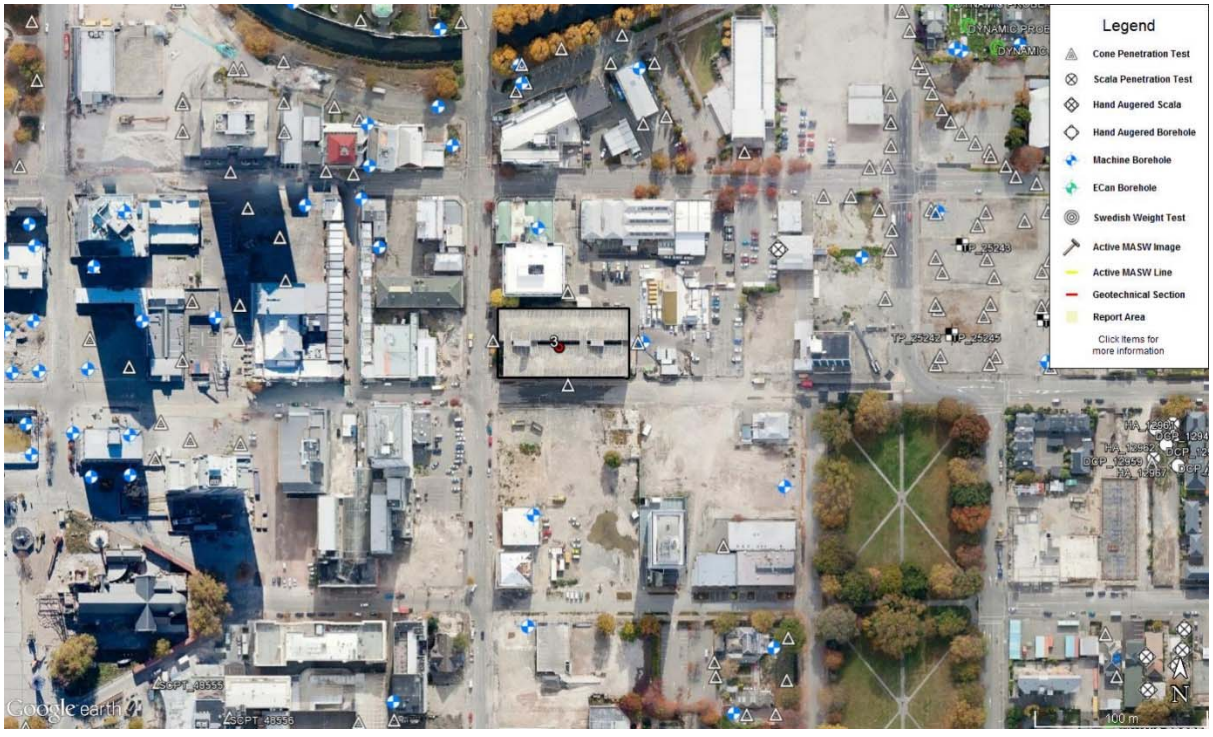

Figure 3: Location of CPT, borehole, and other geotechnical sampling sites in the vicinity of Manchester St Carpark. These data were variably used to construct geologic cross-sections (e.g., Fig. 9-11).

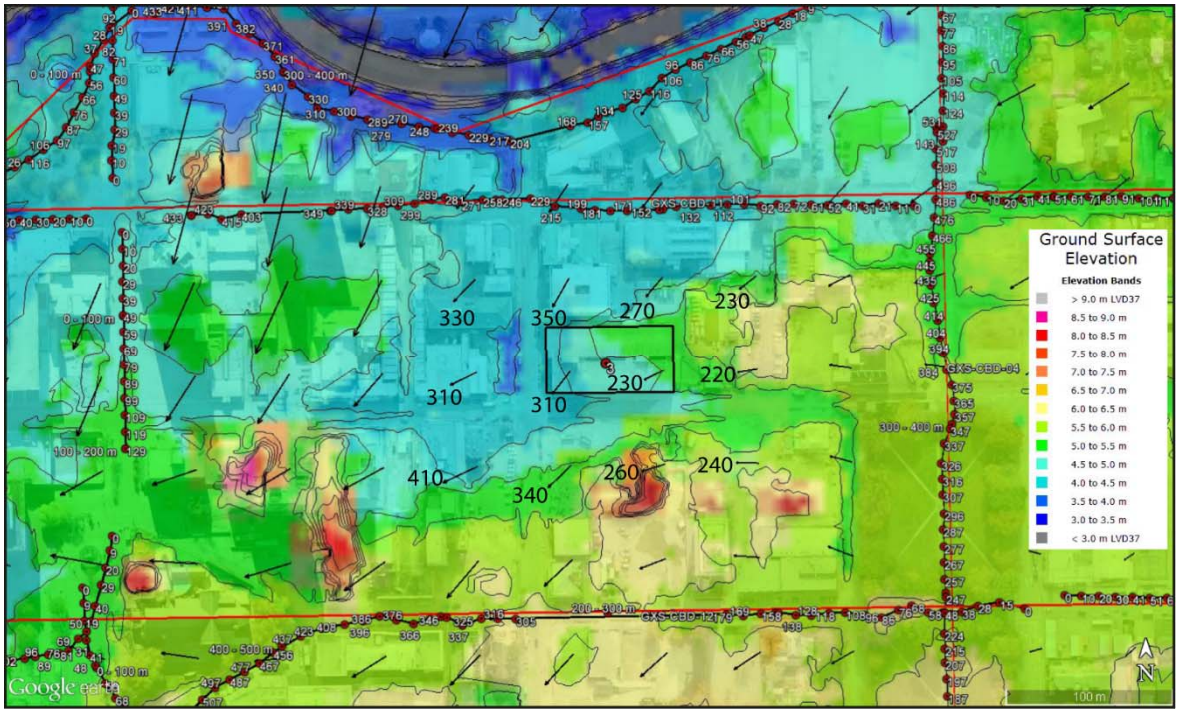

Figure 4: Cumulative horizontal permanent land displacements in mm with tectonic component removed for the Manchester St Carpark area, superimposed on DEM underlay. Location of MASW surveys and geologic cross-sections shown.

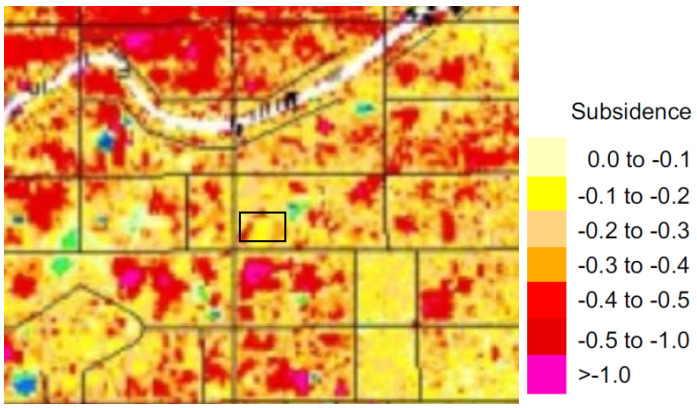

Figure 5: Permanent vertical land displacements from 2003 to December 2011 in metres for the Manchester St Carpark area. Image from Hughes et al. (2015)

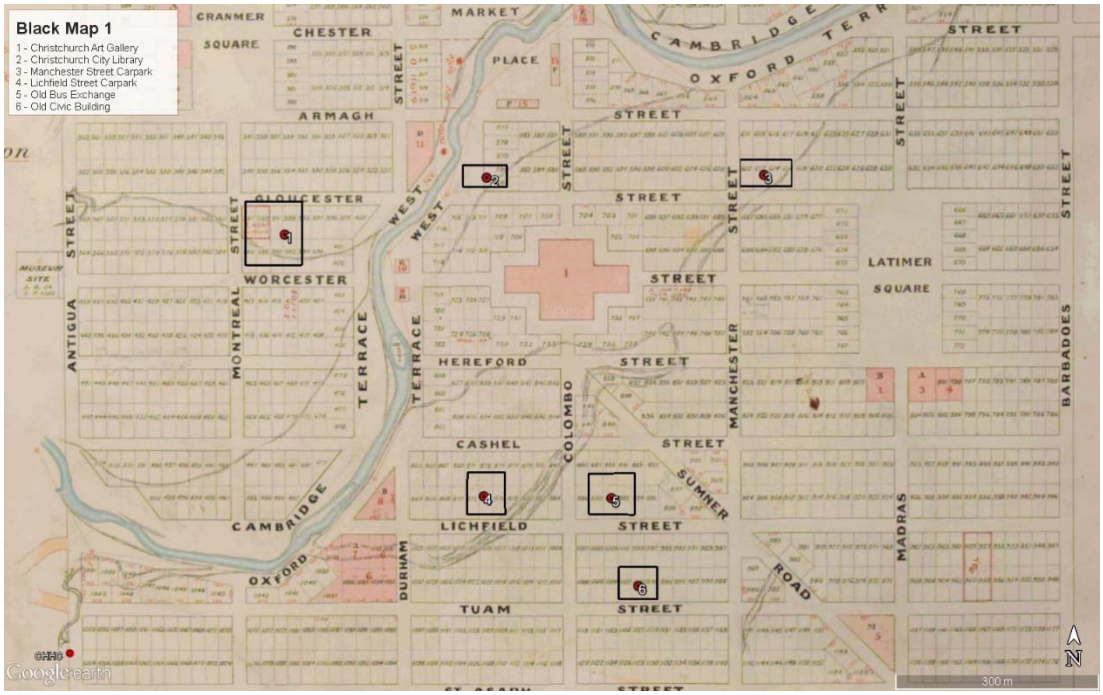

Figure 6: Historic drainage in Christchurch, showing location of historic channel beneath present-day southeast corner of Manchester St Carpark (3).

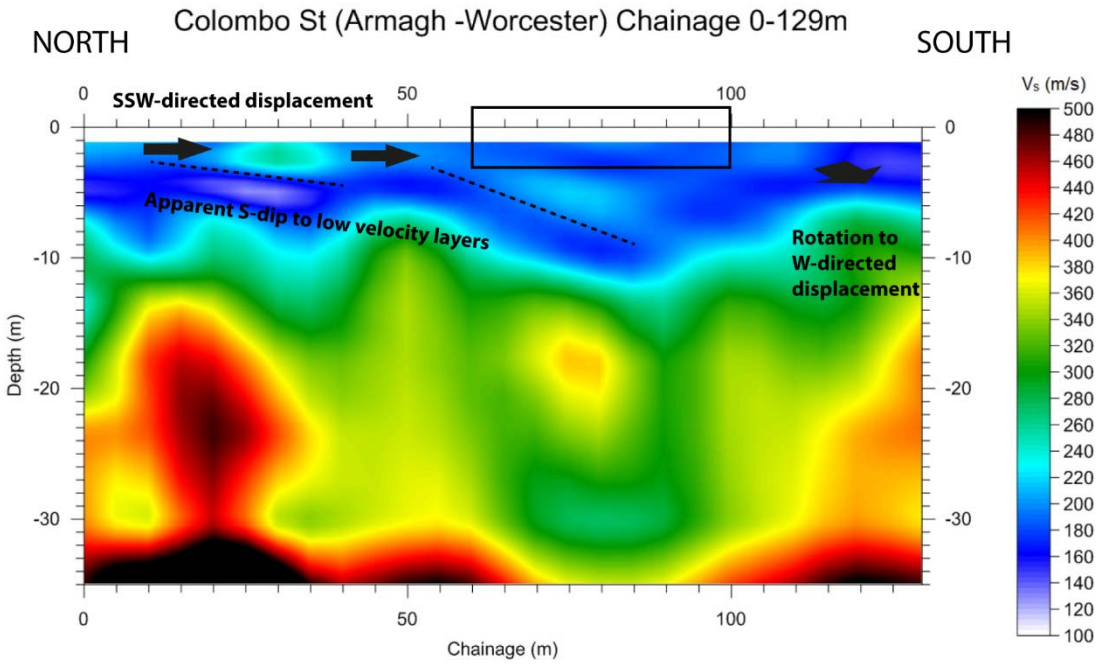

Figure 7: Interpreted MASW survey for Colombo St between Armagh St and Worcester St, immediately west of the Manchester St Carpark. See Fig. 4 for corresponding chainage.

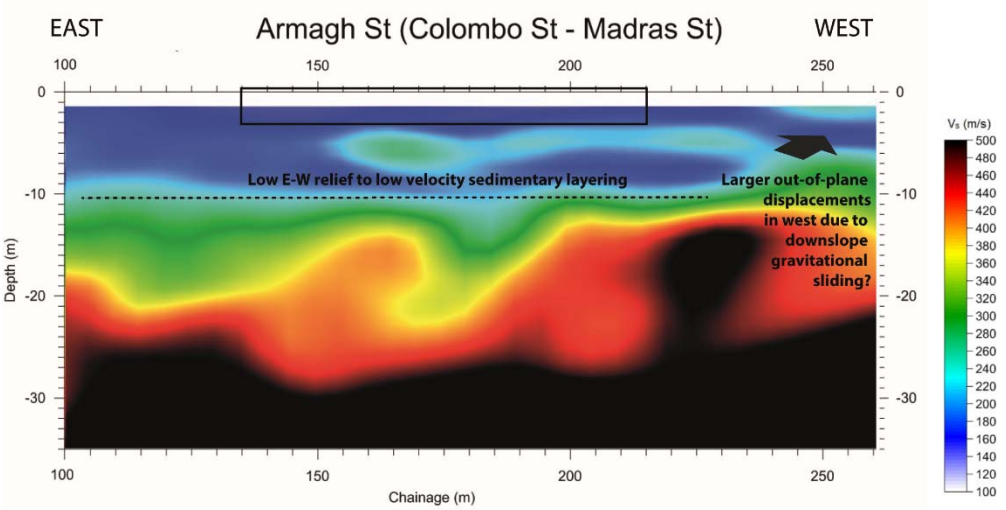

Figure 8: MASW survey for Armagh St, immediately north of the Manchester St Carpark (looking direction to the south). See Fig. 4 for corresponding chainage.

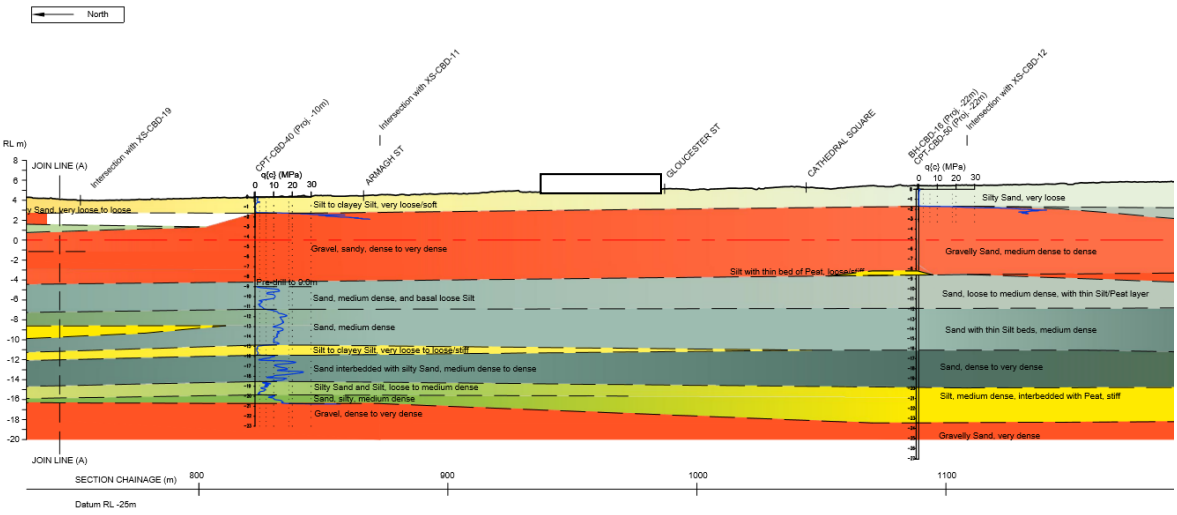

Figure 9: Geologic cross-section GXS-CBD-03 (Colombo St) showing projected position of Manchester Cark Park.

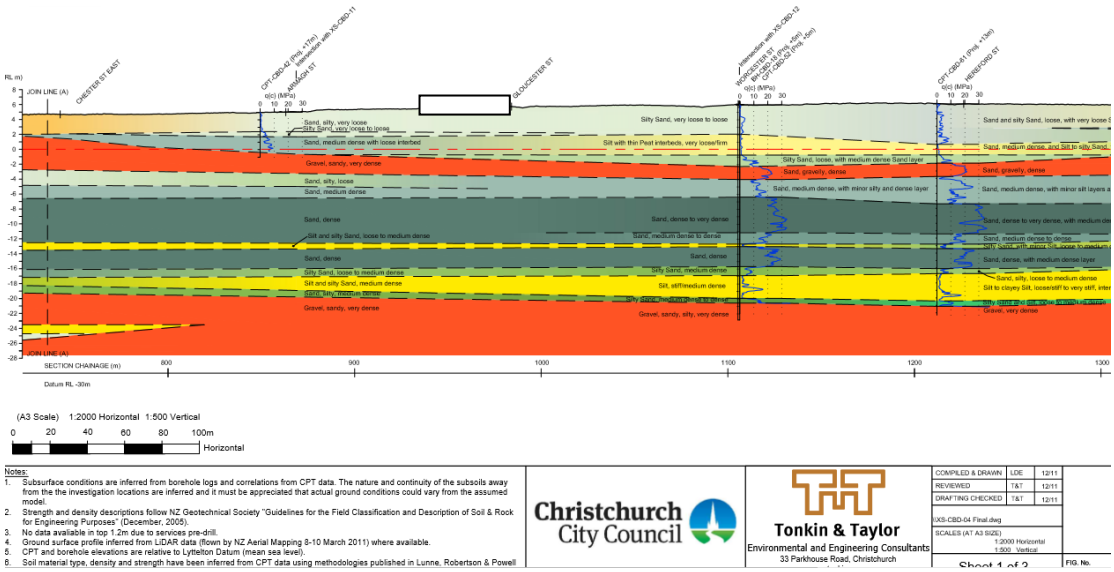

Figure 10: Geologic cross-section GXS-CBD-04 (Madras St) showing projected position of Manchester Cark Park.

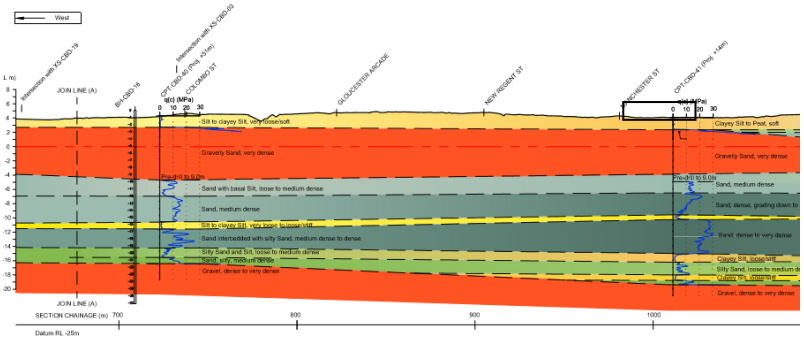

Figure 11: Geologic cross-section GXS-CBD-11 (Armagh St) showing projected position of Manchester Cark Park. Note westward slope and thickening of deep (~10-12m bsl), thin, very loose, highly liquefiable yellow unit, through to perhaps provide an explanation for west-directed lateral displacements in the absence of surface ejecta (further hypothesis testing required).

3. THIS WORK

3.1. MAPPING OF LIQUEFACTION EJECTA

The first part of our analysis was to produce detailed maps of liquefaction surface ejecta (Fig. 11) using airphotos obtained immediately following the 22 February earthquake in order to better quantify the extent of liquefaction surface ejecta. Distributions of liquefaction were characterised as definite or inferred. Former (historic) stream channels were added to maps where present. Liquefaction ejecta were rare in the vicinity of the Manchester St Carpark. The small, circular shape of possible or confirmed ejecta suggest anthropogenic control; it is possible that shallow infrastructure provide conduits for localized pockets of liquefiable material to reach the surface. Fig.

12 highlights the abundance of building damage in the area surrounding the Manchester St Carpark in the absence of abundant surface ejecta and scarcity of liquefiable material at depth; strong transient ground shaking during the 22 Feb Christchurch earthquake is suggested to be the primary cause of observed damage surrounding this site, rather than ground failure.

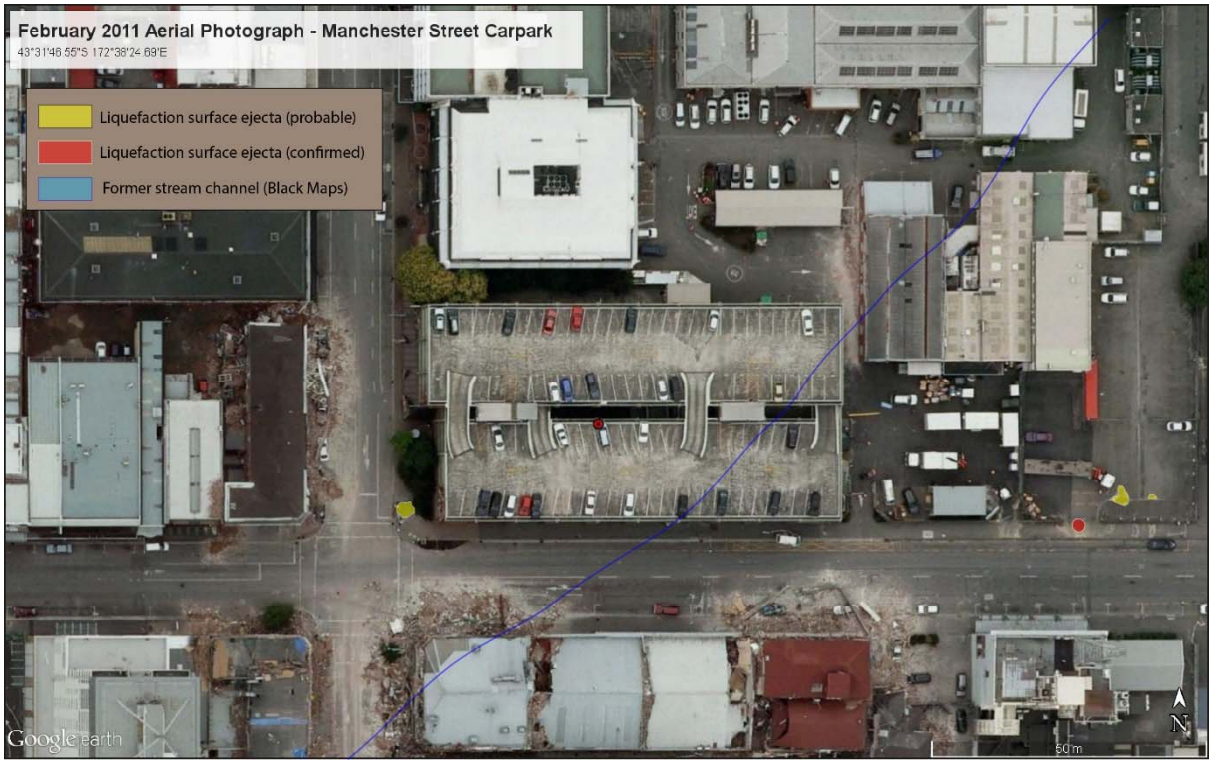

Figure 12: Map of liquefaction surface ejecta in the Manchester St Carkpark site following the 22 February 2011 Mw 6.2 Christchurch earthquake.

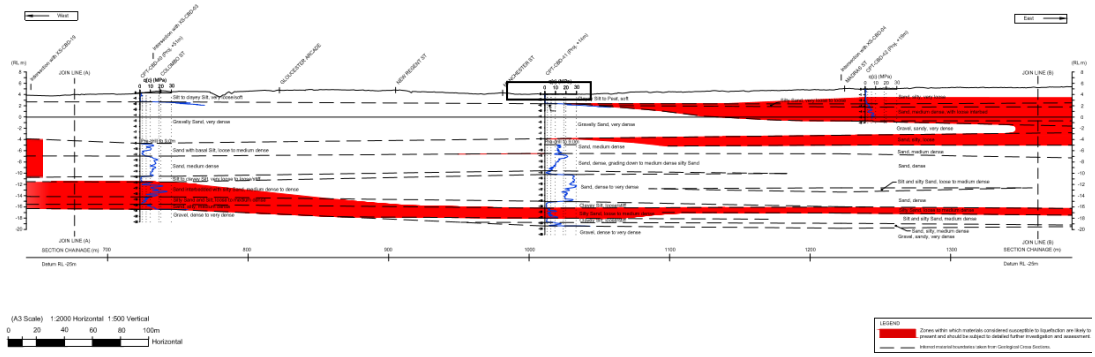

Figure 13: Projected footprint of Manchester Carkpark on to LHXS-CBD-11 (Armagh St). Cross-section showing zones susceptible to liquefaction (RED) from T&T Ref # 51845. *Note eastward thickening of liquefaction-susceptible zones in shallow levels (1-10 m below surface) and westward thickening of liquefaction-susceptible deep zones (15-20 m below surface). It is possible that the regional westward-directed lateral displacements reflect translational slip of the capping units above a deep liquefiable layer.*

4. CONCLUSIONS

Mapping of the Manchester St Carpark site confirms that surface manifestation of liquefaction was minimal at this site. This is consistent with constraints on the subsurface distribution of liquefiable sediments from CPT and borehole data, which are minimal at this location, and the apparent lack of surface subsidence at the site above the resolution of lidar data. However, large (>20-40 cm) west-to-southwest directed cumulative lateral displacements are suggested from differential air photo analysis. We speculate that these lateral displacements, if they can be validated, could reflect a mixture of gravitational creep in southward dipping shallow (<10 m below surface) strata and westward dip in deeper strata (~15 m below surface). This hypothesis requires further testing. A larger component of the observed damage at the Manchester St Carpark and surrounding buildings is likely to relate to transient strong ground motions, rather than liquefaction-induced differential land damage.

5. REFERENCES

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6. APPLICABLILITY

Important Notice

Some of the maps and data presented herein were 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 Canterbury 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 Canterbury Geotechnical Database (https://canterburygeotechnicaldatabase.projectorbit.com/) map and data is made available solely on the basis that:

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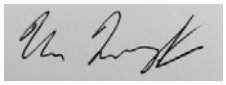

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5. REFERENCES CITED