

Appendix B: Forms of Flat Land Damage

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Table B1.1: EQC Land Damage Categories covered by EQC for the Flat Land Areas in Christchurch

Type	Description
<i>Damage that can be easily observed</i>	
Land cracking caused by lateral spreading ¹	Lateral spreading is the horizontal movement of land, typically toward watercourses. This horizontal movement results in the stretching and cracking of the non-liquefied soil crust overlying liquefied soils. Surface damage can include minor or major cracks in the land and tilting of ground.
Land cracking caused by oscillation movements ¹	Backwards and forwards ground movement during earthquake shaking can result in oscillation cracking. Cracks resulting from oscillation are typically minor and isolated.
Undulating land	Undulating land is caused by the uneven subsidence of the ground surface as a result of topographic re-levelling resulting from the liquefaction of underlying soil layers, the ejection of sand and silt at the ground surface, and the uneven volumetric densification of the underlying liquefied soil layers.
Local ponding	Local ground surface subsidence or lowering of the land caused by topographic re-levelling resulting from the liquefaction of underlying soil layers, the ejection of sand and silt at the ground surface, and the uneven volumetric densification of the underlying liquefied soil layers. This results in water forming ponds on the ground surface for extended periods following rainfall events in locations where it did not pond before the CES.
Local ground surface subsidence causing drainage issues	In some areas where residential land has subsided due to topographic re-levelling resulting from the liquefaction of underlying soil layers, the ejection of sand and silt at the ground surface, and the uneven volumetric densification of the underlying liquefied soil layers it has resulted in a decrease in the drainage capacity of the land. This reduction in drainage capacity can be caused by uneven subsidence of the land beneath public services resulting in the water in the drains not flowing properly or the reduced depth to groundwater decreasing the soakage capacity of the ground.
Groundwater springs	New groundwater springs have emerged and are now flowing over the ground surface where this was not happening before the CES. The spring usually occurs at a specific location on residential land.
Inundation by ejected sand and silt	Water, sand and silt is ejected to the ground surface through cracks and penetrations in the non-liquefying crust. The ejected sand and silt may be deposited in isolated mounds, or over large areas on the residential properties including under the dwellings.
<i>Damage involving an increased vulnerability as a result of ground surface subsidence</i>	
Increased liquefaction vulnerability (ILV)	Throughout Christchurch the ground surface has subsided but the groundwater table has typically remained at the same level. Therefore, the ground surface in some areas is materially closer to the groundwater table than prior to the CES. In some areas this reduces the non-liquefying crust thickness (depending on ground conditions). As a result there has been a material increase in the future liquefaction vulnerability of some residential properties.
Increased flooding vulnerability (IFV)	Throughout Christchurch the ground surface has subsided. As a result, there has been a material increase in the future vulnerability to flooding of some sites situated near waterways and in overland flow paths.

¹ Cracking of the non-liquefying crust also results in increased liquefaction vulnerability. However once the cracks are repaired in accordance with the repair methods listed in the Guide to the Settlement of Canterbury Flat Land Claims (EQC, 2013) then the crust integrity will be reinstated back to the pre-CES

crust integrity and hence pre-CES liquefaction vulnerability. This guide is available at <http://www.eqc.govt.nz/canterbury-earthquakes/land-claims/guide-to-settlement-of-cantebury-flat-land-claims>.

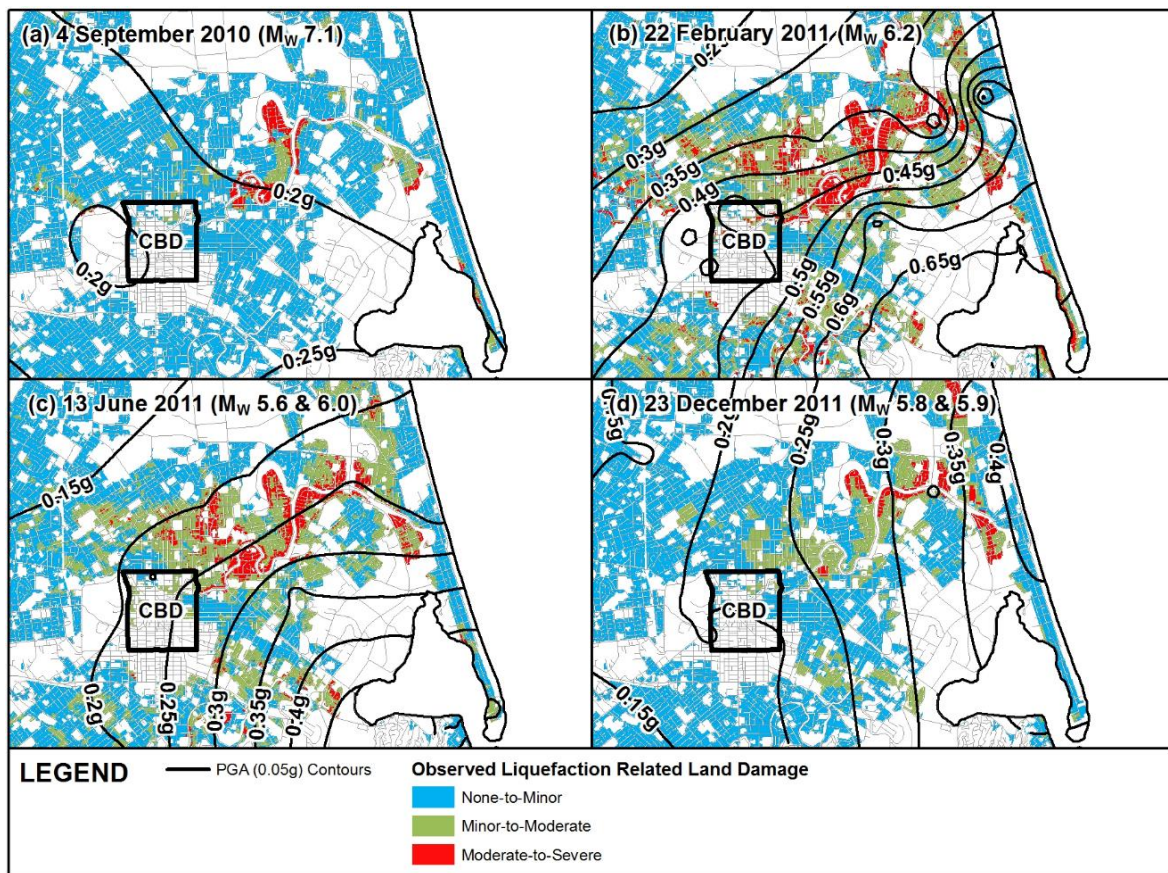


Figure B1.1: Map showing the inferred levels of earthquake shaking and the observed land damage for urban residential properties in Christchurch after the (a) 4 September 2010, (b) 22 February 2011, (c) 13 June 2011 and (d) 23 December 2011 earthquakes

In Figure B1.1 the contour lines for the June 2011 and December 2011 are the estimated PGA contour lines for the main earthquake events on those dates. These do not capture the influence of the PGAs associated with the foreshocks of these events which are relevant to the liquefaction related damage observed. This is discussed in more detail in Section 3.7.3 of the report.

LAND DAMAGE OBSERVATION CATEGORIES

Simplified land damage categories	Land damaged observation categories in Appendix K	CRITERIA / DESCRIPTION
None to Minor	None Observed	<ul style="list-style-type: none"> • No observed cracks, undulation/deformations at the ground surface, and, • No signs of ejected liquefied material at the ground surface, and, • No apparent lateral movement.
	Minor	<ul style="list-style-type: none"> • 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.
Minor to Moderate	Moderate	<ul style="list-style-type: none"> • 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.
Moderate to Severe	Major	<ul style="list-style-type: none"> • Large quantities of ejected liquefied material on ground surface (generally >25% of 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.
	Severe	<ul style="list-style-type: none"> • 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), and, • Ejection of liquefied material at the ground surface may also be observed.
	Very Severe	<ul style="list-style-type: none"> • Extensive lateral spreading (\geq1 m cumulative), and/or, • Large open cracks extending through the ground surface, with very severe horizontal and/or vertical displacements (\geq200 mm), and, • Ejection of liquefied material at the ground surface may also be observed.

Figures B1.2 to B1.3: Photos of land with none-to-minor liquefaction related land damage.

None to minor land damage



Even lawns and undamaged pavers



Undamaged asphalt driveway

None to minor land damage



Undamaged concrete driveway and kerbing



Aerial shot of Broomfield area showing no liquefaction ejecta on the roads or Broomfield Common

None to minor land damage



View of Aston Drive with little damages



View of Centaurus Road with little damage

Figure B1.2: Photos of land with none-to-minor liquefaction related land damage.

None to minor land damage



Flat lawn



Slightly undulating lawn and driveway

None to minor land damage



Slightly undulating lawn



Undulating lawn

None to minor land damage



Undulating lawn



Aerial photo of North New Brighton showing little damage

Figure B1.3: Photos of land with none-to-minor liquefaction related land damage.

Figures B1.4 to B1.11: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Undulating lawns and liquefaction ejecta



Piles of sand along the footpath

Minor to moderate land damage



Undulations on road with ponding water



Liquefaction ejecta pile on road

Minor to moderate land damage



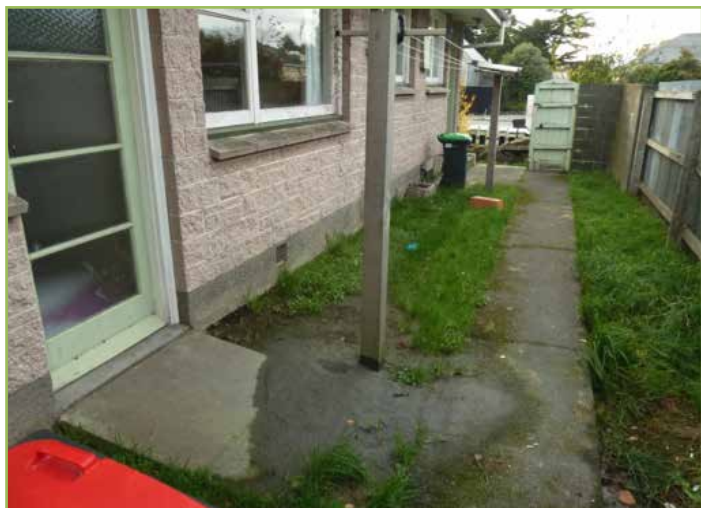
Isolated area of liquefaction ejecta on lawn



Isolated area of liquefaction ejecta on lawn

Figure B1.4: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Liquefaction ejecta around washing line pole



Liquefaction ejecta on lawn

Minor to moderate land damage



Foundation damage



Undulating paving slabs

Minor to moderate land damage



Liquefaction ejecta on lawn



Foundation damage

Figure B1.5: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Foundation damage



Liquefaction ejecta on lawn

Minor to moderate land damage



Liquefaction ejecta on lawn



Liquefaction ejecta in planter

Minor to moderate land damage



Liquefaction ejecta in planter with undulating pavers



Foundation damage

Figure B1.6: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Liquefaction ejecta at a New Brighton Road junction



Aerial photo of liquefaction ejecta at Cashmere High School

Minor to moderate land damage



Liquefaction ejecta on lawn



Liquefaction ejecta on lawn

Minor to moderate land damage



Liquefaction ejecta on lawn



Isolated area of liquefaction ejecta

Figure B1.7: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Damage to asphalt



Liquefaction ejecta on lawn

Minor to moderate land damage



Liquefaction ejecta in piles on road



Undulating paving bricks

Minor to moderate land damage



Isolated area of liquefaction ejecta



Foundation damage

Figure B1.8: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Foundation damage



Liquefaction ejecta on lawn

Minor to moderate land damage



Liquefaction ejecta in many places on lawn



Large area of liquefaction ejecta on lawn

Minor to moderate land damage



Foundation and brickwork damage



Liquefaction ejecta and brickwork damage

Figure B1.9: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Liquefaction ejecta in many areas on lawn



Undulations in lawn

Minor to moderate land damage



Liquefaction ejecta covering driveway



Undulations in paving area

Minor to moderate land damage



Liquefaction ejecta on lawn



Undulations in lawn, liquefaction ejecta removed

Figure B1.10: Photos of land with minor-to-moderate liquefaction related land damage.

Minor to moderate land damage



Foundation damage



Liquefaction ejecta alongside culvert

Minor to moderate land damage



Liquefaction ejecta on lawn



Foundation damage

Minor to moderate land damage



Liquefaction ejecta, dwelling tilting



Liquefaction ejecta, dwelling tilting

Figure B1.11: Photos of land with minor-to-moderate liquefaction related land damage.

Figures B1.12 to B1.14: Photos of land with moderate-to-severe liquefaction related land damage

Moderate to severe land damage



Large patch of liquefaction ejecta



Foundation damage

Moderate to severe land damage



Liquefaction ejecta piles along Androssan Street



Liquefaction ejecta piles along Avonside Drive

Moderate to severe land damage



Liquefaction ejecta around property



Foundation damage

Figure B1.12: Photos of land with moderate-to-severe liquefaction related land damage.

Moderate to severe land damage



Aerial photo showing liquefaction ejecta on Seabreeze Close



Liquefaction ejecta in turning circle of Seabreeze Close

Moderate to severe land damage



Outside of dwelling showing level liquefaction ejecta reached on brickwork and windows



Large amounts of liquefaction ejecta

Moderate to severe land damage



Large amounts of liquefaction ejecta and tilting dwelling



Large amounts of liquefaction ejecta around property

Figure B1.13: Photos of land with moderate-to-severe liquefaction related land damage.

Moderate to severe land damage



Large amounts of liquefaction ejecta



Large amounts of liquefaction ejecta

Moderate to severe land damage



Large amounts of liquefaction ejecta



Large amounts of liquefaction ejecta inside dwelling

Moderate to severe land damage



Close up photo of road damage seen in aerial photo of Woolston



s) Foundation damage, tilting dwelling

Figure B1.14: Photos of land with moderate-to-severe liquefaction related land damage.