Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Review of liquefaction susceptibility for Timaru District

Report No. R20/49
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Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

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Executive summary

Background:

Liquefaction is the process where some soils behave more like a liquid than a solid during strong earthquake shaking. It usually only happens in loose sandy or silty soils that are saturated (below the water table), conditions which generally only occur in geologically young river, stream, lake, estuarine, or beach sediments. Liquefaction will also usually only occur during strong earthquake shaking, when the shaking is so strong it is hard to stand up and things are being knocked over or moved around. Liquefaction can result in damage to buildings and infrastructure (including buried infrastructure) as they sink or tilt into the ground or start floating to the surface, as well as ejection of water and silt onto the ground surface.

Liquefaction caused extensive damage to infrastructure and people's homes during the 2010/11 Canterbury earthquakes and was also reported after other earthquakes in Canterbury such as the 1901 Cheviot, 1922 Motunau, and 2016 Hurunui-Kaikoura earthquakes.

Because of the way sediment is deposited there can be a large difference in liquefaction susceptibility over short distances, so the actual liquefaction susceptibility at a particular site can only be determined through a site-specific geotechnical investigation including testing of the soil. However, general mapping using available geological, geomorphological and groundwater information can indicate areas where liquefaction damage is unlikely, and areas where liquefaction damage is possible and therefore further investigations are warranted before developing or building.

The problem:

Liquefaction susceptibility in Timaru District was assessed in 2013 (McCahon, 2013). Since then, the Ministry of Business, Innovation and Employment (MBIE) has released planning and engineering guidance for potentially liquefaction-prone land in 2017, and higher resolution topographic data has become available for parts of the district. Timaru District Council are reviewing their District Plan, and the existing 2013 liquefaction susceptibility information needed to be reviewed to make sure it was accurate and robust enough to incorporate into the plan with accompanying planning provisions, and that it is consistent with the terminology used in the MBIE guidance.

What we did:

We renamed the 2013 liquefaction susceptibility areas so they are now consistent with the liquefaction vulnerability classes recommended in the 2017 MBIE guidance. We also reviewed the boundaries of the 2013 liquefaction susceptibility areas to ensure they were as accurate as possible, using the most recent topographic information.

What does it mean?

The new liquefaction vulnerability areas are very similar to the 2013 liquefaction susceptibility areas, with only changes to the names of the areas and small changes in the position of the area boundaries.

Liquefaction damage is unlikely in most of the district, as it is underlain by either rock or hill soils, or by older, well-consolidated river sediments with a relatively low groundwater table. Liquefaction damage is possible during strong ground shaking in small parts of the district that are underlain by geologically young, poorly consolidated river or estuarine sediments with a relatively high groundwater table. These areas are generally adjacent to the major rivers in the district, or around small coastal lagoons and estuaries.

We recommend that Timaru District Council use the reviewed liquefaction vulnerability information when implementing planning provisions and building consent processes.

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1 Introduction

Liquefaction is a process whereby some soils behave more like a liquid than a solid during strong earthquake shaking. It is caused by water pressure within the soil becoming so high that the soil particles start to 'float'. This can cause:

- damage to buildings and infrastructure as they sink or tilt into the ground
- damage to buried infrastructure such as underground tanks, as they start to float
- sideways movement of land towards unsupported edges like riverbanks (lateral spreading)
- ejection of water and silt onto the ground surface to form 'sand boils' or 'sand volcanoes' or, in extreme cases, sheets of sand and silt.

Soils must be saturated (below the water table) and predominantly sandy or silty to liquefy. These conditions generally occur in geologically young river, stream, lake, estuarine, or beach sediments. Liquefaction usually only occurs in susceptible soils when the earthquake shaking is strong enough to move furniture and make it hard to stand up.

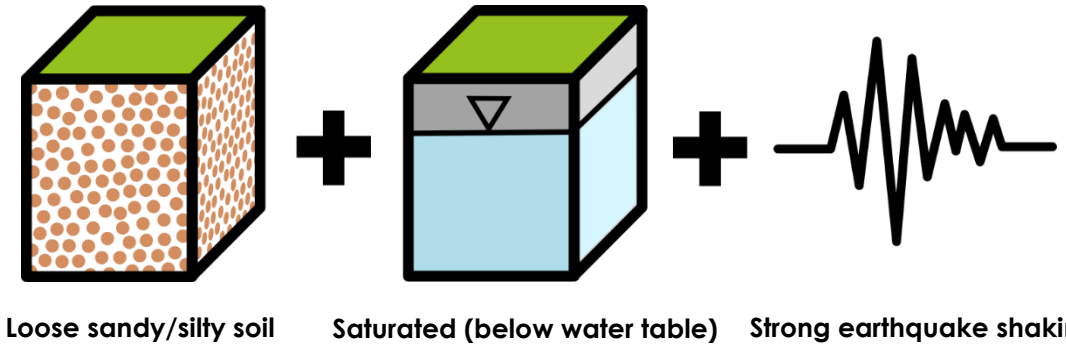


Figure 1-1: Requirements for liquefaction to occur

Liquefaction and lateral spreading caused extensive damage to infrastructure and people's homes in coastal Waimakariri, Christchurch and Selwyn during the 2010/11 Canterbury earthquakes and has also been reported after other earthquakes in Canterbury such as the 1901 Cheviot, 1922 Motunau and 2016 Hurunui-Kaikoura earthquakes. There are no known historic occurrences of liquefaction in Timaru District; ground shaking in Timaru District from historic earthquakes has generally been below the threshold that we would expect liquefaction to occur.

Because of the way sediment is deposited there can be a large difference in liquefaction susceptibility over short distances, so the actual liquefaction susceptibility at a particular site can only be determined through a site-specific geotechnical investigation including testing of the soil. The liquefaction hazard can then be determined by incorporating the susceptibility of the soil with the likelihood of strong earthquake shaking. However, general mapping using available geological, geomorphological and groundwater information can indicate areas where liquefaction damage is unlikely, and areas where liquefaction damage is possible and further investigations are warranted before developing or building.

The risk of damage from liquefaction can be mitigated by:

- treating the ground to reduce its susceptibility to liquefaction (e.g. compacting the ground)
- using enhanced foundations for buildings to reduce the amount of damage to the building if liquefaction occurs
- using measures such as minimum lot sizes to reduce the number of houses exposed to liquefaction in susceptible areas.

In very susceptible areas the cost of mitigating the risk may become uneconomic, and it may be better to avoid the area for development.

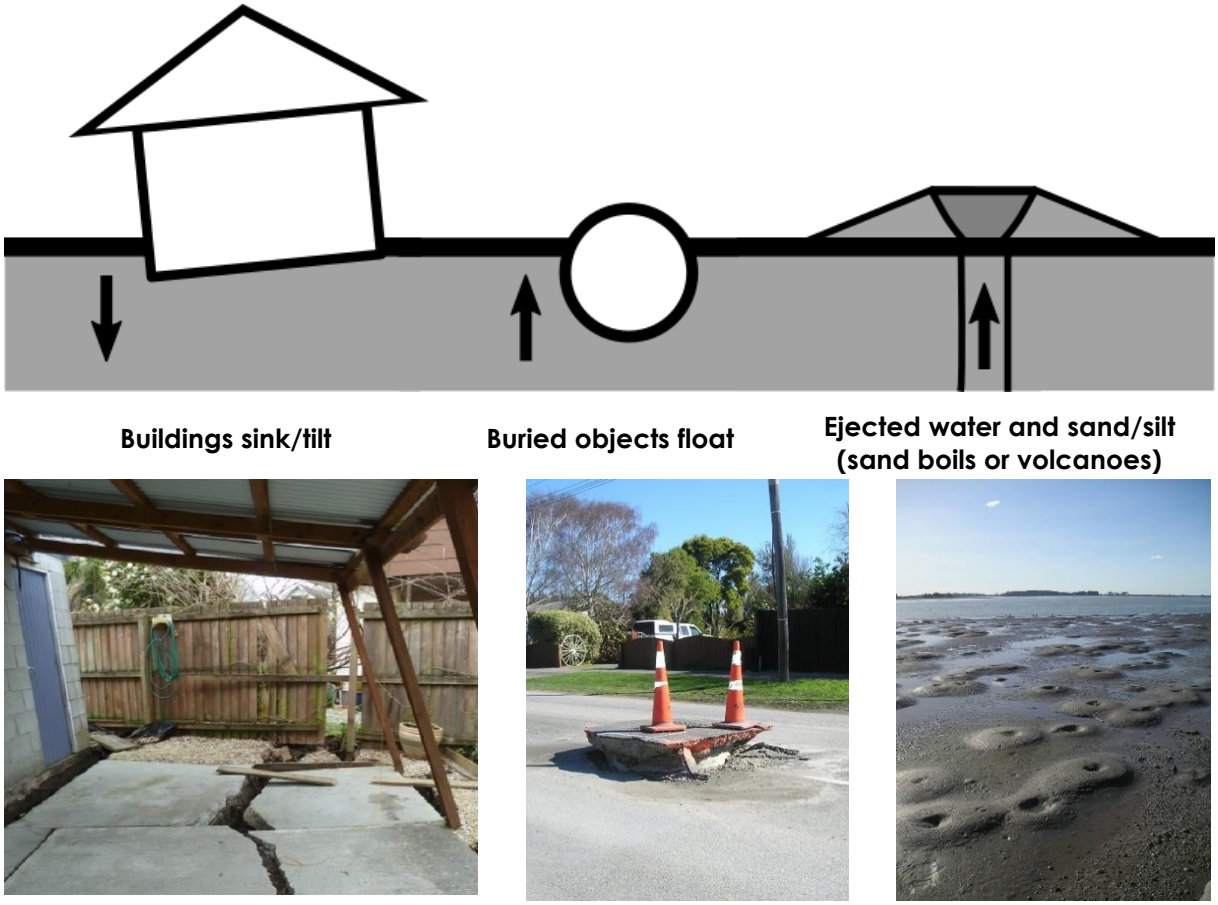


Figure 1-2: Potential effects of liquefaction

A note on terminology: Liquefaction *susceptibility* describes how susceptible the ground is to liquefaction during strong earthquake shaking, which depends primarily on the characteristics of the ground and how deep the water table is. Liquefaction *hazard* is how likely liquefaction is at a particular location, which depends on the liquefaction susceptibility as well as how likely strong earthquake shaking is, which varies around New Zealand. Liquefaction *risk* is the liquefaction hazard combined with the potential consequences. For example, the liquefaction risk can be reduced in a liquefaction-prone area by increasing lot sizes – this does not change the likelihood of liquefaction occurring but decreases the potential consequences by having less houses exposed to liquefaction damage.

2 2013 liquefaction susceptibility assessment

Areas of different liquefaction susceptibility in Timaru District were mapped by Geotech Consulting as part of the Timaru District Engineering Lifelines Project Earthquake Hazard Assessment in 2001 (Yetton and McCahon, 2001). These areas were mapped at a scale of 1:250,000 using the best available geological and soils information, with some groundwater level data, but no geotechnical soil testing.

Following the 2010/11 Canterbury Earthquakes, Timaru District Council requested that the 2001 liquefaction susceptibility maps be reviewed, particularly in areas of development pressure in Geraldine and Washdyke. Environment Canterbury commissioned Geotech Consulting Ltd to undertake this work, which involved using updated geological mapping (Aoraki 1:250,000 geological map, published by GNS Science in 2007) as well as new borelog data and several test pits and cone penetration tests in Geraldine, Washdyke and Timaru township. The report *Liquefaction Hazard in Timaru District* was completed in 2013, peer reviewed by Golder Associates Ltd, and was provided to Timaru District Council in March 2014. The maps were compiled at a scale of 1:25,000 for Timaru township and 1:250,000 for the remainder of the district.

The liquefaction susceptibility areas are shown in Figures 2-1 and 2-2. The 2013 report confirmed that most of Timaru District has low to no liquefaction susceptibility, because it is underlain by either rock or river sediments comprising mostly non-liquefiable gravels.

The areas of highest susceptibility to liquefaction are the valley bottoms close to the coast at Timaru between Washdyke Lagoon and Saltwater Creek where looser fine-grained sediments and shallow groundwater are present. These small areas were classified as ‘moderate liquefaction potential’. Analysis of cone penetrometer test data in these areas suggested significant liquefaction is possible in a strong earthquake with resulting damage to buildings and infrastructure.

In Caroline Bay, limited cone penetrometer testing indicated that the sand deposits that have formed due to recent coastal progradation are too dense to present any significant liquefaction problem. The recent beach deposits south of the Timaru Port also appeared to be too coarse and dense to experience much liquefaction. These areas were classified as ‘low liquefaction potential’. Holocene-aged (less than 10,000 years old) river sediments along the rivers and floodplains in the district were also classified as ‘low liquefaction potential’. The soils in these areas are predominantly sandy gravel but may include lenses of sand and silt, and the groundwater table is relatively shallow. It is possible that areas of saturated sand in these areas may liquefy with strong earthquake shaking, but these would be isolated and limited in extent.

Elsewhere, the older, dense gravel-dominated soils underlying the plains and infilling the larger river valleys are much less susceptible to liquefaction, and the groundwater table is relatively deep. Any liquefaction would be confined to very small local areas where there may be a saturated sand lens within the gravel. These areas were classified as “very low liquefaction potential”.

Rocks and hill soils were classified as “extremely low to no liquefaction potential”.

The 2013 report provides more detailed information on each susceptibility area, as well as recommended liquefaction assessments and potential mitigation options for each area.

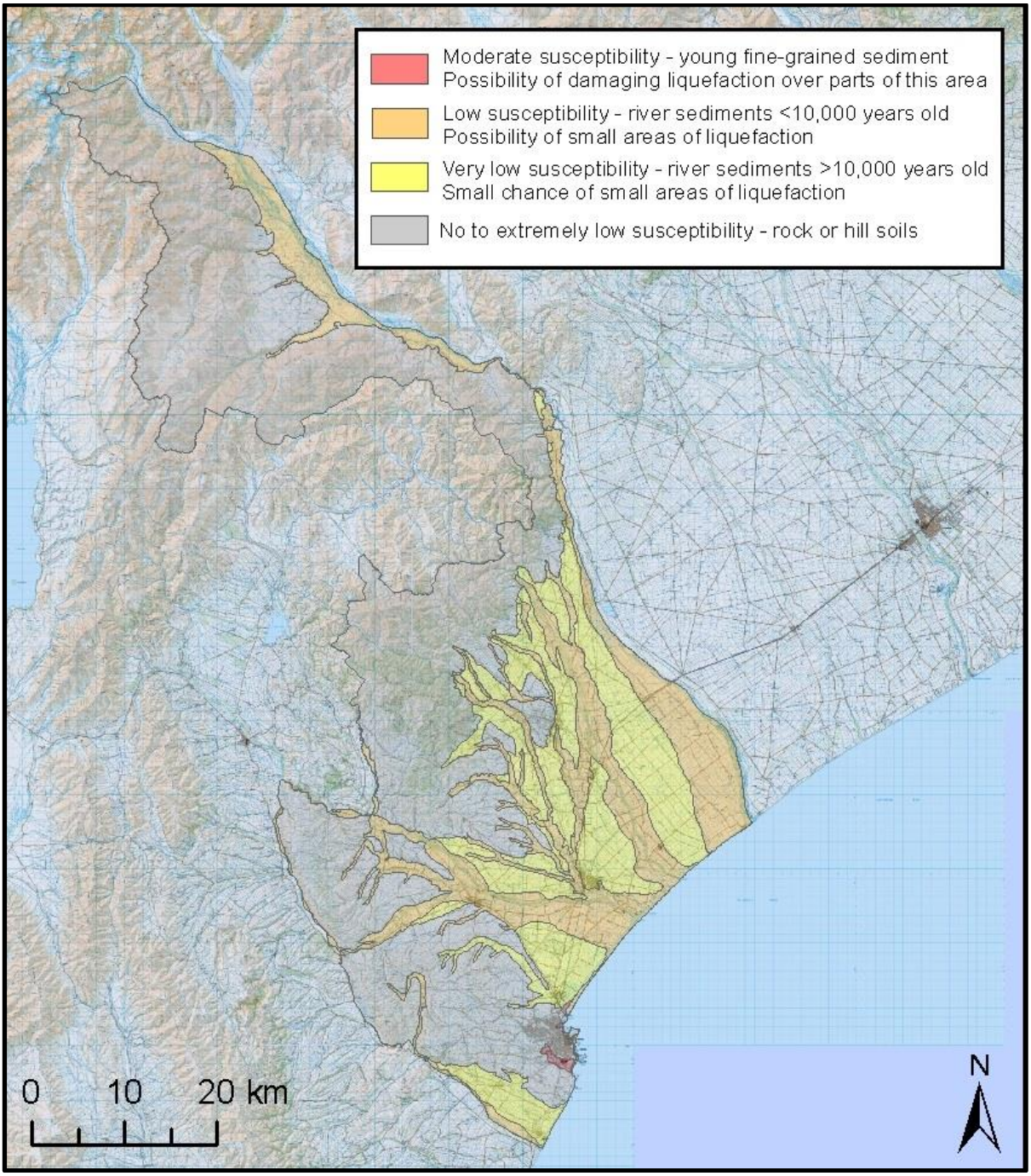


Figure 2-1: Liquefaction susceptibility areas for Timaru District mapped by Geotech Consulting Ltd in 2013

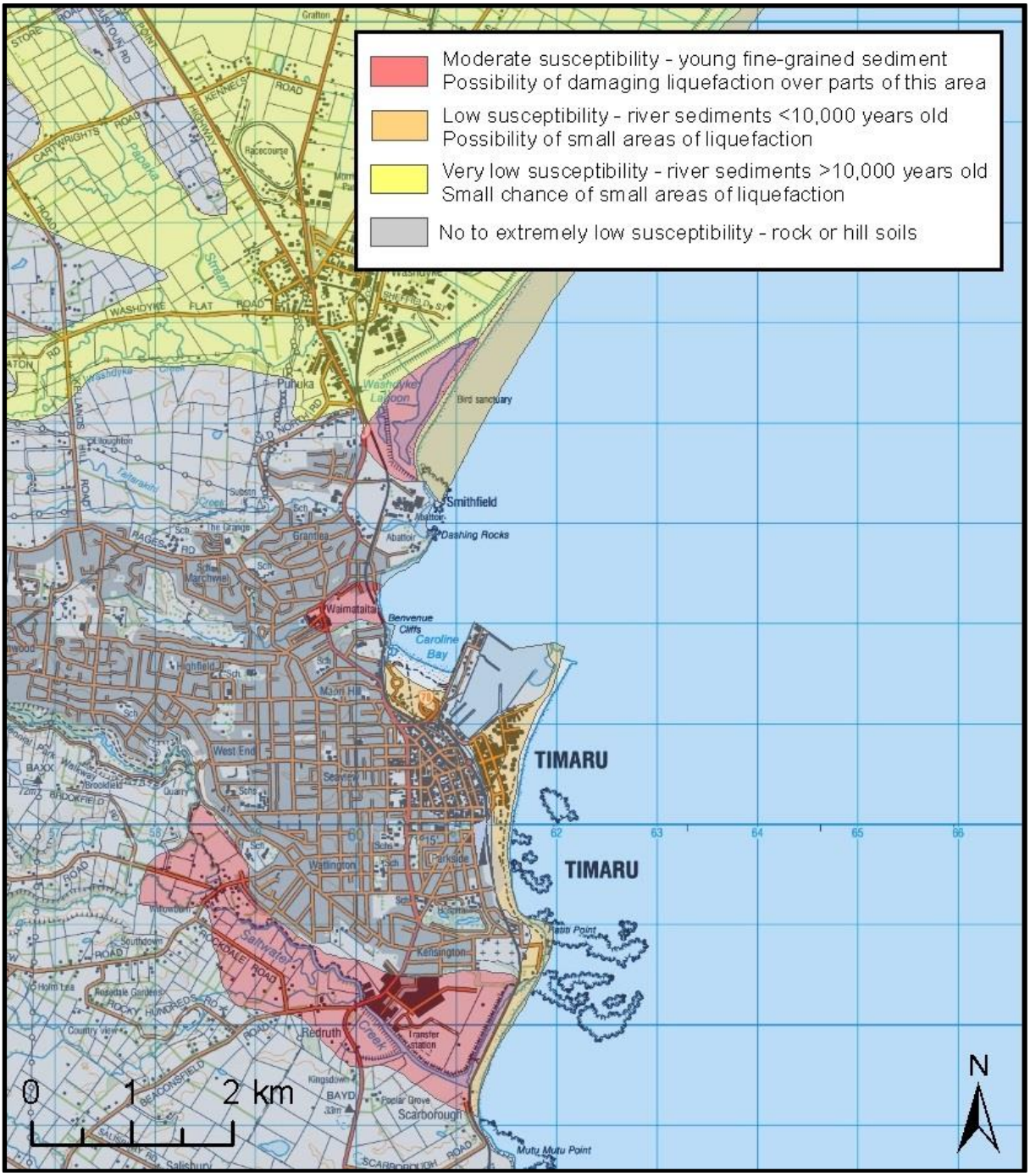


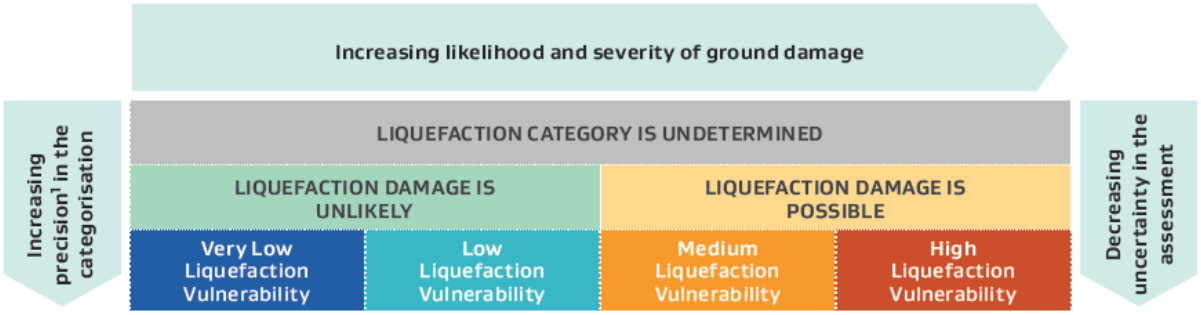
Figure 2-2: Liquefaction susceptibility areas for Timaru township mapped by Geotech Consulting Ltd in 2013

3 Liquefaction vulnerability categories

3.1 Repurposing the 2013 liquefaction susceptibility areas using 2017 MBIE guidance framework

The Ministry of Business, Innovation and Employment released *Planning and engineering guidance for potentially liquefaction-prone land* in 2017. The guidance recommends classifying land into liquefaction vulnerability categories based on the degree of damage that could be expected to occur in an area during strong earthquake shaking. It then adopts a risk-based approach whereby different levels of geotechnical investigation are recommended to determine the liquefaction hazard depending on the vulnerability category and the scope of the proposed development, and it provides guidance on using district plan provisions and building consent processes to mitigate the liquefaction risk. MBIE's vulnerability categories are given in Table 3-1.

Table 3-1: Ministry of Building, Innovation and Employment's liquefaction vulnerability categories (Table 1.1 of the MBIE guidance)



Note:

1 In this context the 'precision' of the categorisation means how explicitly the level of liquefaction vulnerability is described. The precision is different to the accuracy (ie trueness) of the categorisation.

The level of information used to determine the 2013 liquefaction susceptibility areas (geology, geomorphology, some groundwater, but little geotechnical testing of soils[1]) means that the liquefaction vulnerability can only be divided into 'liquefaction damage is unlikely' or 'liquefaction damage is possible'. There is not enough geotechnical data to further refine areas into the four 'very low', 'low', 'medium' or 'high' liquefaction vulnerability categories with certainty. However, the MBIE guidance does allow that areas underlain by rock can be classified with some confidence as 'very low' liquefaction vulnerability.

We have aligned the 2013 liquefaction susceptibility areas with the terminology given in the MBIE guidance as follows in Table 3-2.

The 2013 'extremely low to no' liquefaction susceptibility areas have been renamed 'liquefaction damage is unlikely (very low liquefaction vulnerability)' areas because these areas are underlain by rock or hillslopes so it can be said with some confidence that the liquefaction vulnerability is very low as defined in the MBIE guidance. The 2013 'very low' liquefaction susceptibility areas have been renamed 'liquefaction damage is unlikely' areas; there is not enough geotechnical information to further categorise these areas into 'very low' or 'low' liquefaction vulnerability areas. These are areas underlain by river sediments older than 10,000 years, which are predominantly non-liquefiable gravel. There may be some small lenses of sands and silts in these sediments but the water table in these areas is generally more than 5 metres deep, so any small areas of liquefaction are unlikely to have damaging consequences at the ground surface.

[1] This equates to a 'Level A – Basic Desktop Assessment' or in areas where some subsurface investigations were done a 'Level B – Calibrated Desktop Assessment' in the 2017 MBIE guidance.

The 2013 'low' and 'moderate' liquefaction susceptibility areas have both been renamed 'liquefaction damage is possible' areas. There is, strictly speaking, not enough geotechnical information to further categorise these areas into 'medium' or 'high' liquefaction vulnerability areas. However, it would be useful to retain some distinction between the original 'low' and 'moderate' liquefaction susceptibility areas because the geological processes involved in their formation are different and therefore the vulnerability to liquefaction is higher in the original 'moderate' area than the 'low' area.

Keeping some distinction between the two 'liquefaction damage is possible' areas (fine-grained estuarine sediment vs river sediment) means that the level of site-specific assessment required as part of a consent can be more appropriately matched to the actual hazard posed. This will mean that consent processes, for individual building consents in particular, may not be too onerous given the relatively low likelihood of liquefaction in most of the district. We have provided Timaru District Council with specific guidance for implementing this approach, based on the MBIE guidance (see sections 4.1 and 4.2).

Table 3-2: Liquefaction vulnerability categories for Timaru District

2013 liquefaction susceptibility area	Geology/ geomorphology	2017 MBIE vulnerability category
Moderate	Fine-grained, mostly estuarine sediment younger than 10,000 years	Liquefaction damage is possible
Low	River sediment younger than 10,000 years (active riverbeds and floodplains) and beaches; predominantly gravel	Liquefaction damage is possible
Very low	River sediment older than 10,000 years; predominantly gravel	Liquefaction damage is unlikely
Extremely low to no	Rock or hillslopes	Liquefaction damage is unlikely (Very low liquefaction vulnerability)

3.2 Refining the liquefaction vulnerability category boundaries

As part of reviewing the suitability of the 2013 liquefaction susceptibility areas for use in the Timaru District Plan we also adjusted the area boundaries to ensure they were as accurate as possible with respect to the underlying geology and geomorphology. The original 2013 liquefaction susceptibility areas were drawn using primarily 1:250,000 scale geological map units and were therefore relatively coarse and the boundaries did not always follow obvious geomorphological boundaries such as terrace edges.

Several LiDAR (very high resolution topography) datasets were acquired for parts of Timaru District between 2010 and 2018 (Figure 3-1). These were used to refine the 1:250,000 susceptibility area boundaries where available and in areas with no lidar the 1:50,000 topomap topographic data and aerial photos were used.

Figures 3-2 and 3-3 show examples in urban and rural areas where the area boundaries were adjusted so that they better reflected the actual underlying geomorphology. In Figure 3-2 the boundaries of the moderate liquefaction susceptibility area at Saltwater Creek, based on the 1:250,000 geological map unit boundaries, did not accurately reflect the underlying geomorphology with the boundary going uphill in places, onto areas of rock and very old sediment, to almost the 20 metre contour. The new boundary follows the base of the hills in these areas, using recent LiDAR, which more accurately reflects the area of fine-grained stream and estuarine sediments in the valley bottom where liquefaction damage is possible.

Figure 3-3 shows the area around Limestone Valley near Cave where there is no available LiDAR. The boundary of the original low liquefaction susceptibility area, based on the 1:250,000 geological map units, was adjusted to run along the obvious base of the hills shown on the 1:50,000 topographic maps, to better reflect the boundary between the 'liquefaction damage is possible' and 'liquefaction damage is unlikely (very low liquefaction vulnerability)' areas.

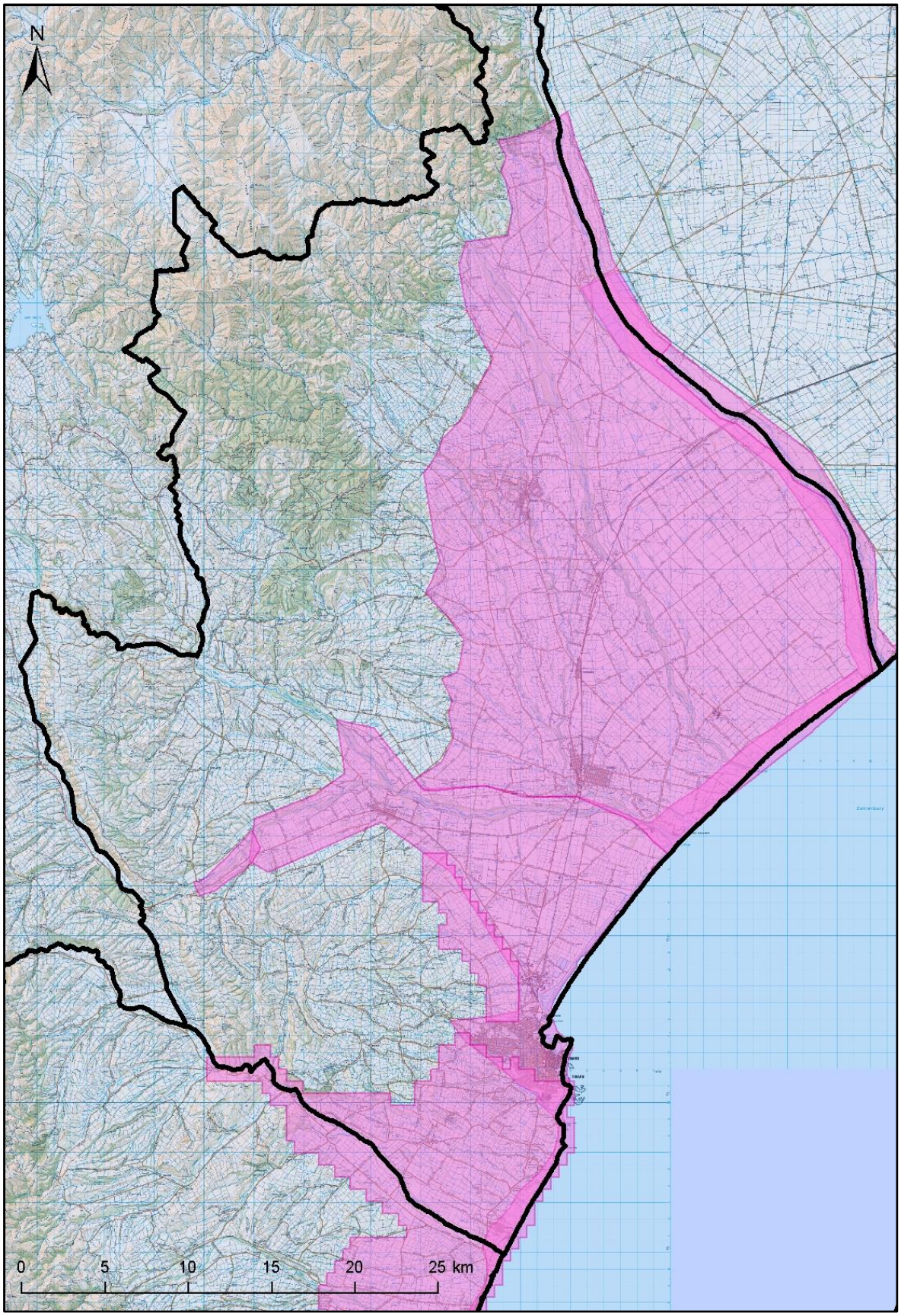


Figure 3-1: LiDAR (high resolution topography) datasets acquired between 2010 and 2018 used to refine the liquefaction vulnerability area boundaries

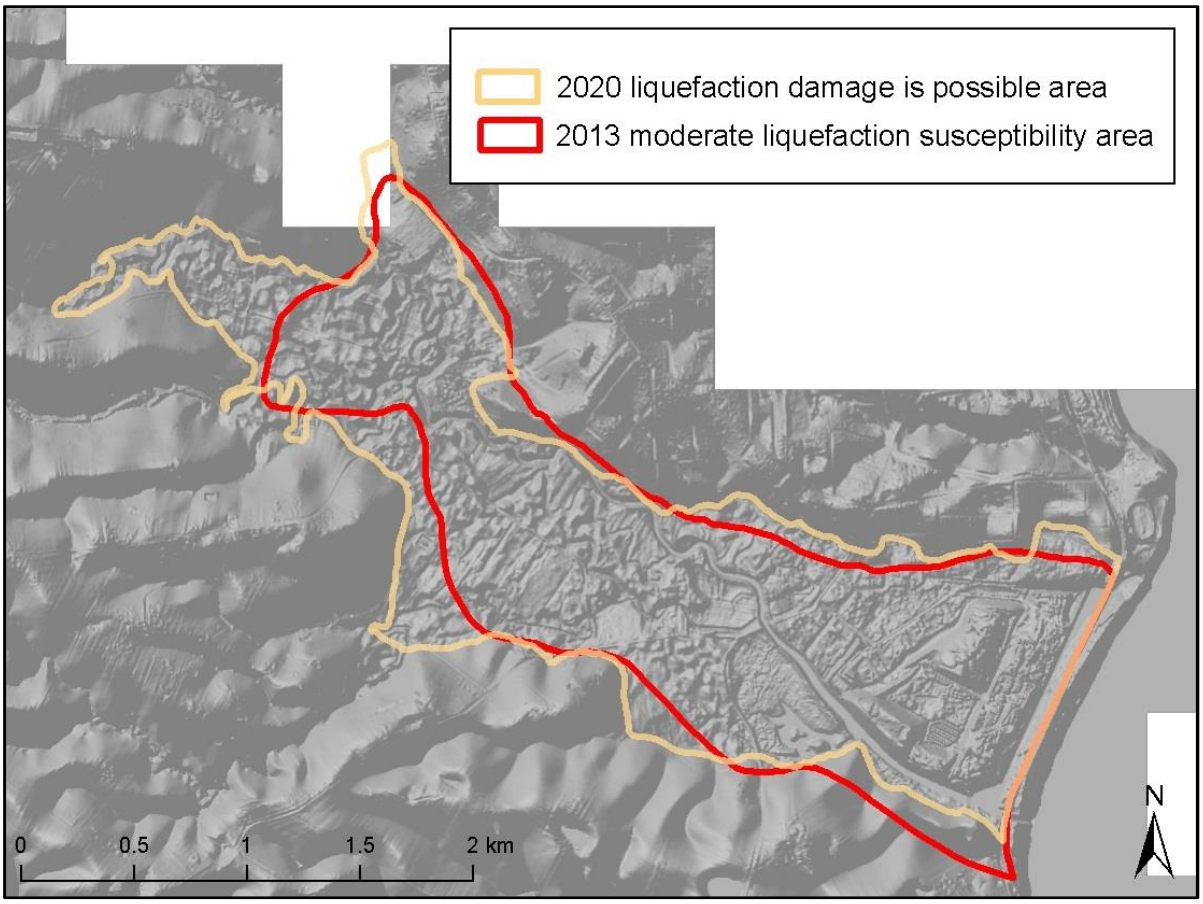


Figure 3-2: **Boundary of the liquefaction damage is possible area at Saltwater Creek, immediately south of Timaru township, compared to the 2013 boundary of the moderate liquefaction susceptibility area. The background is the Timaru Waimate Waitaki River 2018 lidar dataset (FPFA1204)**

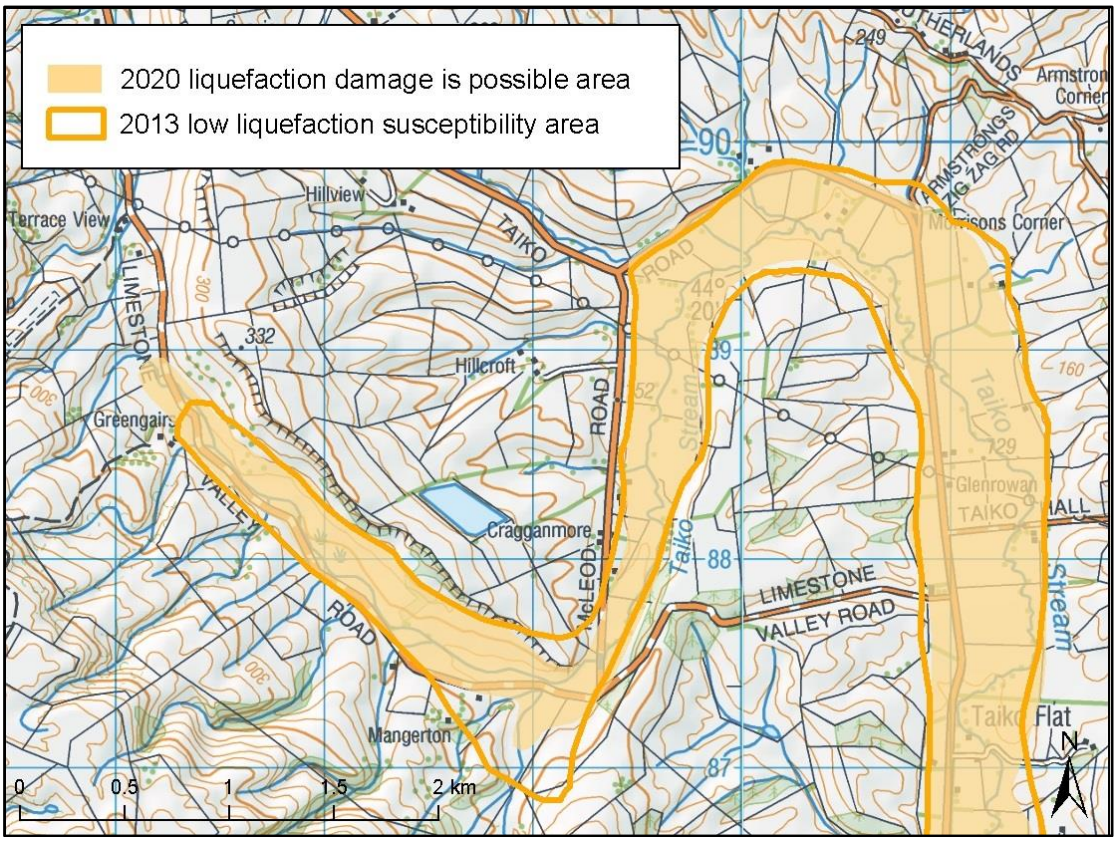


Figure 3-3: Boundary of the liquefaction damage is possible area at Limestone Valley Road compared to the 2013 boundary of the low liquefaction susceptibility area

The revised liquefaction vulnerability categories are shown in Figures 3-4 and 3-5. Note that the valley bottom area along the lower end of Taitarakihi Stream in Timaru township was not included in the 2013 moderate liquefaction susceptibility area but given the fine-grained nature of the sediment and the shallow groundwater table here it has been included in the new 'liquefaction damage is possible' area. The full GIS dataset has been provided to Timaru District Council and is also available to view at and download from Canterbury Maps at https://canterburymaps.govt.nz.

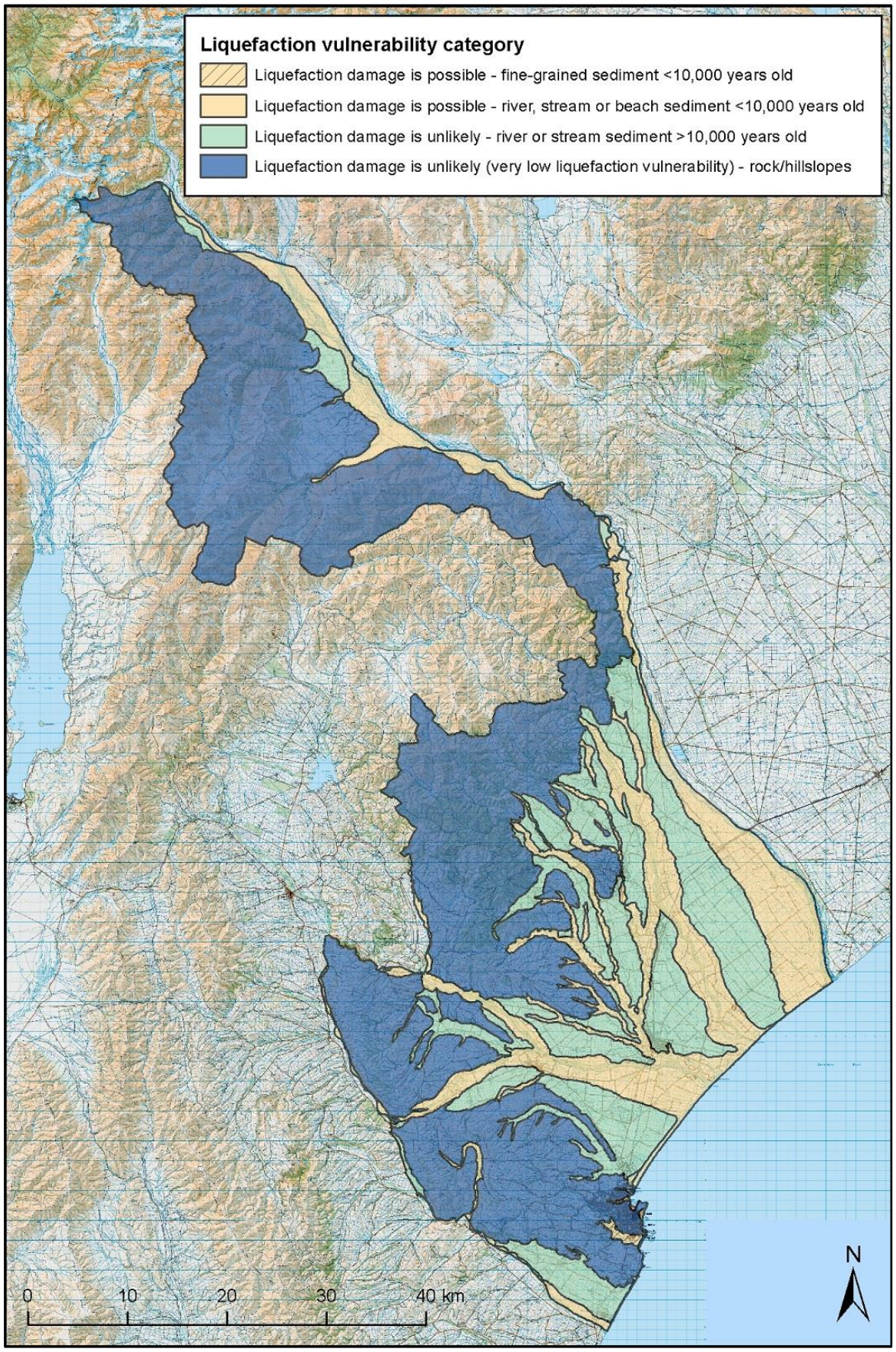


Figure 3-4: Liquefaction vulnerability categories for Timaru District

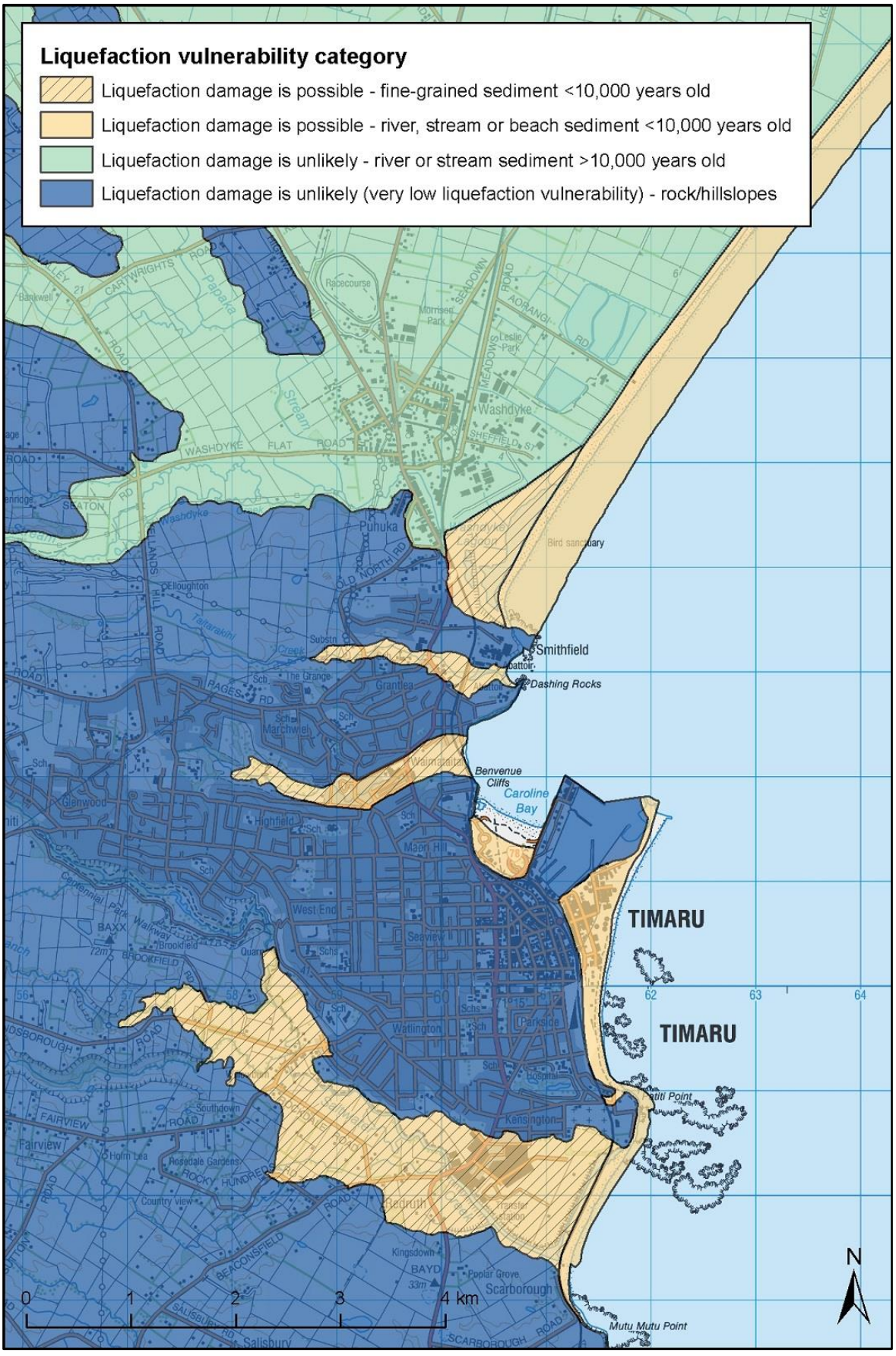


Figure 3-5: Liquefaction vulnerability categories for Timaru township

4 Using the liquefaction vulnerability classes

4.1 Land use planning

The 2017 MBIE guidelines recommend that liquefaction risk be managed through district plan provisions (among other things), for example requiring specific liquefaction assessments for subdivisions and mitigation measures such as more robust foundations if necessary.

Policy 11.3.3 of the Canterbury Regional Policy Statement also requires territorial authorities to set out objectives and policies in district plans to manage new subdivision, use and development of land in areas known to be potentially susceptible to liquefaction and lateral spreading, and provides for territorial authorities to also include methods, such as rules, to do this. It also requires territorial authorities to ensure that the risk of liquefaction and lateral spreading hazards are assessed before any new areas are zoned or identified, in a district plan, in ways that enable intensification of use, or where development is likely to be damaged and/or cause adverse effects on the environment.

We recommend that Timaru District Council uses the information in this report to help manage liquefaction and lateral spread risk through their District Plan review. The 2017 MBIE guidance gives recommendations on this process and we have provided Timaru District Council with specific guidance based on the revised liquefaction vulnerability categories and the MBIE guidance[2].

4.2 Building consenting

From November 2021 liquefaction risk will also be managed through the building consent process. The definition of 'good ground' under the Building Code will be amended to explicitly include ground that is not prone to liquefaction and/or lateral spreading for the whole of New Zealand (it currently only applies to Waimakariri and Selwyn districts and Christchurch City). This means that Building Consent Authorities will need to manage the liquefaction risk in areas prone to liquefaction as part of the building consent process by requiring more robust foundations than the standard B1/AS1 solutions if necessary.

We recommend that Timaru District Council uses the information in this report to help identify where liquefaction susceptibility should be considered during the Building Consent process. The 2017 MBIE guidance gives recommendations on this process and we have provided Timaru District Council with specific guidance based on the revised liquefaction vulnerability categories and the MBIE guidance[3].

4.3 Land Information Memoranda (LIMs) and Land Information Requests (LIRs)

The 2017 MBIE guidance only deals with Resource Management Act and Building Act aspects of liquefaction risk management, and therefore does not comment on using Land Information Memoranda (LIMs) under the Local Government Official Information and Meetings Act 1987.

Information that is provided in a District Plan does not legally need to be provided in a LIM as well. However, we recommend that the liquefaction vulnerability information within this report is provided on LIMs so that potential purchasers are aware of the information.

The information will be included on Land Information Requests (LIRs), which are Environment Canterbury's non-statutory equivalent of a LIM.

4.4 Emergency management and engineering lifelines planning

The revised liquefaction vulnerability categories will be useful for emergency management and engineering lifelines planning, as they show the areas most vulnerable to liquefaction damage.

[2] Memo from Helen Jack to Mark Geddes, Planning Manager, Timaru District Council, dated 29 June 2020.
[3] As above.

From an engineering lifelines planning point of view, the most vulnerable areas to liquefaction damage are those small pockets of coastal stream, estuarine and lagoon sediments in and near Timaru township. The 2010/11 Canterbury earthquakes showed that the greatest damage to buried three water assets occurred in the areas of extensive liquefaction. Several resources, listed in the 2017 MBIE guidance, give detailed learnings and recommendations for building infrastructure networks that are more resilient to liquefaction damage.

5 References

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