# LIQUEFACTION HAZARD IN HURUNUI DISTRICT

Report for

**Environment Canterbury**
**&**
**Hurunui District Council**

Report prepared by GEOTECH CONSULTING LTD

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The liquefaction potential maps contained in this report are regional in scope and detail, and should not be considered as a substitute for site-specific investigations and/or geotechnical engineering assessments for any project. Qualified and experienced practitioners should assess the site-specific hazard potential, including the potential for damage, at a more detailed scale.

# LIQUEFACTION HAZARD IN HURUNUI DISTRICT

## Contents



## Appendix

# 1 Introduction

The magnitude 7.1 4 September 2010 Darfield (Canterbury), the magnitude 6.3 22 February 2011 Christchurch, and the magnitude 6.0 13 June earthquakes caused widespread damage in the greater Christchurch area and parts of north and mid Canterbury. Much of the damage to residential buildings and infrastructure was caused by liquefaction and lateral spreading in areas close to rivers, wetlands and estuaries.

Several liquefaction studies have been completed for parts of the Canterbury region over the last 15 years, including district-scale mapping of liquefaction susceptibility for most territorial authorities in the region. However, no district-scale liquefaction susceptibility mapping has been undertaken for Hurunui District to date. This information is required for Hurunui District Council's District Plan review, asset management, emergency management planning and, potentially, resource consent and building consent processes.

The purpose of this report is to present a district-scale map to define areas of different liquefaction susceptibility within Hurunui District. The report and map cover the area of Hurunui District only. The report and map use primarily publically available geological information and limited borehole data, in a similar way to that done as part of earthquake hazard assessments in other districts within Canterbury.

# 2 Liquefaction Phenomena

Loose granular soils tend to densify on strong shaking. However, if the soil is saturated, water in the voids prevents the movement of the particles into a denser state. As a result the pore water pressure increases, and if the shaking is strong and sustained enough, then the pore water pressure can markedly reduce the friction between soil grains and lead to a reduction and/or loss of strength. The pore water pressure increase occurs progressively over a number of shaking cycles so for earthquakes of similar shaking intensity, the extent of liquefaction is greater for those of longer duration.

Liquefaction induced soil deformation can cause:

- Flow failure, where ground on even very gentle slopes moves laterally
- Ejection of sand and water onto the ground surface
- Post-liquefaction consolidation, with consequent ground settlement
- Large ground oscillations during the earthquake.

Damage from liquefaction commonly includes:

- Flotation of buried structures such as manholes, storage tanks, and large pipelines
- Lateral spreading of ground on gentle slopes with resultant ground fissuring, stretching and shear damage to services and structures.
- Settlement of large areas due to consolidation
- Differential settlement, which can damage services and structures
- A foundation failure as the liquefied soil loses its shear strength and its ability to support structures.
- Damage to fittings and contents from inundation by ejected water and silt.

Liquefaction can occur in a range of soils from silts to gravelly sand. However, it is most likely to occur in saturated, relatively uniform fine sands and coarse silts in a loose state, at depths less than 10 to 15m below ground level, and where the water table is within about 5m of the surface. Typically only geologically recent (Holocene age) sediments are susceptible to liquefaction because consolidation and cementation tends to be more developed in older sediments.

More details on seismic liquefaction and effects on lifelines can be found in chapter 3 of *Risks and Realities* (CAE, 1997).

## 3 Historical Liquefaction in the District

Liquefaction within Hurunui District was reported from the 1901 and the 1922 Motunau earthquakes.

The 1901 Cheviot earthquake was M 6.9 +/- 0.2, centred near Parnassus. Shaking of MM VII was recorded in Christchurch, greater shaking would have occurred in the Leithfield and Amberley areas, and MMIX would have occurred in the epicentral area through to Cheviot (see Appendix for explanation of MM intensities). Contemporary newspapers and scientific papers contain several reports of ejected sand and water in the Parnassus area, and other incidents of ground movement which were almost certainly liquefaction induced lateral spreading. Phenomena consistent with minor liquefaction was reported at Leithfield Beach (and there was significant liquefaction further south at Kaiapoi).

The Motunau earthquake of 1922 was smaller (M 6.4) but produced shaking intensities of MM IX in the Motunau and Waipara areas decreasing to about MM VII by Rangiora. It appears from press reports that water ejection occurred behind the sandhills at Waikuku, south of the district, and liquefaction leading to loss of soil strength caused a tree to topple and motor cars to become bogged at Leithfield Beach.

The Canterbury earthquake sequence of 2010 – 2011 produced extensive liquefaction in the Selwyn, Christchurch City and Waimakariri Districts. Aerial photographic and satellite imagery interpretation for surface liquefaction has been carried out by GNS Science for the Canterbury area. Their draft map for the 4 September 2010 M 7.1 Darfield earthquake shows relatively extensive liquefaction around the Ashley River – Saltwater Creek estuary and river mouth area, a short distance south of the Hurunui District boundary. Small areas up to 1.5 km into the District are also shown. It is not known whether any of this has been verified on site. No reports of liquefaction from this earthquake elsewhere in Hurunui District are known. The smaller magnitude (M6.3) Christchurch earthquake of 22 February 2011 produced less liquefaction in Waimakariri and Selwyn districts and there is no indication of liquefaction within Hurunui District with this event.

## 4 Liquefaction Susceptibility in the Hurunui District

As liquefaction is generally confined to geologically recent sediments with high water tables, an initial screening of susceptible areas can be made from the geology of the district. The mountain lands in the north and west of the district can be excluded as being underlain with rock or hillsoils.

Most of the more populated areas of the district are on flatter terrain formed on alluvial deposits from the major rivers. Much of the Hurunui district landscape is made from large scale folding of the underlyng rock which forms alternating basins elevated hill country. The basins are infilled with predominantly gravel from the Waiau River (Hamner, Waiau – Culverden, and Parnassus plains), Hurunui River (Culverden basin and lower valley) and the Waipara River (Waipara area) and their tributaries. The Kowai River has also formed alluvial fan surfaces in the south east of the district. Most of this alluvium was deposited during the glacial periods, when glaciers provided vast quantities of gravelly sediment to the river systems. Because of the age and coarse grading of this alluvium, there is little liquefaction potential within these areas.

About 6,500 years ago, the sea level reached a maximum of about 2 m above current level. For much of the coastline in the district the steep hillsides would not have been markedly affected by this, but south of the Waipara River, the higher sea level eroded a coastal cliff across the ends of the alluvial fans between the Waipara and Ashley rivers. Subsequently, the coastline retreated seaward as sediment brought down by the rivers was deposited along the shore. There is therefore a wedge of recent sediment overlying the 6,500 year old seabed and original fan surface along this section of coast, and thinner veneers of alluvium over the lower flood plains of the rivers. These areas are likely to be the most susceptible to liquefaction, in particular the coastal soils which are a complex inter-layering of alluvial silts, sands and gravels with beach, estuarine and marine deposits. It is this south eastern extremity of the district where liquefaction is most likely. This area is included in the review of liquefaction hazard information for

Christchurch City, Waimakariri, and Selwyn districts currently being undertaken by Environment Canterbury and the Natural Hazards Research Platform.

Other coastal areas with recent sediment are very restricted. They include the coastal margin at the mouth of the Conway River between Claverly and Conway Flat, The mouth of the Waiau River (uninhabited), Gore Bay, Hurunui river mouth and Motunau. The major river mouths are gravel dominated, but the smaller rivers at Gore Bay and Motunau carry finer sediment from catchments with tertiary aged sediments as well as the harder greywacke basement rock.

## 5 Liquefaction Potential Zones

Figure 1 is a map of Hurunui District, indicating those areas where liquefaction could occur. The map shows four zones of liquefaction potential. The boundaries between these zones are approximate only. The location of any site within one of these zones does not imply that liquefaction will, or will not occur, but it designates the relative susceptibility. For important structures a site specific investigation is required to determine the actual degree of hazard.

The map is shown at greater scale and with more detail in Figures 2 and 3.

These maps are essentially taken from geological maps of the district by grouping Holocene and Pleistocene aged soils into two zones, adding a third coastal zone and zoning the remaining hill and mountain country as a fourth zone. No field check has been carried out, and some of the Pleistocene soils making up zone 3 will be elevated or rolling topography where water tables and soil grading make liquefaction extremely unlikely. The zones are therefore generalised only and can not be used for prediction at any specific site.

**Zone 1** is the south eastern coastal margin. It is composed of a complex inter-layering of gravels, sand, and silt, of marine, estuarine and alluvial origin. Environment Canterbury well log data in this coastal strip contains 29 well logs. Of these only six show sand layers, which may be susceptible to liquefaction, with the remainder of the logs recording predominantly gravel or sandy gravel with liquefaction less likely. There is no known in situ geotechnical data within the district, but parts of the same general geomorphic formation further south in Waimakariri district is known to have a potential for extensive liquefaction. This zone is likely to have the greatest extent of liquefiable soils in the district, but it is clear that only parts of the zone are susceptible. If liquefaction hazard is to be considered for any site within this zone, appropriate site investigation and liquefaction analysis is recommended.

The boundary to this zone is clearly defined by the abandoned coastal cliff forming a linear feature 1 – 2 km inland from the current beach from the sea cliffs north of Waipara River mouth to the south boundary of the district.

**Zone 2** is the main area of recent or Holocene age alluvium. These are essentially the recent flood plain and riverbed areas of the major rivers. The soil is predominantly gravel but includes lenses of sand and silt, and the proximity to rivers implies that water tables could be close to the surface. There is the possibility of local areas of saturated sand within this zone liquefying during strong seismic shaking, but potentially liquefiable areas are likely to be small.

For all the rivers, the surfaces assessed as being Holocene to present in age may overlie Holocene or younger deposits, or may be erosion surfaces with a thin veneer of reworked gravel over much older glacial outwash gravel. In the latter case, this further restricts the potential for any significant liquefaction. This is particularly true of the entrenched reaches in the south of the district where the rivers have cut down below the older Pleistocene surfaces.

It should also be noted that the susceptibility to liquefaction in these deposits is likely to decrease with distance from the coast to the foothills, as gravel predominates closer to the river headwaters. The increased river gradients away from the coast tend to carry sand sized particles away, and the higher energy environment will generally produce denser deposits of any sand beds that do form.

However, Holocene age deposits within the high country basins, such as the Hurunui River lakes, may be more susceptible, in places where lake deposits and low river gradients are present.

**Zone 3** covers areas of alluvium older than Holocene age. These will mainly be dense gravel dominated soils. There may be small areas of Holocene alluvium in places, along watercourses and the like. Much of this zone may have ground water tables at considerable depth, and liquefaction would require a combination of perched water table as well as loose sand. There is a very small likelihood of liquefaction of small, isolated areas within this zone.

**Zone 4** is the remaining areas of the map, which are underlain with rock or hill soils that would not be expected to contain any liquefiable deposits. No guarantee can be given that liquefaction cannot occur in these areas, because of the very broad nature of this general zoning procedure, but the susceptibility is considered to be extremely low.

# 6 Conclusions

There are substantial areas within Hurunui District which have some potential for liquefaction susceptibility, but in the main the risk is very small and would occur only in small isolated areas. There is a low susceptibility to liquefaction in Holocene aged river alluvium along the rivers in the district, but this is mainly confined to active flood plains and river beds with little infrastructure in place or likely to be in place. The highest susceptibilty area is the coastal margin between the south district boundary and the Waipara River, where a prograding coastline has deposited young granular soils. Even within this area, it is likely that liquefaction will occur with strong shaking only in parts of this area, as borelog data indicates that much of the recent soils are too coarse to liquefy easily.

Liquefaction has occurred historically with observations consistent with liquefaction on two occasions near Leithfield Beach, in the Cheviot – Parnassus area in 1901, and in the southern extremity of the district in 2010.

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# APPENDIX  A

## Modified Mercalli Intensity Scale

**INTENSITY SCALES**

**MODIFIED MERCALLI (MM) INTENSITY SCALE**
**(Table from Downes, 1995)**

| | After Eiby (1966) | After Study Group (1992) |
|---|---|---|
| **MM I** | Not felt by humans, except in especially favourable circumstances, but birds and animals may be disturbed. Reported mainly from the upper floors of buildings more than 10 storeys high. Dizziness or nausea may be experienced.<br><br>Branches of trees, chandeliers, doors, and other suspended systems of long natural period may be seen to move slowly.<br><br>Water in ponds, lakes, reservoirs etc. may be set into seiche oscillation. | *People*<br>Not felt except by a very few people under exceptionally favourable circumstances. |
| **MM II** | Felt by a few persons at rest indoors, especially by those on upper floors or otherwise favourably placed.<br><br>The long-period effects listed under MM I may be more noticeable. | *People*<br>Felt by persons at rest, on upper floors or favourably placed. |
| **MM III** | Felt indoors, but not identified as an earthquake by everyone. Vibration may be likened to the passing of light traffic.<br><br>It may be possible to estimate the duration, but not the direction. Hanging objects may swing slightly. Standing motorcars may rock slightly. | Felt indoors; hanging objects may swing, vibration similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake. |
| **MM IV** | Generally noticed indoors, but not outside. Very light sleepers may be wakened.<br><br>Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. | **People**<br>Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic or to the jolt of a heavy object falling |

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| | Walls and frame of buildings are heard to creak.<br>Doors and windows rattle. Liquids in open vessels may be slightly disturbed.<br><br>Standing motorcars may rock, and the shock can be felt by their occupants. | or striking the building.<br><br>*Fittings*<br>Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock.<br><br>*Structures*<br>Walls and frame of buildings, and partitions and suspended ceilings in commercial buildings may be heard to creak. |
| **MM V** | Generally felt outside, and by almost everyone indoors.<br>Most sleepers awakened. A few people frightened.<br><br>Direction of motion can be estimated.<br>Small unstable objects are displaced or upset.<br>Some glassware and crockery may be broken.<br>Some windows cracked.<br>A few earthenware toilet fixtures cracked.<br>Hanging pictures move.<br>Doors and shutters may swing.<br>Pendulum clocks stop, start, or change rate. | **People**<br>Generally felt outside, and by almost everyone indoors.<br>Most sleepers awakened.<br>A few people alarmed.<br>Direction of motion can be estimated.<br><br>*Fittings.*<br>Small unstable objects are displaced or upset<br>Some glassware and crockery may be broken.<br>Hanging pictures knock against the wall.<br>Open doors may swing. Cupboard doors secured by magnetic catches may open.<br>Pendulum clocks stop, start or change rate (H*).<br><br>*Structures*<br>Some window type I* cracked. A few earthenware toilet fixtures cracked (H) |
| **MM VI** | Felt by all.<br>People and animals alarmed.<br>Many run outside.<br>Difficulty experienced in walking steadily.<br><br>Slight damage to Masonry D.<br>Some plaster cracks or falls.<br>Isolated cases of chimney damage. | ***People***<br>**Felt by all.**<br>People and animals alarmed.<br>Many run outside.<br>Difficulty experienced in walking steadily.<br><br>*Fittings*<br>Objects fall from shelves. |

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| | Windows, glassware and crockery broken.<br>Objects fall from shelves, and pictures from walls.<br>Heavy furniture moved. Unstable furniture overturned. Small church and school bells ring.<br><br>Trees and bushes shake, or are heard to rustle.<br>Loose material may be dislodged from existing slips, talus slopes, or shingle slides. | Pictures fall from walls (H*).<br>Some furniture moved on smooth floors.<br>Some unsecured free-standing fireplaces moved.<br>Glassware and crockery broken.<br>Unstable furniture overturned.<br>Small church and school bells ring (H).<br>Appliances move on bench or table tops.<br>Filing cabinets or “easy glide" drawers may open (or shut).<br><br>*Structures*<br>Slight damage to Buildings Type I*.<br>Some stucco or cement plaster falls.<br>Suspended ceilings damaged.<br>Windows Type I* broken.<br>A few cases of chimney damage. |
| **MM VII** | General alarm.<br>Difficulty experience in standing.<br>Noticed by drivers of motorcars.<br><br>Trees and bushes strongly shaken.<br>Large bells ring.<br>Masonry D cracked and damaged. A few instances of damage to Masonry C.<br>Loose brickwork and tiles dislodged. Unbraced parapets and architectural ornaments may fall.<br>Stone walls cracked.<br>Weak chimneys broken, usually at the roofline.<br>Domestic water tanks burst. Concrete irrigation ditches damaged.<br><br>Waves seen on ponds and lakes.<br>Water made turbid by stirred-up mud.<br>Small slips, and caving-in on sand and gravel banks. | *People*<br>General alarm.<br>Difficulty experienced in standing.<br>Noticed by motorcar drivers who may stop.<br><br>*Fittings*<br>Large bells ring.<br>Fumiture moves on smooth floors, may move on carpeted floors.<br><br>*Structures*<br>Unreinforced stone and brick walls cracked.<br>Buildings Type I cracked and damaged.<br>A few instances of damage to Buildings Type II.<br>Unbraced parapets and architectural ornaments tall.<br>Roofing tiles, especially ridge tiles may be dislodged.<br>Many unreinforced domestic chimneys broken.<br>Water tanks Type I* burst.<br>A few instances of damage to brick veneers and plaster or cement-based linings.<br>Unrestrained water cylinders (Water Tanks Type II*) may move and leak. Some Windows Type 11* cracked.<br><br>*Environment*<br>Water made turbid by strirred up mud.<br>Small slides such as falls of sand and gravel banks.<br>Instances of differential settlement on poor |

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| | | or wet or unconsolidated ground.<br>Some fine cracks appear in sloping ground.<br>a few instances of liquefaction. |
| **MM VIII** | Alarm may approach panic.<br>Steering of motorcars affected.<br><br>Masonry C damaged, with partial collapse.<br>Masonry B damaged in some cases.<br>Masonry A undamaged.<br><br>Chimneys, factory stacks, monuments, towers and elevated tanks twisted or brought down.<br>Panel walls thrown out of frame structures.<br>Some brick veneers damaged.<br>Decayed wooden piles broken.<br>Frame houses not secured to the foundation may move.<br>Cracks appear on steep slopes and in wet ground.<br>Landslips in roadside cuttings and unsupported excavations.<br>Some tree branches may be broken off.<br>Changes in the flow or temperature of springs and wells may occur.<br>Small earthquake fountains. | *People*<br>Alarm may approach panic. Steering of motorcars greatly affected.<br><br>*Structures*<br>Buildings Type II damaged, some seriously<br>Buildings Type III damaged in some cases.<br>Monuments and elevated tanks twisted or brought down.<br>Some pre-1965 infill masonry panels damaged.<br>A few post-1980 brick veneers damaged.<br>Weak piles damaged.<br>Houses not secured to foundations may move.<br><br>*Environment*<br>Cracks appear on steep slopes and in wet ground.<br>Slides in roadside cuttings and unsupported excavations.<br>Small earthquake fountains and other manifestations of liquefaction. |
| **MM IX** | General panic.<br><br>Masonry D destroyed.<br>Masonry C heavily damaged, sometimes collapsing completely.<br>Masonry B seriously damaged.<br>Frame structures racked and distorted.<br>Damage to foundations general.<br>Frame houses not secured to the foundations shifted off.<br>Brick veneers fall and expose frames.<br>Cracking of the ground conspicuous. Minor damage to paths and roadways.<br><br>Sand and mud ejected in alluviated areas, with the formation of earthquake fountains and sand craters.<br>Underground pipes broken.<br>Serious damage to reservoirs. | *Structures*<br><br>Very poor quality unreinforced masonry destroyed.<br>Buildings Type II heavily damaged, some collapsing.<br>Buildings Type III damaged, some seriously.<br>Damage or permanent distortion to some buildings and bridges Type IV.<br>Houses not secured to foundations shifted off.<br>Brick veneers fall and expose frames.<br><br>*Environment*<br>Cracking of ground conspicuous.<br>Landsliding general on steep slopes.<br>Liquefaction effects intensified, with large earthquake fountains and sand crater. |
| **MM X** | Most masonry structures destroyed, together with their foundations. | *Structures* |

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| | Some well built wooden buildings and bridges seriously damaged.<br>Dams, dykes and embankments seriously damaged.<br>Railway lines slightly bent.<br>Cement and asphalt roads and pavements badly cracked or thrown into waves.<br><br>Large landslides on river banks and steep coasts<br>Sand and mud on beaches and flat land moved horizontally.<br>Large and spectacular sand and mud fountains<br>Water tram rivers, lakes and canals thrown up on the banks | Most unreinforced masonry structures destroyed.<br>Many Buildings Type II destroyed.<br>Many Buildings Type III (and bridges of equivalent design) seriously damaged. Many Buildings and Bridges Type IV have moderate damage or permanent distortion. |
| **MM XI** | Wooden frame structures destroyed.<br>Great damage to railway lines and underground pipes. | |
| **MM XII** | Damage virtually total. Practically all works of construction destroyed or greatly damaged.<br>Large rock masses displaced.<br>Lines of sight and level distorted.<br>Visible wave-motion of the ground surface reported.<br>Objects thrown upwards into the air. | |

| **After Eiby (1966)**<br>**Categories of non-Wooden Construction** | **After Study Group (1992)**<br>**Categories of Construction** |
|---|---|
| **Masonry A**<br><br>Structure design to resist lateral forces of about 0.1g, such as those satisfying the New Zealand Model Building Bylaw, 1955. Typical buildings of this kind are well reinforced by means of steel or ferroconcrete bands, or are wholly of ferro-concrete construction. All mortar is good quality and the design and workmanship is good. Few buildings erected prior to 1935 can be regarded as in category A.<br><br>**Masonry B**<br><br>Reinforced buildings of good workmanship and with sound mortar, but not designed in detail to | **Buildings Type I**<br><br>Weak materials such as mud brick and rammed earth; poor mortar; low standards of workmanship (Masonry D in other MM scales).<br><br>**Buildings Type II**<br><br>Average to good workmanship and materials, some including reinforcement but not designed to resist earthquakes (Masonry B and C in other MM scales).<br><br>**Buildings Type III**<br><br>Buildings designed and built to resist |

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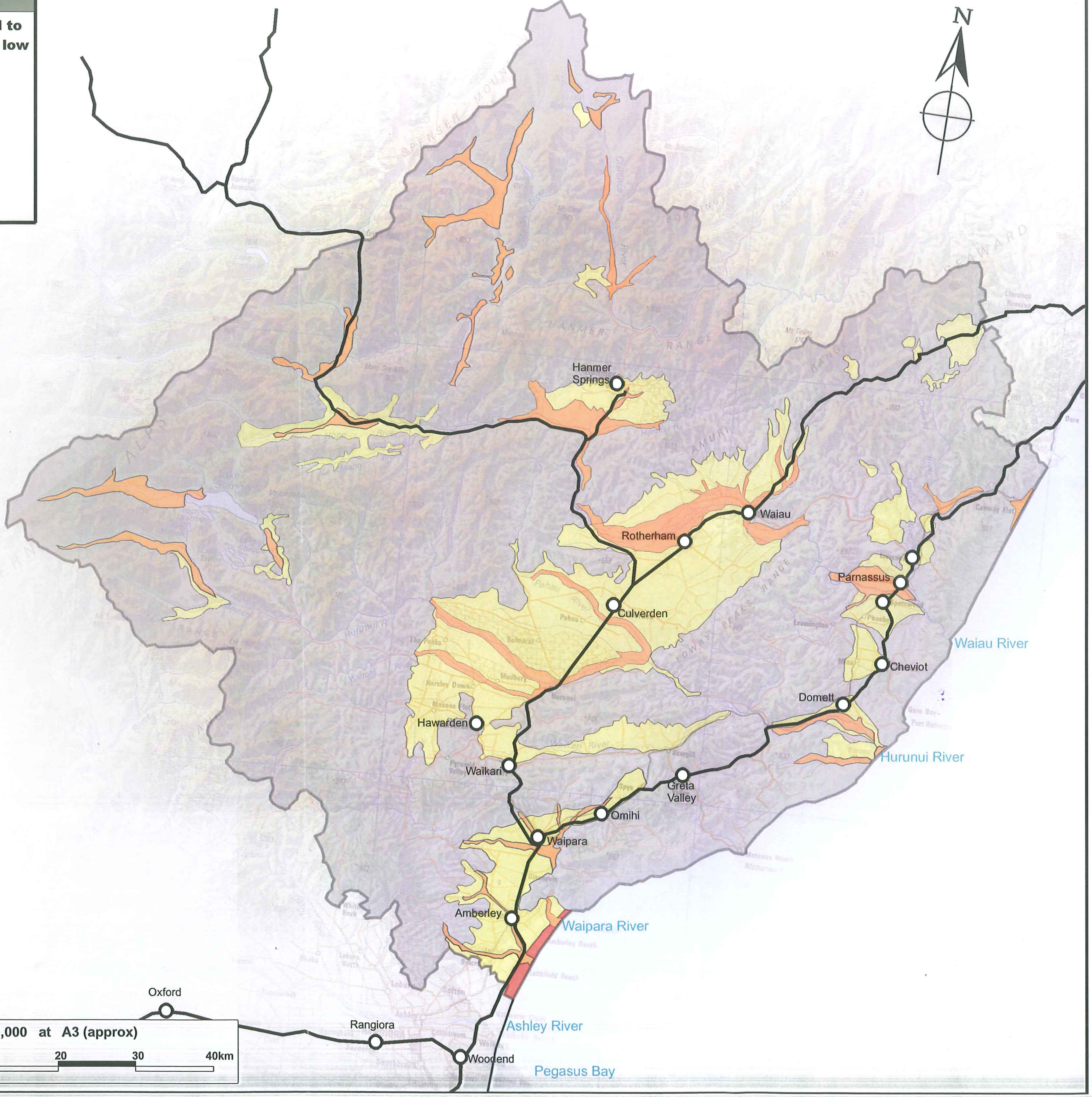
| resist lateral forces.<br><br>**Masonry C**<br><br>Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the comers, but neither designed nor reinforced to resist lateral forces.<br><br>**Masonry D**<br><br>Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick and rammed earth. Weak horizontally.<br><br>**Windows**<br><br>Window breakage depends greatly upon the nature of the frame and its orientation with respect to the earthquake source. Windows cracked at MM5 are usually either large display windows, or windows tightly fitted to metal frames.<br><br>**Water Tanks**<br><br>The "domestic water tanks" listed under MM7 are of the cylindrical corrugated-iron type common in New Zealand rural areas. If these are only partly full, movement of the water may burst soldered and riveted seams.<br><br>Hot water cylinders constrained only by supply and delivery pipes may move sufficiently to break the pipes at about the same intensity. | earthquakes to normal use standards, i.e. no special damage limiting measures taken (mid - 1930's to c. 1970 for concrete and to c. 1980 for other materials).<br><br>**Buildings and bridges Type IV**<br><br>Since c. 1970 for concrete and c. 1980 for other materials, the loadings and materials codes have combined to ensure fewer collapses and less damage than in earlier structures. This arises from features such as "capacity design" procedure, use of elements (such as improved bracing or structural walls) which reduce racking (i.e. drift), high ductility, higher strength.<br><br>**Windows**<br><br>Type I - Large display windows, especially shop windows.<br>Type II - Ordinary sash or casement windows.<br><br>**Water Tanks**<br><br>Type I - External, stand mounted, corrugated iron water tanks.<br>Type II - Domestic hot-water cylinders unrestrained except by connecting pipes.<br><br>**H - (Historical)**<br><br>Important for historical events. Current application only to older houses, etc.<br><br>**General Comment**<br><br>“Some” or a “few” indicates that the threshold of a particular effect has just been reached at that intensity. |

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Zone of low to high potential:** Areas of Holocene age alluvium, beach, estuarine, & marine deposits. Potential varies low to high. | **Zone of low potential:** Areas of Recent Holocene age alluvium; essentially the active flood plain and river bed areas of the major rivers. | **Zone of very low potential:** Areas of alluvium older than Holocene age. Very small risk of liquefaction of local, isolated areas. | **Zone of nil to extremely low potential:** Rock or hill soils. |

Zone boundaries have been determined principally from geological maps of the district, with some additional limited borehole information. The zone boundaries are approximate only. Some areas within one zone may behave more like an area in another zone. For any critical structure, a specific site study is needed to determine the actual degree of hazard.




SCALE 1 : 500,000 at A3 (approx)

0 10 20 30 40km

# Map of Hurunui District Liquefaction Potential

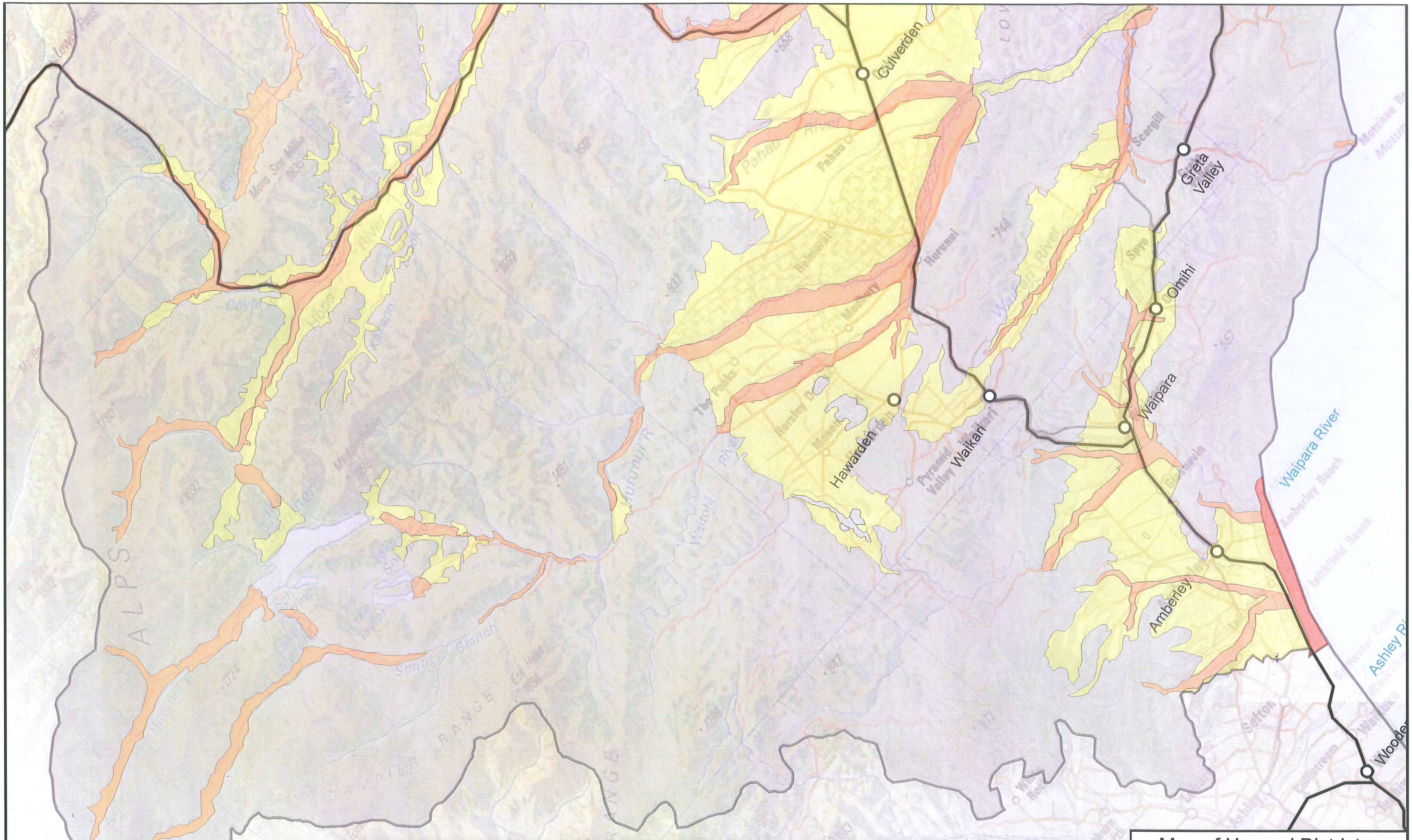
**SCALE: 1:500 000 (approximate)**

Hurunui District Liquefaction Susceptibility Study

Environment Canterbury

GEOTECH

| | |
|---|---|
| **DATE DRAWN:** | **Sep 2011** |
| **DRAWN BY:** | **PEW** |
| **NUMBER:** | **FIGURE 1** |




| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Zone of low to high potential:** | **Zone of low potential:** | **Zone of very low potential:** | **Zone of nil to extremely low potential:** |
| Areas of Holocene age alluvium, beach, estuarine, & marine deposits. Potential varies low to high. | Areas of Recent Holocene age alluvium essentially the active flood plain and river bed areas of the major rivers. | Areas of alluvium older than Holocene age. Very small risk of liquefaction of local, isolated areas. | Rock or hill soils. |

Zone boundaries have been determined principally from geological maps of the district, with some additional limited borehole information. The zone boundaries are approximate only. Some areas within one zone may behave more like an area in another zone. For any critical structure, a specific site study is needed to determine the actual degree of hazard.

SCALE 1 : 250,000 at A3 (approx)

0 5 10 15 20km

GEOTECH

DATE DRAWN: Sep 2011
DRAWN BY: PEW
NUMBER: FIGURE 2

# Map of Hurunui District Liquefaction Potential (South)

SCALE: 1:250 000 (approximate)

Hurunui District
Liquefaction Susceptibility Study

Environment Canterbury

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Zone of low to high potential:** | **Zone of low potential:** | **Zone of very low potential:** | **Zone of nil to extremely low potential:** |
| Areas of Holocene age alluvium, beach, estuarine, & marine deposits. Potential varies low to high. | Areas of Recent Holocene age alluvium essentially the active flood plain and river bed areas of the major rivers. | Areas of alluvium older than Holocene age. Very small risk of liquefaction of local, isolated areas. | Rock or hill soils. |

**SCALE 1 : 250,000 at A3 (approx)**

0 5 10 15 20km

Zone boundaries have been determined principally from geological maps of the district, with some additional limited borehole information. The zone boundaries are approximate only. Some areas within one zone may behave more like an area in another zone. For any critical structure, a specific site study is needed to determine the actual degree of hazard.

# Map of Hurunui District Liquefaction Potential (North)

**SCALE: 1:250 000 (approximate)**

Hurunui District Liquefaction Susceptibility Study

Environment Canterbury

GEOTECH

| | |
|---|---|
| DATE DRAWN: | Sep 2011 |
| DRAWN BY: | PEW |
| NUMBER: | FIGURE 3 |