Dr M. R. JOHNSTON CHANGES 18-1-2013
Consulting Geologist
395 Trafalgar Street
NELSON 7001

Phone: 03 546 7575
Fax: 03 546 7574
Email mike.johnston@xtra.co.nz

18 January 2013

Mr. Glenn Stevens
Resource Scientist (Water & Land)
Tasman District Council
Private Bag 4
RICHMOND 7050

Mr Martin Workman
Monitoring & Research Manager
Nelson City Council
PO Box 645
NELSON 7040

Dear Sirs

RE: Revised Preliminary Assessment of the Liquefaction Hazard in Tasman and Nelson

1. INTRODUCTION

As a result of a series of shallow earthquakes in Canterbury in September 2010 and February and June 2011, there was considerable damage from the ground liquefying. This prompted many regional and district councils, organisations and individuals in New Zealand questioning whether liquefaction could occur elsewhere and if so where. In an email dated 24 March 2011 you asked for a summary of what is known of the liquefaction risk in Nelson and Tasman regions. This was forwarded on 30 June 2011. In the light of subsequent discussion, the assessment has been revised by including detailed maps of Nelson city (Appendix One), the prioritising of areas where further testing, depending on present and future land use, may be warranted. Within the city areas where further investigation is warranted have been prioritised.

In geology, liquefaction is defined as the process by which ground that is generally firm takes on, albeit temporarily, the properties of a liquid. This can occur in sediment when an increase in pore pressure in water it contains effectively reduces the stress between its component particles, such as sand or silt grains. It largely results from severe seismic ground shaking. Thus for liquefaction to occur three factors must be present:

- Unconsolidated or loose fine-grained (silt to more commonly sand) sediments.
- The sediments have to be water saturated.
- A source of ground shaking (MM VII or greater on the Modified Mercalli Scale).

When ground liquefies and loses strength it behaves, like water, as a fluid and consequently cannot support what is above it be it firm ground or structures, including buildings and services. Differential settlement of the ground is common and buildings, empty tanks and pipelines may literally float in the liquefied material. Liquefied material may also, particularly if within a confined layer, burst through to the surface or flow towards lower ground causing further disruption.

Sediments that have the potential to liquefy are geologically very young and as they have to be saturated are found close to water.

2. PREVIOUS ASSESSMENTS OF LIQUEFACTION HAZARD

The hazard of liquefaction, and the risk it may pose, has been broadly discussed in geohazards assessments commissioned by the two councils from GNS Science[1] and more recently it has been addressed in the Natural Hazards section of the *Nelson Tasman Engineering Lifelines – Limiting the Impact.*

3. POTENTIALLY LIQUEFIABLE SEDIMENTS IN NELSON AND TASMAN

Nelson and Tasman regions have a great variety of different rocks but those that may have the potential to liquefy, being loose water logged sediments of geologically Recent age[2] with a preponderance of sand or silt particles, are restricted to the coast or in river valleys (Figure 1). It should also be noted that the water table will fluctuate due to the amount of rain (the sediments, in effect, largely constitute unconfined aquifers) and, with a large tidal range in Golden and Tasman bays, the state of the tide may also have a bearing on the water table in coastal sediments. The Recent sediments underlie flat lying ground that commonly has a relatively high level of development. However, it is stressed that these sediments may contain materials within them that could liquefy, not that these sediments would do so. Consequently, further work is needed to determine susceptibility to liquefaction. The following sections summarise the known extent of fine-grained, water-logged sediments in the two regions.

3.1 Valleys (sediments of terrestrial origin)

The terrestrial sediments filling the valleys are dominated by gravel but sand is more abundant in the Motueka catchment because of widespread, erosion-prone, Separation Point Granite. Silt-rich deposits may also be present throughout the terrestrial sediments but are mostly of small extent, such as those filling cut off, and now buried, river channels. Swamp deposits are relatively rare, the most extensive being at Maungarakau on the west coast with lesser areas near Cape Farewell and, probably grading into estuarine deposits, in the inlets of Golden and Tasman bays such as Puponga, Pakawau and Ruataniwha and Delaware inlets and Nelson Haven.

---

[1] Johnston, M. R.; Hull, A. G.; Downes, G. L. 1993: *Earthquake, Landslide and Coastal Hazards in Nelson City*. GNS client report 1993/413399.21.
Coote, T. P.; Downes, G. L. 1995: *Preliminary Assessment of Earthquake and Slope Instability Hazards in Tasman District*. GNS client report 1995/41430D.16.

[2] Sediments deposited since the Last Glaciation, which ended approximately 10,000 years ago. Also referred to as Holocene.

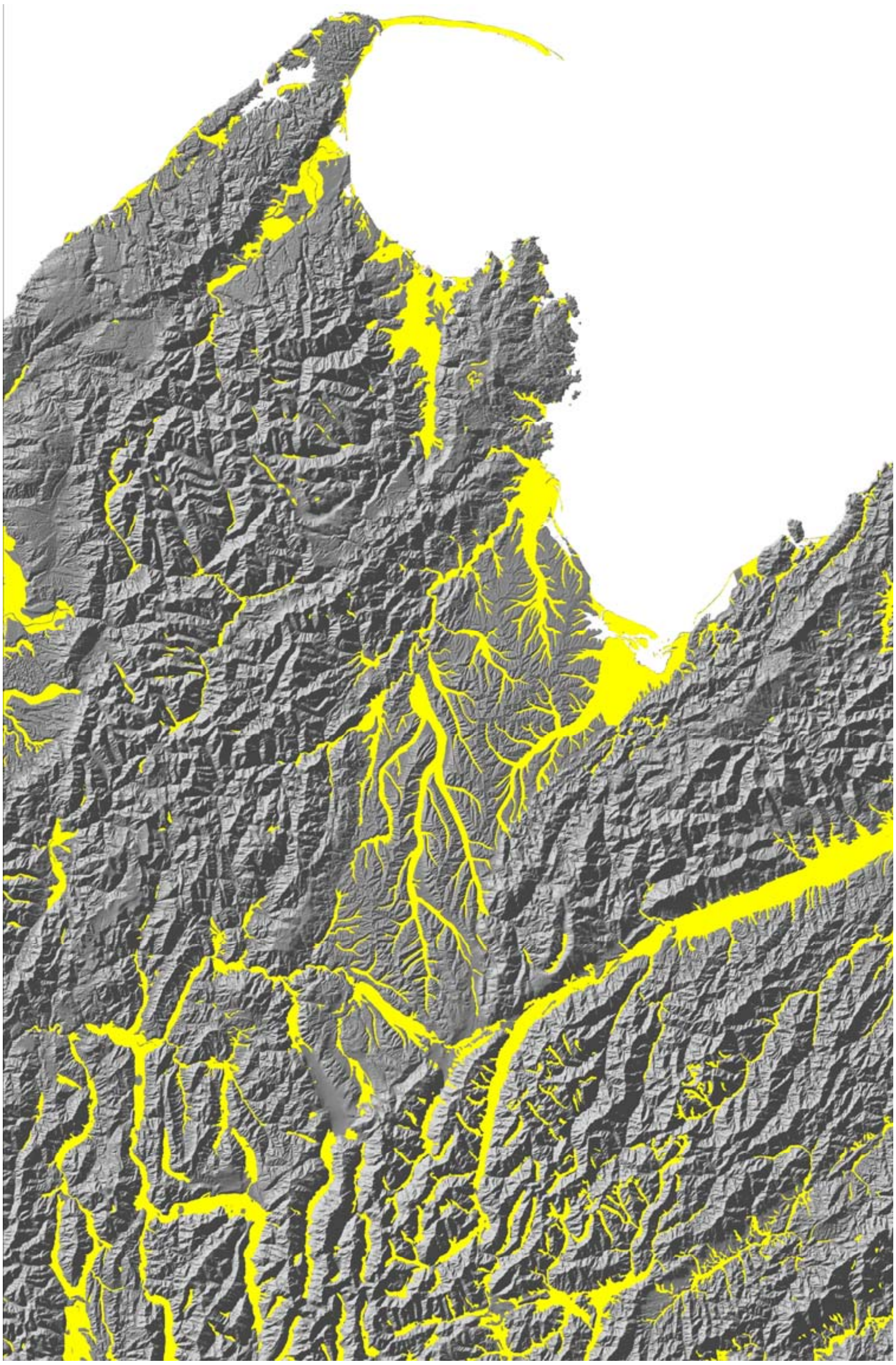


Figure 1. Hill areas (grey) are composed of materials that will not liquefy. Holocene floodplain, terrace, swamp, beach, estuarine and dune deposits and Last Glaciation terrace deposits (yellow) may contain fine-grained sediments that, where waterlogged, could potentially liquefy. (*GNS Science QMAP*)

Although terrestrial sediments are relatively widespread, generally only the floodplain gravels, deposited during the past 10,000 years and filling the valley floors, are sufficiently water saturated that, where suitable deposits are present within them, may result in liquefaction. These deposits underlie the most populated parts of the two regions and correspondingly have significant infrastructure. However, the deposits are dominantly gravel and finer-grained materials are relatively insignificant. In valleys within the Moutere Gravel, the proportion of gravel is generally less but the clay content is correspondingly higher, thereby diminishing the potential for liquefaction. Minor swamp deposits may be present but are probably not at high risk of liquefying.

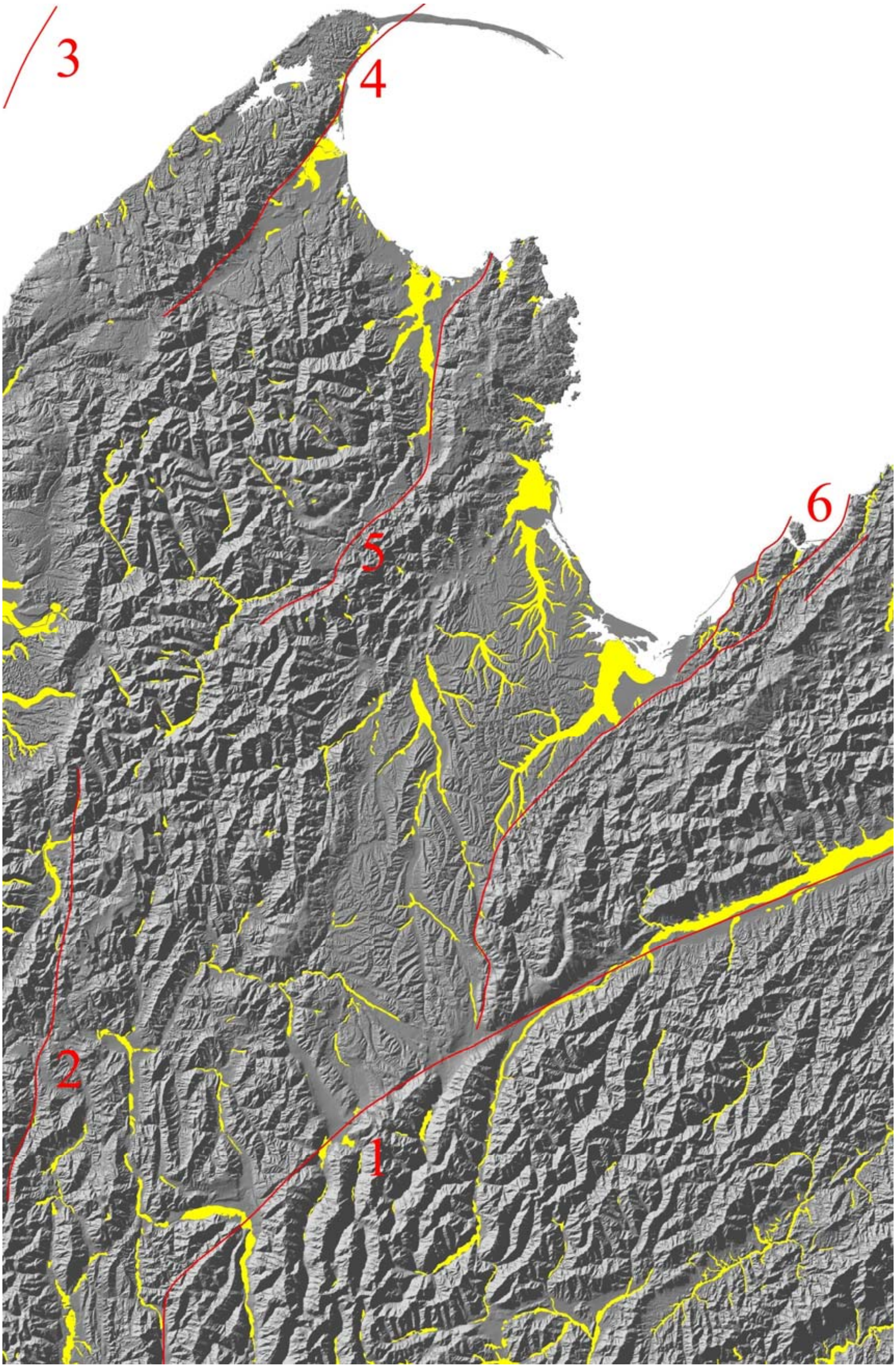
That liquefaction is not likely to be a major problem in the alluvial sediments tends to be confirmed by the Murchison and Inangahua earthquakes. A detailed account of the 1929 Murchison Earthquake (M 7.8 on Richter Scale) makes no mention of any phenomena associated with liquefaction[3]. However, liquefaction did occur as one account states that spouts of sand and mud were ejected through a metalled gravel road (now SH6) near Lyell and near Murchison water was observed spurting over a metre into the air[4]. The lesser magnitude (M 7.1) Inangahua Earthquake caused widespread sand ejection onto the alluvial flats in the vicinity of the epicentre. However, apart from some localised settling, its effects were muted as demonstrated by buildings clad in weatherboards and with iron roofs on well constructed foundations suffering minimal structural damage[5]. Similarly, during the 1929 earthquake in Murchison township it was reported that “on the whole the injury to reasonably well-built houses was relatively slight”. During both earthquakes in centres distant from the epicentres, including Westport, Greymouth, Karamea and Nelson, there was apparently relatively little disruption to infrastructure in natural gravel although cracking parallel to river banks appeared in alluvium, particularly where it overlies estuarine deposits, on the West Coast.

Thus potentially liquefiable deposits are likely to be restricted in their distribution and may include silt in buried cut off meanders, localised swamp deposits and, more commonly in the lower Motueka Valley, clean sand filling former river channels.

Caption (page 5)
Figure 2. Recent terrestrial (floodplain) deposits (yellow). These sediments are anticipated to give rise to areas of sand and silt ejection when subjected to MM VII or greater levels of ground shaking as measured on the Modified Mercalli Scale. As such sediments are dominantly gravel, large scale liquefaction is unlikely. Sediments such as sand lenses, swamp deposits and silt occur throughout and may result in localised liquefaction. The extent of the areas in yellow are shown in more detail in Appendix One. Major faults (generalised) shown are: 1 = Alpine Fault, 2 = White Creek Fault, 3 = Cape Foulwind Fault Zone, 4 = Wakamarama Fault, 5 = Karamea-Pikikiruna Fault, 6 = Waimea-Flaxmore Fault System (*Base map: GNS Science QMAP*)

---

[3] Henderson, J. 1937: *The West Nelson Earthquakes of 1929*. DSIR bulletin 55.
[4] Lammas, K. 1979 and Peacock, A. 1979: *In* Stories of Murchison Earthquake 17th June, 1929. Murchison District Museum and Historical Society.
[5] Lensen, G. J.; Suggate, R. P. 1968: *Inangahua Earthquake-preliminary account of the geology In* DSIR bulletin 193.


3
4
5
6
2
1

3.2 Coastal Areas (sediments of marine origin)

The marine sediments comprise marine sands and gravel that have been deposited over approximately the last 7,000 years when, following the last glacial period, sea level rose to its existing height. Also included are areas of dune sands. In favourable locations this resulted in a progradation of the coastline.

3.2.1 Whangamoa Inlet

Fine grained sediments, ranging from silty clay to sand partly infill the inlet and it is possible that they also interfinger with terrestrial gravel deposited by the Whangamoa River. The extent of any fine-grained sediments underlying the flood plain of the river is expected to be very restricted and, although subsurface information is lacking, are probably also of no great thickness. Although potentially liquefaction could occur, such areas are subject to flooding and therefore development is unlikely.

3.2.2 Delaware Inlet

Similar comments to those made with regard to the Whangamoa Inlet apply to Delaware Bay. Marine and estuarine deposits are likely to be thin and much of the low-lying land is either flood plain gravel deposited by the Wakapuaka River or the coastal margins of fans deposited by creeks draining westward into the inlet.

3.2.3 The Glen

The head of Nelson Haven is slowly infilling with fine-grained low-lying and poorly drained sediments. As part of farm development an extensive drainage system has been installed but despite this, the area remains prone to flooding. The sediments are reported, from seismic and gravity observations, to be in the order of 100 m thick[6], although this has not been confirmed. Nevertheless, the sediments are extensive and may be not sufficiently fine-grained to liquefy. However, until it is shown otherwise it should be assumed that under suitable conditions there could be liquefaction within the head of the haven. Furthermore, it is possible that there are confined water bearing layers at depth. Around the eastern margin of the head of the haven the sediments are likely to be more variable with a mixture of material, including clay and weathered angular rock fragments, from the adjacent hillsides. This material, and reportedly sediments adjacent to the Boulder Bank, is expected to have a lower risk of liquefaction.

3.2.4 Southern end of Nelson Haven

The southern end of the haven is largely infilled with gravel deposited by the Maitai River. As well as forming the now highly modified delta of the present river, Maitai

[6] Dickinson, W. W.; Woolfe, K. J. 1996: An *in situ* transgressive barrier for the Nelson Boulder Bank, New Zealand. *Journal of Coastal Research 13*: 937-952.

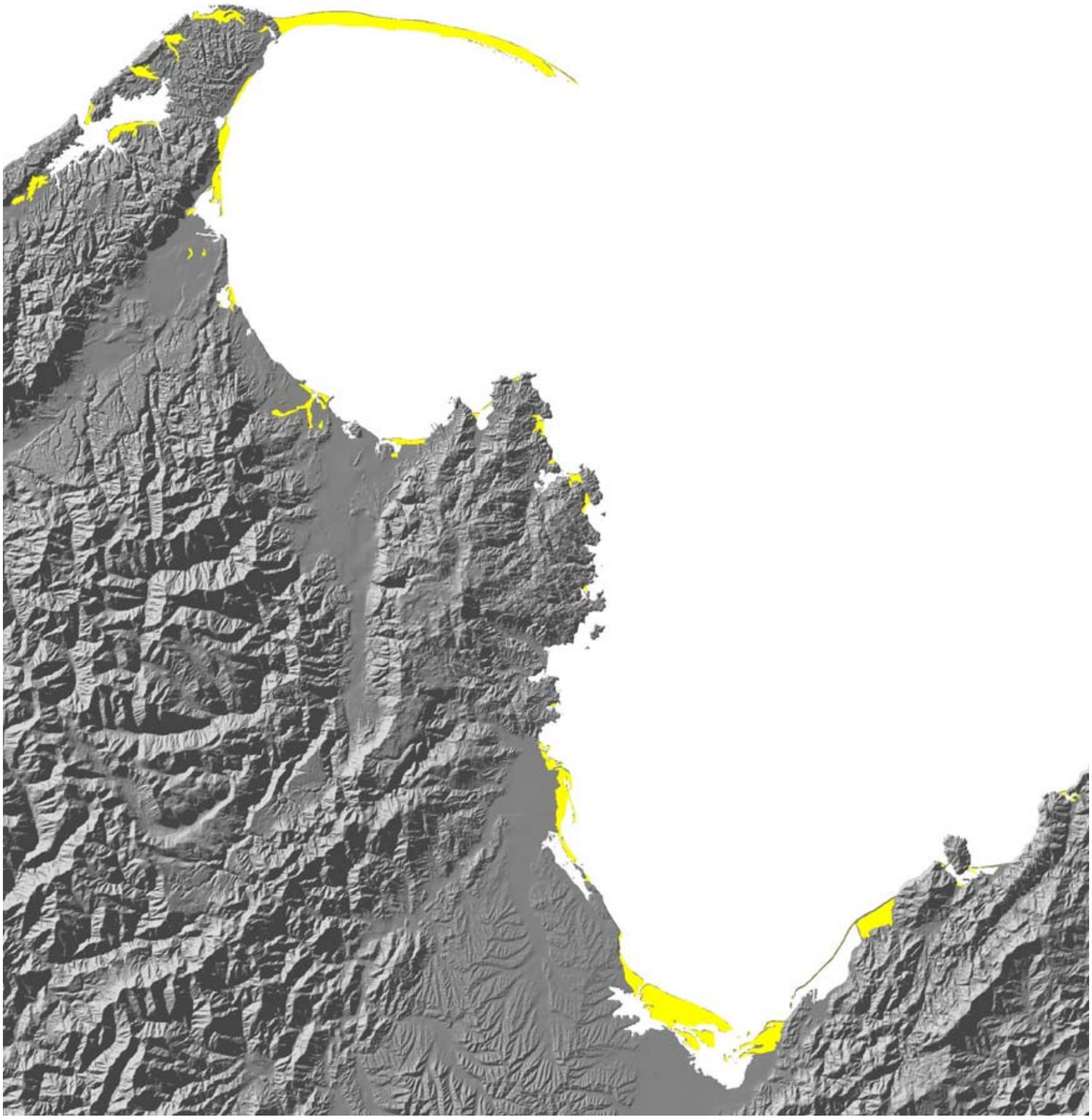


Figure 3. Recent marine and estuarine deposits and associated swamp deposits (yellow). These sediments have the greatest potential to contain sediments that may liquefy during MM VII or greater ground shaking. However, no sediments have been confirmed as having properties that would result in liquefaction and the deposits should be more appropriately regarded as highlighting where further investigation is warranted, particularly land that already contains infrastructure or is proposed for development. The extent of the areas in yellow are shown in more detail in Appendix One. (*GNS Science QMAP*).

gravel extends under the estuarine and marine sediments of the haven to as far west as Port Nelson. However, to the southwest of the present delta an embayment extended into Toi Toi Valley and is filled with silty sediments which must be regarded as suspect as far as liquefaction is concerned. However, from what is known of the sediments they have a high degree of plasticitiy and would also be expected to become more clay-rich with increasing distance from the haven. These characteristics would diminish the potential for liquefaction. Most of these sediments are overlain by fill comprising Port Hills Gravel quarried from the Port Hills or, such as Anzac Park and to the east of Saltwater Creek, landfill materials largely comprising domestic rubbish. During the 1893 Nelson Earthquake (M7) the greatest concentration of damage was to structures, mostly chimneys, on the softer sediments extending from the lower Maitai River west to Haven Road-Vanguard Street[7]. No liquefaction was reported but ground shaking levels may not have reached MM VII.

Fine-grained sediments are also present in the valleys immediately either side of Church Hill (lower Rutherford and middle Collingwood streets) although they are terrestrial rather than estuarine in origin. Although commonly water saturated, they appear to be more clay rich than estuarine sediments and this would also considerably diminish any potential risk of liquefaction.

3.2.5 Port Nelson

The port area comprises reclaimed land arising from infilling with Port Hills Gravel formation or hydraulic fill dredged from the bed of Nelson Haven and retained by bunds sitting on estuarine and silty, locally sandy, sediments. All of this area must be regarded as suspect in that under severe seismic shaking some of the fill materials, more particularly those rich in silty sand or sand, could liquefy. There is also an elevated risk of settlement of the materials, including in response to lateral movement of the bunds. It is understood that Port Nelson Ltd, the owner of the whole of the port, is undertaking its own evaluation of the risk of liquefaction and lateral spreading of reclaimed areas

3.2.6 Tahunanui

The Tahunanui area, north from a sea cliff extending from Monaco to the SH6 roundabout at Annesbrook and cut in Stoke fan Gravels, comprises marine sand with, particularly in the east, some sandy gravel. In more sheltered embayments more silty sediments may have locally accumulated. The sand and gravel formed beach ridges parallel to the sea cliff but these topographic features have been largely destroyed by development. While the ridges have been deposited by longshore drift southwest into the head of Tasman Bay, much of the sand within them has originated from the west of the bay. Thin swampy peat deposits accumulated between the ridges and extensive areas of dunes, now highly modified, are present in the west. From the Christchurch earthquakes, it appears that dune sands may be less susceptible to liquefaction and in any case, they are generally above the water table. The marine deposits are 29 m thick at the western

[7] *Colonist* (newspaper) 13 February 1893.

end of Tahunanui Beach[8]. Until it is shown otherwise by further investigation, it should be assumed that there are materials within all these deposits that have an elevated risk of liquefaction under high levels of seismic shaking.

3.2.7 Waimea Inlet to Riwaka

The islands of the Waimea Inlet and Mapua, from the township to the McKee Domain, are of similar materials to Tahunanui although gravel is more abundant in the southern parts of the islands and at Mapua. The marine deposits have been progressively built up by beach ridges formed by southeast longshore drift transporting sand and gravel into the head of Tasman Bay. On the eastern end of Rabbit Island the sand is up to 30 m thick but in the west the deposits are considerably thinner, thereby reducing the risk if sediments prone to liquefaction are present[9]. Adjacent to the margins of the inlet, apparently minor and probably relatively thin, estuarine or swamp deposits are locally present. However, overall these sediments are very similar to those at Tahunanui.

Marine deposits between the Moutere Inlet and Riwaka are a mixture of sand and gravel with minor swamp deposits and some dunes. Like the deposits at the head of Tasman Bay they have been deposited by longshore drift transporting materials, largely from the Riwaka and Motueka rivers, southeast. Because of this southeast drift the deposits tend not to accumulate and therefore they form relatively narrow strips along the coast. In Motueka the deposits front, and may partially overlie, estuarine and perhaps swamp, deposits. All of the sediments are water saturated and there is potential for liquefaction.

3.2.8 Abel Tasman Coast

Marine sand and estuarine silt and mud are present in the larger bays and inlets around the Abel Tasman coast, such as Kaiteriteri, Marahau and Totaranui. However, the area of such sediments is not extensive and although little is known of their subsurface extent and properties, there is likely only a local elevated risk of liquefaction.

3.2.9 Golden Bay

Around the shores of Golden Bay, marine and estuarine sediments, along with dune sands, are limited, except for Farewell Spit. South of the spit the greatest extent of these sediments is from Pakawau to Ruataniwha Inlet, with much smaller areas elsewhere such as Collingwood, Parapara, Pariwhakaoho, Patons Rock, Rangihaeata and Pohara[10]. While some fine-grained estuarine deposits will be present these are thought to be relatively restricted. As around the coast of Tasman Bay the sandy water logged sediments are

---

[8] Johnston, M. R. 1981: *Sheet 027AC Dun Mountain*. Geological Map of New Zealand 1: 50 000. NZ Department of Scientific and Industrial Research.

[9] Johnston, M. R. 1981: *Sheet N27pt Richmond*. Geological Map of New Zealand 1: 50 000. NZ Department of Scientific and Industrial Research.

[10] Bishop, D. G. 1971: *Sheet S1 and S3 Farewell-Collingwood*. Geological Map of New Zealand 1: 63 360. NZ Department of Scientific and Industrial Research.

Grindley, G. W. 1971: *Sheet S8 Takaka*. Geological Map of New Zealand 1: 63 360. NZ Department of Scientific and Industrial Research.

those that have the greatest potential to liquefy but without specific testing wheter a hazard exists can not be determined

4. SEISMIC HAZARD

The presence of water logged silty to sandy sediments in themselves do not pose a liquefaction hazard. Instead what is needed is sufficient ground shaking so that the particles in the sediments lose cohesion and become a fluid. Beneath Christchurch potentially liquefiable materials had been known for many years. What was difficult to ascertain was the risk of seismic shaking that would be sufficient to induce liquefaction although this hazard was assessed as relatively low. However, even prior to the 2010 earthquake, perception of the risk was increasing as a greater understanding of the structure of the crust beneath and adjacent to Christchurch became known. For liquefaction to occur, felt intensities need to be at least MM VII on the Modified Mercalli Scale. In Christchurch the February 2011 earthquake resulted in felt intensities of MM VIII and this had been calculated, from a statistical analysis prior to the earthquake, as having a mean return period of 630 years[11].

In the Nelson and Tasman regions, MM VIII intensities have been calculated as having mean return periods of <200 years[12]. Identifying the potential faults that could give rise to this level of ground shaking is not a straightforward exercise in that the activity of many faults has not been determined and there may be concealed faults that could, like Christchurch, be the source of damaging earthquakes.

4.1 Alpine Fault

Of the known faults in or close to the Nelson and Tasman regions, the most active is the Alpine Fault (Figure 2), which extends through the south of the Tasman Region and thence down the Wairau Valley. A paleoseismic investigation of the Alpine Fault in 2002[13] provided estimates for ground shaking intensities arising from three scenarios of fault rupture:

- Fault rupture along its full length in the South Island would result in ground shaking levels that would reach MM VIII in most of the lowlands, or Moutere Depression, extending inland from Tasman Bay. Northwest and northeast of the depression, including most of the Nelson and Tasman coastline a MM VII level of ground shaking would prevail.
- If rupture was confined to the section of the Alpine Fault between Lake Roto-iti and Cloudy Bay the pattern and level of shaking intensities would be similar to that if the whole of the fault was involved.

---

[11] Forsyth, P. J.; Barrell, D. J. A.; Jongens, R. 2008: *Geology of the Christchurch Area*. Institute of Geological & Nuclear Sciences 1: 250 000 Geological Map 16.

[12] Rattenbury, Cooper, R. A.; Johnston, M. R. 1998: *Geology of the Nelson Area*. Institute of Geological & Nuclear Sciences 1: 250 000 Geological Map 9.

[13] Yetton, M. D. 2002: *Paloeseismic investigation of the North and West Wairau sections of the Alpine Fault, South Island, New Zealand*. Unpublished report EQC 99/353 prepared by Geotech Consulting Ltd for the Earthquake Commission Research Foundation and Tasman District Council.

- If the fault ruptured along a relatively short length extending southwest from Lake Rotoroa the Modified Mercalli intensities would be one level lower than predicted for the other two scenarios.

The scenarios giving MM VIII levels of shaking would therefore be capable of producing liquefaction in any sediment prone to this phenomenon in the Moutere Depression, including the marine deposits between the Whangamoa Inlet and the vicinity of Motueka. The investigation also showed that Alpine Fault has ruptured since AD 200 but the timing of this event is uncertain. Nevertheless, the investigation concluded that it was likely that sufficient strain had built up on the fault in the Tophouse area to an extent that there was a high risk of surface rupture. Trenching in the lower Wairau valley indicated that the stress may not be as high as previously assessed. If this is so, then the risk of an earthquake from this source is reduced but not removed[14]. Further work is needed to confirm the activity on the fault in the lower Wairau valley.

4.2 Southwest Tasman Faults

Branching off the Alpine Fault, southwest of Nelson Lakes, there are a number of faults that trend north through the Tasman Region and Buller District. These include the White Creek and Mt William faults that gave rise to the Murchison and Inangahua earthquakes of 1929 and 1968 respectively. The largest of these earthquakes (Murchison) gave MM VIII levels of ground shaking in most of the Tasman and Nelson regions[15] although liquefaction was not reported as a major problem, including in the vicinity of the epicentres (see Sec 3.1 above) although, for instance, in the lower Motueka valley there was ground cracking as well as “little cones like miniature volcanoes in cultivated paddocks where water jets had emerged”[16]. In the north of the Nelson and Tasman regions it is likely that the earthquake was responsible for some minor differential settlement and lateral spreading in unconsolidated sediments.

4.3 Golden Bay Faults

There are three major northeast trending faults in the Golden Bay area. These are, from east to west, the Pikikiruna and Wakamarama faults and, off shore of the west coast, the Cape Foulwind Fault Zone. Only the latter fault is considered to be active but more information on it is not known. Because the Pikikiruna (and to the southwest the Karamea Fault) and Wakamarama faults are responsible for impressive range fronts they should not be regarded as dead faults. Nevertheless, earthquakes originating on any of these faults are likely to have a long recurrence interval. Movement on any one of these faults, plus others such as the Golden Bay Fault extending from Parapara south into the

---

[14] Yetton, M. D. 2002: *Paloeseismic trench investigation of the active trace of the Wairau section of the Alpine Fault, Renwick area, Marlborough District*. Unpublished report 1490 prepared by Geotech Consulting Ltd for the Marlborough District Council.
[15] Coote, T. P.; Downes, G. L. 1995: *Preliminary assessment of earthquake and slope instability hazards in Tasman District*. Unpublished GNS report 1995/41430D.16.
[16] Beatson, K.; Whelan, H. 1993: *The River Flows On*. Published by the authors.

Takaka valley, would likely produce ground shaking levels sufficiently high to induce liquefaction should any suitable water logged sediments be present.

4.4 Waimea-Flaxmore Fault System

The Waimea-Flaxmore Fault System branches off the Alpine Fault in the vicinity of Lake Roto-iti and extends NNE to northeast through the east of the Tasman Region and Nelson City. This fault system comprises several major faults, such as the Waimea, Flaxmore, Eighty-eight, Heslington and Whangamoa, as well as numerous smaller cross faults. The system is active with most of the faults in the south having ruptured the existing ground surface. However, northeast of the Wairoa River, fault ruptures are intermittent and are generally of short length. North of the river, ground ruptures are present on the Eight-eight, Whangamoa, Bishopdale and probably also Waimea Fault in the vicinity of Hope and possibly the Flaxmore Fault between Bishopdale and Stoke. These faults are in or close to the Nelson-Richmond urban area as well as the marine sediments within or adjacent to the Waimea Inlet. The activity on the fault system is poorly known but at Mt Heslington, the Waimea Fault (northwestern branch) has ruptured the ground surface three times in the past 18,000 years. Although the last movement was approximately 6000 years ago, the two earlier events are poorly dated so it is not possible to conclude that the fault ruptures about every 6000 years. There is evidence that the Flaxmore Fault moved also about 6000 years ago, although further work is required to confirm this. Large landslides in the hills from Atawhai to the foothills of the Barnicoat Range at Hope were most likely initiated by severe earthquake ground shaking. If so, the obvious source of this shaking would be the Waimea-Flaxmore Fault System.

Because of the large number of faults in the system this will reduce the interval between earthquakes. In the southern part of the fault system, rupture during an earthquake on an individual fault could be in the order of tens of kilometres. Further north, as judged by the fault traces that are preserved, rupture lengths are much less being 1.5 (Eighty-eight Fault at Hope) to 13 km (Whangamoa Fault in the Whangamoa valley) in length. Using these figures earthquakes of magnitudes up to 7.4 and 6.5 could be expected in the south and north of the fault system respectively[17]. These magnitudes would be enough to result in ground shaking sufficient to cause liquefaction in suitable sediments in the east of the Moutere Depression and in eastern Tasman Bay.

5. CONCLUSIONS

Within the Tasman and Nelson regions, sediments that are water saturated and have properties that make them potentially susceptible to liquefaction are very restricted, being confined largely to the marine and estuarine sands and silts adjacent to the coast (Figure 3). Nevertheless, these sediments are commonly built on with both above and below ground infrastructure, particularly adjacent to the south end of Nelson Haven, including

[17] Fraser, J. G.; Nicol, A.; Pettinga, J. R.; Johnston, M. R. 2006: *Paleoearthquake investigation of the Waimea-Flaxmore Fault System, Nelson, New Zealand. In:* Earthquakes and urban development: New Zealand Geotechnical Society 2006 Symposium, Nelson, February 2006. Institution of Professional Engineers. Proceedings of Technical Groups 31(1): 59-67.

Port Nelson, Tahunanui and coastal Motueka. Elsewhere the only sediments that may contain liquefiable materials are the flood plain deposits of the major river. However, these are not thought to be extensive as the main lithology is gravel, but unconsolidated sand is more abundant in the floodplain deposits of the Motueka valley (Figure 2).

Although potentially liquefiable sediments are likely to be present, there remains considerable uncertainty as to the frequency of earthquakes that will result in MM VII or greater levels of ground shaking that would be sufficient to induce liquefaction in any sediments prone to this phenomenon. This is a matter that is being currently addressed by Tasman and Nelson councils, in conjunction with GNS Science and others, in undertaking investigations into the major faults within the north of the South Island, including the Alpine Fault and the Waimea-Flaxmore Fault System. Of these faults the Waimea-Flaxmore Fault System remains the one with the greatest capability to generate ground shaking sufficient to cause liquefaction in any waterlogged sediments with the potential to liquefy in the vicinity of eastern Tasman Bay. However, while the earthquake risk has been refined over the past decade, including demonstrating that the Waimea-Flaxmore Fault System is more active that previously supposed, much more work is needed to quantify the seismic risk.

In the meantime, it would be prudent to assume, until proved otherwise, that the waterlogged marine or estuarine deposits (Figure 3), along with very localised and poorly defined sediments in the floodplains, could contain materials that may liquefy during ground shaking of MM VII or greater.

6. RECOMMENDATIONS

It is recommended that:

1. The areas identified in Figure 3, which are known to contain sandy water logged sediments should be representatively assessed, such as by seismic cone penetration testing, to determine whether a liquefaction hazard exists. Priority should be given to areas containing developed infrastructure, such as Tahunanui, or those areas where major developments are planned. While the port area may contain materials that could react adversely during a major seismic event, it is recommended that this area be reconsidered once the results of the port company's own investigation is known
2. If the testing confirms there is a high risk of liquefaction in the fine grained sediments then a review of the infrastructure within the relevant areas where they are known should be initiated. This should be coupled with a reassessment of all areas with known fine grained water logged sediments, particularly those of marine origin.
3. For new subdivisions, either for housing or other buildings, within the areas that have been confirmed as being subject to, or potentially subject to, liquefaction that this potential hazard be assessed as a condition of resource consent. Building consents for major buildings or other infrastructure may also need to be similarly assessed. If necessary, appropriate mitigation measures should be implemented

during development, including adopting the most appropriate design for infrastructure, to minimise the risk of this hazard.

4. Investigation of the faulting hazard that could potentially induce liquefaction be continued, including an offshore survey to determine whether active faults are present close to the coastline (such a survey would also be of considerable benefit in quantifying the risk from locally induced tsunamis).

Yours faithfully

Mike Johnston

Limitations

This report is based largely on existing geological databases, principally geological maps at scales of 1: 50 000, 1: 63,360 and 1: 250 000. No specific on site investigations have been undertaken to assess whether sediments that are fine-grained and waterlogged, particularly those that are sand rich, would in fact liquefy although this work should be undertaken, particularly in areas with significant infrastructure.

Appendix One

Maps showing in greater detail the areas depicted on Figures 2 and 3:

Map – Nelson City

Explanatory Notes:

1) The area shown as yellow of Figs 2 and 3 within the text of the assessment are depicted on Qmap as Q1al and Qan, Q1as, Q1d and Q1b respectively.
2) In Map 3 in the Appendix, the marine and estuarine deposits and reclaimed ground are divided into two units, viz:

   Reclaimed land that may contain significant areas that could settle during severe seismic ground shaking (MM VII or greater).

   Natural and reclaimed land that may contain significant areas of material that could potentially liquefy during severe seismic ground shaking. It should be noted that the boundaries of these units are approximate, being inferred from exiting data.