

A close-up, front-facing view of a yellow Kiwi Rail locomotive. The locomotive is on a railway track, and its headlights are illuminated. The number '5114' is visible in two black boxes on the top front. Below the windshield, the 'Kiwi Rail' logo is displayed. At the bottom front, the identification number 'DXB5114' is printed. The locomotive is pulling a red freight car. The background shows a blurred landscape with trees and a clear sky.

# SPECIALIST ASSESSMENT – RESILIENCE CRITERION

PALMERSTON NORTH REGIONAL FREIGHT HUB MULTI  
CRITERIA ANALYSIS AND DECISION CONFERENCING  
PROCESS

PREPARED FOR KIWIRAIL

June 2020

# Resilience Assessment

## 1. Introduction

Date: 23.9.19

Author(s)

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The following is a comparative assessment of long list site options to inform the MCA workshop for KiwiRail's future Palmerston North Rail and Freight Hub.

The assessment details Geotech (Seismic and liquefaction) and Regional Stormwater hazards for 9 sites and has relied on the following information:

### General

- General site visit and Workshop 1 discussion and scope.
- GIS data collated by Stantec for the purpose of this assessment.

### Geotech (Liquefaction and Seismic)

- GNS QMaps and ArcGIS database for anticipated ground conditions and topography.
- Google Earth Pro.
- NZ Geotechnical Database for existing ground information to characterize QMap material types Q1a, Q3a and Q5a in terms of liquefaction potential. Information included:
  - Boundary of sites 6, 7 and 8 – T&T BH1 SH56 Longburn 7/3/14 (NZGD ID BH\_107471)
  - Boundary of sites 5, 6 and 8 – T&T CPT4 (NZGD ID: CPT\_72247)
  - Boundary of sites 3 and 4 – T&T CPT18 (NZGD ID: CPT\_72221)
  - Site 4 – Miyamoto BH1 (NZGD ID: BH\_124994)
- GNS Active Faults Database for known active faults within the Palmerston North area.
- NZS 1170.5 'z' numbers to assess seismic risk in and around Palmerston North.
- Horizons Regional Council website - natural hazards.

### Regional Stormwater

- Horizons Flood Extent Maps for the Oroua River<sup>1</sup>, Upper Mangaone Stream<sup>2</sup>, and Manawatu River<sup>3</sup>
- Horizons Modelled Wet Areas Map
- **Feilding – Flooding the Manawatu** – a website ([https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y\\_GHeAp.Awc](https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y_GHeAp.Awc))
- **Flooded Farmland near Palmerston North** – a website (<https://manawatuheritage.pncc.govt.nz/item/39a5982a-d11e-4dbf-922b-68ba88b66a5e>)
- **Destructive Deluge**. A pictorial coverage of flooding in the Manawatu, Tararua Rangitikei and Horowhenua in February 2004. *Book by Westmount School, Palmerston North, 2004.*

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<sup>1</sup> 50 year Ari, 100 year ARI, 200 year ARI

<sup>2</sup> 50 year Ari, 100 year ARI, 200 year ARI

<sup>3</sup> 200 year ARI

## Central North Island Freight Hub - - Workshop 2

- News report: <https://www.stuff.co.nz/manawatu-standard/news/109342333/surface-flooding-causes-havoc-in-kelvin-grove-palmerston-north>
- News report: <https://www.stuff.co.nz/manawatu-standard/news/79659454/warning-for-horowhenua-as-wet-weather-sets-in>
- Horizons Regional Council website: <https://www.horizons.govt.nz/flood-emergency-management>
- Fuller, I.C.; Heerdegen, R.G.; 2005. *The February 2004 flood in the Manawatu, New Zealand: hydrological significance and impact on channel morphology*. Journal of Hydrology (NZ) 44 (2): 75 – 90, 2005.

The following information was not available for this assessment

### Geotech

- No ground investigation information for Sites 1 and 2. The remainder of the sites had very limited ground information available resulting in generalized comments.
- Limited information on the nature of the GNS Fault Database active faults closest to Palmerston North.

### Regional Stormwater

- Flood modelling output for events with magnitudes less than 1 in 50 year ARI. As a result, it is difficult to establish the impact of more frequent events for each site.
- No flood maps show predicted flood extents north of Campbell Rd (Site 2, and upstream of Site 2). It is possible that this area has not been modelled to date, so it is difficult to assess how flood prone site 2 is.
- Modelled flooding in the vicinity of Sites 5 to 8 from the Mangaone Stream. Upper Mangaone Stream flood maps do not extend to these sites 5 to 8, so the predicted impact of flooding from the stream at these sites is not known.
- No intermediate return interval flood extents are shown in the Modelled Wet Areas map. This map shows a composite of 50 year ARI, 100 year ARI, 200 year ARI flood extents for the various the Oroua River and Mangaone Stream, and the 1 year ARI extent for the Manawatu River.

## 2. Constraints identified in each area

### 2.1 Geotech

The **liquefaction** assessment is based on published geological mapping at a scale of 1:250,000 (low detail) supplemented by limited specific ground investigation information. Those materials with a silt/sand size range, are geologically recent/are loose and have a high groundwater table are more susceptible to liquefaction. Geological mapping information is summarized below:

- **Q1a Highest Liquefaction Risk** = 12,000 years ago to recent age. Moderately to well sorted alluvial flood plain gravel with minor sand/silt and overbank silt deposits. Assumed high groundwater.
- **Q3a Lower Liquefaction Risk** = 24,000 to 59,000 age. Poorly to moderately sorted gravel with minor sand or silt, sometimes weathered, underlying a terrace surface and/or overlying loess/paleosol couplets and tephra (ash).
- **Q5b Lower Liquefaction Risk** = 71,000 to 128,000 age. Sand and gravel with some lacustrine silt and clay, commonly overlain by 3 loess/paleosol couplets and tephra.

The **seismic** assessment is based on published values ('z' values) for larger towns and cities. As a

## Central North Island Freight Hub - - Workshop 2

comparison, Wellington has a  $z=0.4$  value while Auckland a value of  $z=0.14$ .

Liquefaction and seismic summary:

Area for Investigation	Constraints
Site 1	Q1a=25%, Q3a=75% (gullies cover 20% of the site). Seismic risk for Fielding $z=0.37$
Site 2	Q1a=15%, Q3a=85% (gullies cover 20% of the site). Seismic risk for Fielding $z=0.37$
Site 3	Q1a=75%, Q3a=25% (gullies cover 30% of the site). Seismic risk for Palmerston North $z=0.38$ .
Site 4	Q3a=90%, Q5a=10% (gullies cover 100% of the site). Seismic risk for Palmerston North $z=0.38$ .
Site 5	Q1a=100%. Seismic risk for Palmerston North $z=0.38$ .
Site 6	Q1a=100%. Seismic risk for Palmerston North $z=0.38$ .
Site 7	Q1a=100% (Recent river meander bends). Seismic risk for Palmerston North $z=0.38$ .
Site 8	Q1a=100% (Recent river meander bends). Seismic risk for Palmerston North $z=0.38$ .
Site 9	Q1a=75%, Q3a=25%. Seismic risk for Palmerston North $z=0.38$ .

## 2.2 Regional Stormwater

Area for Investigation	Constraints
Site 1	Regional flooding from Oroua River and Mangaone Stream north of Bunnythorpe in at least the 50yr ARI event. Confluence of multiple streams
Site 2	Subject to regional flooding from Oroua and Mangaone Stream north of Bunnythorpe - in at least the 50yr ARI event
Site 3	Regional flooding from Oroua and Mangaone Stream north of Bunnythorpe - in at least the 50yr ARI event. Confluence for multiple local streams
Site 4	Varied topography with multiple through channels, would only be subject to local flooding
Site 5	Subject to flooding from Mangaone Stream and local streams to the north. Oroua flood flows do reach this site even in at least the 50yr ARI event
Site 6	Some flooding from local drains. Not so prone to large river flooding. Does not fall into modelled Oroua, Mangaone, and Manawatu 200 yr ARI flooded areas.
Site 7	Potential due to proximity to Manawatu River, for flooding from Manawatu River (as reporting as occurring in February 2004 above ). Horizons modelling suggests S. end of
Site 8	Potential due to proximity to Manawatu River, for flooding from Manawatu River, as reported in 2004
Site 9	Unlikely to be flooded from major rivers. Possibly flooded from Mangaone. Recent flooding in PN - 2016, 2018, shows flooding on Tremaine Ave

## 3. Resilience Criteria

### 3.1 General

As well as liquefaction, seismic and regional flooding, the following hazards identified by Horizons Regional Council as affecting the region were also considered in this assessment:

- Tsunami – limited to several km of the coast and does not reach the site areas
- Landslide – sites are on flood plains (relatively flat). Some gullies and terracing are present although it is assumed that these will be filled as part of works or only minor instability is possible.
- Volcanic – The site is at least 105km from the nearest volcanic centre (assumed to affect all sites equally)
- Storms – assumed to be equal risk across sites.
- Fire – sites are in agricultural areas and assumed to be affected equally.

Liquefaction, seismic and regional flooding criteria for each site have been assessed using a scale of 1 to 5 with a score of 1 being a low impact and a score of 5 being a high impact.

Regional flooding was assessed as having a higher impact on the sites than liquefaction or seismicity since flooding has a higher frequency of events, and effects are better understood. Flooding also had a higher variance between sites. A weighting factor of  $x4^4$  was added to the flooding values in order to show variations between sites which were then added to liquefaction and seismic (low variation). The lowest scores represent the most suitable sites. Results are shown on Table 1.

### 3.2 Geotech

#### Approach to the assessment

Liquefaction scored based on proportion of each geological unit in an area and limited ground investigation records to characterize geological units. The Palmerston North area has a high seismic risk and has been scored accordingly. However, there is anticipated to be a low variation in seismic response across the sites.

#### Assumptions

For the purpose of this assessment it has been assumed that ground conditions within each geological unit (Q1a, Q3a and Q5a) are similar. While there may be some general engineering characteristics across a geological unit, the alluvially derived deposits in particular will be highly variable with gravels, sand silt and possible organic material. As a consequence, liquefaction potential will vary even where there might be a relatively low liquefaction potential for a given site/value.

Similarly, while seismic values for an area might be similar, there is likely to be a slightly different response for different soil types and depths which is beyond the scope of this assessment without additional ground information and undertaking site specific seismic studies. All sites have therefore been given the same seismic score.

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<sup>4</sup> 4 was used as the weighting factor as it was considered an appropriate factor to allow for variation between sites in the flooding assessment while still taking account of the liquefaction and seismic criteria.

### 3.3 Regional Stormwater

#### Approach to the assessment

Flooding is the most frequent emergency experienced by the Manawatu Region (Horizons Regional Council website<sup>5</sup>, 2019). The area is subject to regional flooding such as the catastrophic February 2004 event (Fuller, I.C.; Heerdegen, R.G.; 2005 and Westmount School, 2004) as well as more frequent, nuisance events such as those described in news articles from 2016 and 2018.

A review of flood extent mapping undertaken by Horizons Regional Council shows the majority of the proposed infrastructure hub sites are at risk of flooding from either the Oroua River and Mangaone Stream in the north (sites 1 to 6), or the Manawatu River in the south (sites 7 and 8). An assessment of the potential for flooding from regional watercourses at each site has been made based on the review of the flood extent maps, as well as news reports found online of past flooding and photographs of flooding (posted online) during various flood events. The key sources of information used are listed in Section 1 above. Below is a list of the maps and photographs reviewed along with a summary of the conclusions from each.

- **200 Year flooding extent for Upper Mangaone Stream** – shows flooding from Campbell Rd to Rangitikei Line, dominantly affects sites 1 and 3 and a little of 2. Mapping does not extend to sites 5 – 8, so impact of flooding is not known.
- **50 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1, 3, and 5 and a little of 6. The map does not show any flooding north of Campbell Rd, which is appears unrealistic. Flood modelling output is likely unavailable in this area.
- **100 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1, 3, and 5 and a little of 6. The map does not show any flooding north of Campbell Rd, which is appears unrealistic. Flood modelling output is likely unavailable in this area.
- **200 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1, 3, and 5 and a little of 6. The map does not show any flooding north of Campbell Rd, which is appears unrealistic. Flood modelling output is likely unavailable in this area.
- **200 Year flooding extent for Manawatu River** – shows flooding from a little way north of Campbell Rd to the Manawatu River. Dominantly affects sites 1, 3, 4, 5 and a little of 2, 6, 7, 8. The map does not show significant flooding across sites 7 and 8, however, aerial photography from the February 2004 event (200yr ARI), presented in *Destructive Deluge* – pages 114 and 115, shows significant flooding over 7 and 8.
- **Modelled Wet Areas across the Region** - shows flooding from Campbell Rd to the Coast. Dominantly affects sites 1, 3, and 5 and a little of 6. A portion of site 7 appears to be affected in the 1 yr ARI event. The map does not show any flooding north of Campbell Rd (site 2), which is appears unrealistic. Flood modelling output is likely unavailable in this area.
- **Feilding – Flooding the Manawatu** – a website ([https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y\\_GHeAp.Awc](https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y_GHeAp.Awc)) that contains 5 photographs showing flooding on either side of, and across, Campbell Road during an event in June 2015. No information is available regarding the magnitude of the event, however it shows flooding in areas covered by sites 1 and 2.
- **Flooded Farmland near Palmerston North** – a website (<https://manawatuheritage.pncc.govt.nz/item/39a5982a-d11e-4dbf-922b-68ba88b66a5e>) with an aerial photograph showing flooded farmland north of Palmerston North, east of Fielding.

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<sup>5</sup> <https://www.horizons.govt.nz/flood-emergency-management>

## Central North Island Freight Hub - - Workshop 2

Interpreted orientation of photo is looking north to south. Interpreted coverage is of areas in and around sites 1, 2, and 3. Flood event occurred in June 1976.

- **Destructive Deluge.** A pictorial coverage of flooding in the Manawatu, Tararua, Rangitikei and Horowhenua in February 2004. *Book by Westmount School, Palmerston North, 2004.*

### Assumptions.

Below are a list of the assumptions have been adopted for the assessment.

- Review of available flood modelling output, photography, and news reports is suitable for assessing how flood prone each site is at this stage of the investigation.
- The drainage channels provided in the in the background topo map of the ArcGISOnline workspace and the KiwiRail NIWA Rivers layers are an adequate representation, for the purposes of this assessment, of drainage channels in the vicinity of the potential KiwiRail PN Hub sites. It is assumed that all of these channels have the potential to be sources of overland flow during significant rainfall events.
- Site 2 is adjacent to and upstream of Site 1 and has been assessed based on flooding of Site 1 and news reports. It is expected that flooding that impacts Site 1 will also impact Site 2.

## 4. Comparative assessment

Area for Investigation	Assessment of the option	Score
Site 1	Mainly older age soils but regional flooding from Oroua River and Mangaone Stream north of Bunnythorpe (>50 yr ARI) confluence of multiple streams.	4
Site 2	Mainly older age soils, subject to regional flooding from Oroua and Mangaone Streams north of Bunnythorpe in at least the 50 yr ARI.	3
Site 3	Mainly older age soils. Regional flooding (Oroua and Mangaone Stream) north of Bunnythorpe - in at least the 50 yr ARI. Confluence for multiple local streams	4
Site 4	Older age soils. Varied topography with multiple through channels, would only be subject to local flooding	2
Site 5	Recent soils. Subject to flooding (Mangaone Stream and local streams) to the north. Oroua flood flows do reach this site even in at least the 50 yr ARI event	3
Site 6	Recent soils. Some flooding from local drains. Not prone to large river flooding. Does not fall into modelled Oroua, Mangaone, and Manawatu 200 yr ARI flooded areas.	3
Site 7	Recent soils. Potential for flooding from Manawatu River (2004). Horizons modelling suggests S. end of site prone to flooding even in a 1 yr ARI event on the Manawatu River.	5
Site 8	Recent Soils. Potential for flooding from Manawatu River, as happened in 2004	4
Site 9	Recent Soils. Unlikely to be flooded from major rivers. Possibly flooded from Mangaone. Recent flooding in PN - 2015, 2018, shows flooding on Tremaine Ave	3

## Addendum to the Workshop 2 Resilience Assessment

### Reasons for the addendum

The reason for this addendum is to provide a:

- record of the reasons why area options 7 and 8 were fatally flawed at workshop 2; and
- further assessment of the area options with the masterplan layout applied

### Fatal flaw of area options 7 and 8

During the Workshop 2 resilience assessment presentation, flooding risks for Option 7 and 8 were discussed and the following comments made:

- **Option 7** - Potential for flooding due to proximity to the Manawatu River (2004). Aerial photography from the 2004 floods showed extensive flooding across the area option.  
  
Horizons modelling suggests that the southern end of the area option is prone to flooding from the Manawatu River, even in a 1 year ARI event. The 200 year ARI indicates extensive flooding as illustrated by the 2004 flood event.
- **Option 8** - Potential for flooding due to proximity of the Manawatu River, as reported in 2004.

It was noted by the hydrology presenter that, although there were photographs of the 2004 floods and other flooding information available, there had not been comprehensive flood modelling undertaken for all of these areas.

Group discussion was undertaken and it was noted that engineering solutions may not entirely mitigate an extreme flood event at these locations. The workshop participants agreed that Options 7 and 8 should be fatally flawed.

### Further assessment

During Workshop 2, participants acknowledged that having a specific site to assess within the areas identified could potentially result in changes to the scores presented at Workshop 2.

As a result, after Workshop 2, the masterplan was applied to the area options assessed in Workshop 2, and sites within those areas identified. The rail connection was included on the refined options, and the implications for connecting to the North Island Main Trunk line were identified.

There are two layout options for areas 1 and 2 (Options 1a, 1b, 2a, 2b). Three layouts were originally developed for area 3, however only one layout was taken forward for assessment because the others did not meet the project objectives. Area 4 could only accommodate one layout option. There were significant constraints at the ends of areas 5 and 6, therefore the parts of these two areas without the constraints were combined to create site 5.

Sites in areas 7, 8 and 9 were not identified as these areas were fatally flawed at Workshop 2.

### Assessments

The following table sets out the resilience assessment and scoring for each of the site options

Site Option	Score	Assessment
Option 1a	4	Geology: Q1a = 25%, Q3a=75% (gullies cover 20% of the site). Seismic risk for Fielding z=0.37 Regional flooding from Oroua River and Mangaone Stream in at least the 50yr ARI event. Also potential flooding from Taonui Stream
Option 1b	4	Geology: Q1a = 35%, Q3a=65% (gullies cover 5% of the site). Seismic risk for Fielding z=0.37 Regional flooding from Oroua River and Mangaone Stream in at least the 50yr ARI event. Also potential flooding from Taonui Stream
Option 2a	3	Geology: Q1a = 10%, Q3a=90% Seismic risk for Fielding z=0.37 Potential flooding from Oroua River, Mangaone Stream, and Taonui Stream north of Bunnythorpe in at least the 50yr ARI event. However, current modelling does not show significant flooding.
Option 2b	4	Geology: Q1a = 50%, Q3a=50% (gullies cover 10% of the site)

		Seismic risk for Fielding $z=0.37$ Potential flooding from Oroua River, modelled flooding from Mangaone Stream north of Bunnythorpe in at least the 50yr ARI event. Also potential flooding from Taonui Stream
<b>Option 3a</b>	5	Geology: Q1a = 80%, Q3a=20% (gullies cover 20% of the site) Seismic risk for Palmerston North $z=0.38$ Potential flooding from Oroua River, modelled significant flooding from Mangaone Stream north of Bunnythorpe in at least the 50yr ARI event. Also potential flooding from Taonui Stream in the west and local streams draining from the east.
<b>Option 3b</b>	3	Geology: Q1a = 15%, Q3a=85% (gullies cover 40% of the site) Seismic risk for Palmerston North $z=0.38$ Modelled flooding from local streams draining from the east under Railway Rd and ponding from Managone Stream and Oroua River flooding in 50yr event.
<b>Option 3c</b>	4	Geology: Q1a = 15%, Q3a=85% (gullies cover 50% of the site) Seismic risk for Palmerston North $z=0.38$ Modelled flooding from local streams draining from the east under Railway Rd and ponding from Managone Stream and Oroua River flooding in 50yr event. Intersects more flooding than 3b.
<b>Option 4</b>	2	Geology: Q1a = 10%, Q3a=90% (gullies cover 90% of the site) Seismic risk for Palmerston North $z=0.38$ Varied topography with multiple through channels, would only be subject to flooding from local streams east of Railway Rd. Modelled flooding shown for 200yr event.
<b>Option 5</b>	3	Geology: Q1a = 100% Seismic risk for Palmerston North $z=0.38$ Not so prone to large river flooding. Does not fall into modelled Oroua, Mangaone, and Manawatu 200 yr ARI flooded areas. However, it is affected by local flooding in 200yr event.

### Conclusion

Seismic and liquefaction conditions do not vary significantly between options (particularly between Options 1 to 4). Within any particular option, it is likely that ground conditions will vary significantly and so at this stage of the assessment only high level comments can be made. Flooding has a more significant effect on the options and shorter return period.

# KiwiRail: Palmerston North - Assessment Template Workshop 3 Resilience

## 1. Introduction

Date: 20.11.19

### Authors

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The following is a comparative assessment of short list site options as part of Workshop 3 for KiwiRail's future Palmerston North Rail and Freight Hub.

The assessment details Geotech (Seismic and liquefaction) and Regional Stormwater hazards for 3 shortlisted sites (Sites 2A, 3C and 4) referred to in this assessment as Sites 2, 3 and 4, located to the north and west of Palmerston North. The shortlisted sites have a significantly reduced area than presented at previous workshops, includes possible infrastructure and building layouts, and has relied on the following information:

### **General**

- Kiwirail Hub - Fig 01 (Site2A), Fig 02 (Site 3C), and Fig 03 (Site 4)
- Workshop 1 and 2, discussion and scope.
- GIS data collated by Stantec for the purpose of this assessment.

### **Geotech (Liquefaction and Seismic)**

- GNS QMaps and ArcGIS database for anticipated ground conditions and topography.
- Google Earth Pro.
- NZ Geotechnical Database for existing ground information to characterize QMap material types Q1a, Q3a and Q5a in terms of liquefaction potential. Information included:
  - Boundary of sites 3 and 4 – T&T CPT18 (NZGD ID: CPT\_72221)
  - Site 4 – Miyamoto BH1 (NZGD ID: BH\_124994)
- GNS Active Faults Database for known active faults within the Palmerston North area.
- NZS 1170.5 'z' numbers to assess seismic risk in and around Palmerston North.
- Horizons Regional Council website - natural hazards.
- Palmerston North City Council, media release. Palmerston North and Liquefaction. Document ID 2537901.
- Palmerston North City Council District Plan, Section 22: Natural Hazards. May 2018

- Beetham, D. Barker, P. Beetham, J. Begg, J. and Levick, S. 2011. Assessment of liquefaction and related ground failure hazards in Palmerston North, New Zealand. GNS Science Consultancy Report 2011/108.

### Regional Flooding

- Horizons Flood Extent Maps for the Oroua River<sup>1</sup>, Upper Mangaone Stream<sup>2</sup>, and Manawatu River<sup>3</sup>
- Horizons Modelled Wet Areas Map
- **Feilding – Flooding the Manawatu** – a website ([https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y\\_GHeAp.Awc](https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y_GHeAp.Awc))
- **Flooded Farmland near Palmerston North** – a website (<https://manawatuheritage.pncc.govt.nz/item/39a5982a-d11e-4dbf-922b-68ba88b66a5e>)
- **Destructive Deluge.** A pictorial coverage of flooding in the Manawatu, Tararua Rangitikei and Horowhenua in February 2004. *Book by Westmount School, Palmerston North, 2004.*
- News report: <https://www.stuff.co.nz/manawatu-standard/news/109342333/surface-flooding-causes-havoc-in-kelvin-grove-palmerston-north>
- News report: <https://www.stuff.co.nz/manawatu-standard/news/79659454/warning-for-horowhenua-as-wet-weather-sets-in>
- Horizons Regional Council website: <https://www.horizons.govt.nz/flood-emergency-management>
- Fuller, I.C.; Heerdegen, R.G.; 2005. *The February 2004 flood in the Manawatu, New Zealand: hydrological significance and impact on channel morphology.* Journal of Hydrology (NZ) 44 (2): 75 – 90, 2005.

The following information was not available for this assessment

### Geotech

- Site specific ground information for the sites. Very limited ground information available on the NZGD resulting in generalized comments regarding liquefaction.
- Limited information on the active faults closest to Palmerston North in the GNS Active Faults Database.

### Regional Flooding

- Flood modelling output for events with magnitudes less than 1 in 50 year ARI. As a result, it is difficult to establish the impact of more frequent events for each site.
- No flood maps show predicted flood extents north of Campbell Rd (Site 2, and upstream of Site 2). It is possible that this area has not been modelled to date, so it is difficult to assess how flood prone site 2 is.
- No intermediate return interval flood extents are shown in the Modelled Wet Areas map. This map shows a composite of 50 year ARI, 100 year ARI, 200 year ARI flood extents for the Oroua River and Mangaone Stream and the 1 year ARI extent for the Manawatu River.

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<sup>1</sup> 50 year Ari, 100 year ARI, 200 year ARI

<sup>2</sup> 50 year Ari, 100 year ARI, 200 year ARI

<sup>3</sup> 200 year ARI

## 2. Constraints identified in each site

### 2.1 Geotech

The **liquefaction** assessment is based on:

- published Geological and Nuclear Sciences (GNS) Q map geological mapping at a high level scale of 1:250,000 where:
  - **Q1a Moderate to High Liquefaction Potential** = 12,000 years ago to recent age. These ground conditions occur on low lying ground to the west of Bunnythorpe (Site 2) and are also likely to be encountered the base of gullies (Site 3 and 4). Moderately to well sorted alluvial flood plain gravel with minor sand/silt and overbank silt deposits. Assumed high groundwater.
  - **Q3a Negligible Liquefaction potential** = 24,000 to 59,000 age. These ground conditions occur in slightly elevated terrain to the east and west of the North Island Main Trunk line (NIMT). Poorly to moderately sorted gravel with minor sand or silt, sometimes weathered, underlying a terrace surface and/or overlying loess/paleosol couplets and tephra (ash).
  - **Q5b Negligible Liquefaction potential** = 71,000 to 128,000 age. Ground conditions as part of this category occur within elevated terrain to the east of the NIMT Sand and gravel with some lacustrine silt and clay, commonly overlain by 3 loess/paleosol couplets and tephra.
- a low detail Liquefaction Ground Damage Potential map (Figure 14) within the 2011/108 GNS report for sites 3 and 4. Liquefaction damage potential for site 2 is inferred from similar anticipated ground conditions for sites 3 and 4.
- Limited ground investigation information from outside the sites reported within the NZ Geotechnical Database (NZGD). Those materials with a silt/sand size range, are geologically recent/are loose and have a high groundwater table are more susceptible to liquefaction.

The **seismic** assessment is based on:

- Published values ('z' values) for larger towns and cities. The 'z' value refers to the seismic hazard factor for a given area. The sites have a z value of between approximately z=0.38 (Palmerston North) and z=0.37 (Fielding) reflecting proximity to active faults including the Wellington Fault. As a comparison, Wellington has a z=0.40 value while Auckland a value of z=0.14.
- Locations and information relating to known active faults in the area as shown on the GNS's Active Faults Database. There are no known active faults within approximately 4km of site boundaries, and very little information regarding active faults closest to the sites. There may be active faults present beneath or close to the sites which are obscured by soil.
- Ground Shaking Hazard Map (Map 22.6.1) within the Palmerston North District Plan. Sites 3 and 4 are covered within the map and assessment is inferred for Site 2 based on geological map ground conditions and anticipated engineering properties.

Liquefaction and seismic summary:

Area for Investigation	Constraints
Option 2	<b>Liquefaction susceptible soils</b> - Q1a=15%, Q3a=85% (no gullies). <b>Seismic</b> - Seismic risk for Fielding z=0.37, no known active faults within approximately 9km of the site. Inferred no significant amplification for majority of site. Some moderate amplification may occur within Q1a material within low lying area.
Option 3	<b>Liquefaction susceptible soils</b> - Q1a=15%, Q3a=85% (gully sides and bases cover approx. 50% of the site). <b>Seismic</b> - Seismic risk for Palmerston North z=0.38. No known active faults within approximately 5km of the site. No significant amplification for majority of the site. Some moderate amplification may occur within Q1a material in the base of gullies.
Option 4	<b>Liquefaction susceptible soils</b> - Q1a=10%, Q3a=90% (gully sides and bases cover approx. 70% of the site). <b>Seismic</b> - Seismic risk for Palmerston North z=0.38. No known active faults within approximately 4km of the site. Some moderate amplification may occur within Q1a material in the base of gullies.

Regional Flooding Summary:

Site	Constraints
Option 2	Potential for flooding from the Oroua River, Mangaone Stream, and Taonui Stream in at least the 50 year ARI event.
Option 3	Potential for flooding from the Oroua River and Mangaone Stream in at least the 50 year ARI event, as well local streams draining towards the site from the northeast.
Option 4	Potential for flooding from local streams draining towards the site from the northeast.

## 3. Criteria being assessed

### 3.1 General

As well as liquefaction, seismic and regional flooding, the following hazards identified by Horizons Regional council as affecting the region were also considered in this assessment:

- Tsunami – limited to several km of the coast and does not reach the site areas
- Landslide – sites are on flood plains (relatively flat). Some gullies and terracing are present although it is assumed that these will be filled as part of works or minor instability likely.
- Volcanic – The site is at least 105km from the nearest volcanic centre (assumed to affect all sites equally)
- Storms – assumed to be equal risk across sites.

- Fire – sites are in agricultural areas and assumed to be affected equally.

Security has not been assessed as part of resilience and is assumed to have been undertaken elsewhere.

Liquefaction, seismic and regional flooding criteria for each site have been assessed using a scale of 1 to 5 with a score of 1 being a low impact and a score of 5 being a high impact.

Liquefaction susceptible soils and seismic effects were not shown to vary significantly between the shortlisted sites. Regional flooding was assessed as having a higher impact on the sites than liquefaction or seismicity since flooding has a higher frequency and effects are better understood. The lowest scores represent the most suitable sites.

### **3.2 Geotech**

#### Approach to the assessment

Liquefaction has been scored based on the proportion of geological units in a site area (eg Q1a and Q3a), limited ground investigation records to characterize geological units and published GNS reporting for the Palmerston North area.

The Palmerston North area has a high seismic risk as shown by 'z' values and proximity to active faulting, and has been scored accordingly. However there is anticipated to be a low variation in seismic response and amplification effects between the sites.

Where the sites lie over geologically recently deposited alluvial material (ie. Q1a), liquefaction and amplification risks are higher and may lead to differential settlement in significant seismic events.

#### Assumptions

For the purpose of this assessment it has been assumed that ground conditions within each geological unit (Q1a and Q3a) are similar. While there may be some general engineering characteristics across a geological unit, the alluvially derived deposits, particularly those in Q1a will be highly variable with gravels, sand silt and possible organic material. As a consequence, liquefaction potential will vary even where there might be a relatively low liquefaction potential for a given site/value.

Similarly, while seismic values for an area might be similar, there is likely to be a slightly different response for different soil types and depths which is beyond the scope of this assessment without specific ground information and undertaking site specific seismic studies.

### **3.3 Regional Stormwater**

#### Approach to the assessment

Flooding is the most frequent emergency experienced by the Manawatu Region (Horizons Regional Council website<sup>4</sup>, 2019). The area is subject to regional flooding such as the catastrophic February 2004 event (Fuller, I.C.; Heerdegen, R.G.; 2005 and Westmount School, 2004) as well as more frequent, nuisance events such as those described in news articles from 2016 and 2018.

A review of flood extent mapping undertaken by Horizons Regional Council shows the proposed infrastructure hub sites are at risk of flooding from either the Oroua River and/or Mangaone Stream. An assessment of the potential for flooding from regional watercourses at each site has been made based on a review of flood extent maps, as well as news reports found online of past flooding and photographs of

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<sup>4</sup> <https://www.horizons.govt.nz/flood-emergency-management>

flooding (posted online) during various flood events. The key sources of information used are listed in Section 1 above. Below is a list of the maps and photographs reviewed along with a summary of the conclusions from each.

- **200 Year flooding extent for Upper Mangaone Stream** – shows flooding from Campbell Rd to Rangitikei Line, dominantly affects sites 1 and 3 and a little of 2.
- **50 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1 and 3. The map does not show any flooding north of Campbell Rd, which is seems unlikely. Flood modelling output is likely unavailable in this area.
- **100 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1 and 3,. The map does not show any flooding north of Campbell Rd, which is seems unlikely. Flood modelling output is likely unavailable in this area.
- **200 Year flooding extent for Oroua River** – shows flooding from Campbell Rd to the Manawatu River. Dominantly affects sites 1 and 3. The map does not show any flooding north of Campbell Rd, which is unlikely. Flood modelling output is likely unavailable in this area.
- **200 Year flooding extent for Manawatu River** – shows flooding from a little way north of Campbell Rd to the Manawatu River. Dominantly affects sites 1 and 3.
- **Modelled Wet Areas across the Region** - shows flooding from Campbell Rd to the Coast. Dominantly affects sites 1 and 3. The map does not show flooding north of Campbell Rd (site 2), which is unlikely. Flood modelling output is likely unavailable in this area.
- **Feilding – Flooding the Manawatu** – a website ([https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y\\_GHeAp.Awc](https://snpa.photoshelter.com/gallery/Feilding-Flooding-in-the-Manawatu/G0000wXqkd0jD1E0/C0000Y_GHeAp.Awc)) that contains 5 photographs showing flooding on either side of, and across, Campbell Road during an event in June 2015. No information is available regarding the magnitude of the event, however it shows flooding in areas covered by sites 1 and 2.
- **Flooded Farmland near Palmerston North** – a website (<https://manawatuheritage.pncc.govt.nz/item/39a5982a-d11e-4dbf-922b-68ba88b66a5e>) with an aerial photograph showing flooded farmland north of Palmerston North, east of Fielding. Interpreted orientation of photo is looking north to south. Interpreted coverage is of areas in and around sites 1, 2, and 3. Flood event occurred in June 1976.
- **Destructive Deluge.** A pictorial coverage of flooding in the Manawatu, Tararua, Rangitikei and Horowhenua in February 2004. *Book by Westmount School, Palmerston North, 2004.*

### Assumptions.

Below are a list of the assumptions that have been adopted for the assessment.

- Review of available flood modelling output, photography, and news reports is suitable for assessing how flood prone each site is at this stage of the investigation.
- The drainage channels provided in the in the background topo map of the ArcGIS Online workspace and the KiwiRail NIWA Rivers layers are an adequate representation, for the purposes of this assessment, of drainage channels in the vicinity of the potential KiwiRail PN Hub sites. It is assumed that all of these channels have the potential to be sources of overland flow during significant rainfall events.
- Site 2 has been assessed based on flooding of Site 1 and news reports. It is expected that flooding that impacts Site 1 will also impact Site 2.

## 4. Fatal Flaws

Site	Flaw Description	Explanation
Option 2	No fatal flaws for Liquefaction and Seismic effects or for Regional Stormwater	N/A
Option 3	No fatal flaws for Liquefaction and Seismic effects or for Regional Stormwater	N/A
Option 4	No fatal flaws for Liquefaction and Seismic effects or for Regional Stormwater	N/A

## 5. Comparative assessment

### Geotech – Liquefaction and Seismic

Output from the Geotechnical assessment is provided in the table below. In summary, the sites are anticipated to contain similar types and proportions of largely low liquefaction prone soils, and so liquefaction is likely to affect all sites similarly.

The sites are in a relatively high seismic area and are relatively close to one another. Since soils are likely to be similar in nature and extent then seismic amplification effects are also likely to be similar. Consequently, all the sites have been scored highly and similarly.

It is important to note that comments regarding soil types and proportions are high level and that site specific ground investigation should be undertaken in order to confirm assumptions. The assessments characterizes likely significant differences between sites but does not reflect local ground conditions at each site. Given the soil types, nature of formation and size of each site, ground conditions may vary significantly within a site. Equally, seismic effects at each site are high level and generalized and would require a localized site specific seismic assessment to characterize individual locations which is beyond the scope of this assessment.

### Geotech Assessment – Liquefaction and Seismic

Site	Liquefaction Assessment	Score	Seismic Assessment	Score
Site 2	Q1a = 15%, Q3a=85% (no gullies) Liquefaction potential low to negligible	2	Seismic risk for Fielding z=0.37. No significant amplification (Zone 2)	4
Site 3	Q1a = 15%, Q3a=85% (gullies cover approx. 50% of the site). GNS liquefaction potential negligible (except gullies)	2	Seismic risk for Palmerston North z=0.38. No significant amplification (Zone 2)	4

Site 4	Q1a = 10%, Q3a=90% (gullies cover approx. 70% of the site). GNS liquefaction potential negligible (except gullies)	2	Seismic risk for Palmerston North z=0.38. No significant amplification (Zone 2)	4
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### Regional Flooding Assessment

Site	Assessment	Score
Site 2	Mainly older age soils, subject to regional flooding from Oroua and Mangaone Streams north of Bunnythorpe in at least the 50 yr ARI.	3
Site 3	Mainly older age soils. Regional flooding (Oroua and Mangaone Stream) north of Bunnythorpe - in at least the 50 yr ARI. Confluence for multiple local streams	4
Site 4	Older age soils. Varied topography with multiple through channels, would only be subject to local flooding	3

### RESILIENCE ASSESSMENT SUMMARY

Geotech (liquefaction and seismic) has been removed from the final assessment score and regional flooding values adopted since:

- There is no variation between the geotech sites and combining them with regional flooding would mask the variation within regional flooding.
- There is a lower level of confidence with the geotech information. Ground investigation may change the values adopted in the assessment.
- Regional flooding events have a higher degree of confidence and are a higher frequency (ie. will occur more often) than liquefaction or seismic events.

Site	Score
Site 2	3
Site 3	4
Site 4	3

## 6. Mitigation

For geotech (liquefaction and seismic) there have been no mitigation assumptions other than it is assumed that gullies will be filled as part of site earthworks and so landsliding (Section 3.1) will not be an issue. Liquefaction and seismic effects outlined in the assessment can be managed / engineered during the design stage.

Site	Regional Flooding Mitigation
Option 2	<p>Proposed stormwater management approach for offsite drainage and the proposed perimeter road may provide sufficient protection. If not, bunding around the site will be required. Any required bunding could potentially sit between the perimeter road and the proposed diversion channel.</p> <p>Proposed mitigation options (bunding) are based on an assessment of 50-year ARI flood maps for the Mangaone Stream, 50-year ARI flood, 100-year ARI flood ,and 200 year ARI flood maps for the Oroua River and 200 year ARI flood maps for the Palmerston North area. All maps have been supplied by Horizons Regional Council, based on modelling undertaken by Horizons. No modelling has been undertaken by KiwiRail/Stantec.</p>
Option 3	<p>Potential for flooding from the Oroua River and Mangaone Stream in at least the 50 year ARI event, as well local streams draining towards the site from the northeast. Proposed stormwater management approach for offsite drainage and the proposed perimeter road may provide sufficient protection in places. However, additional bunding may be required along the western boundary of the northern half of the site to provide protection from flood water spilling from the Mangaone Stream.</p> <p>Proposed mitigation options (bunding) are based on an assessment of 50-year ARI flood maps for the Mangaone Stream, 50-year ARI flood, 100-year ARI flood ,and 200 year ARI flood maps for the Oroua River, and 200 year ARI flood maps for the Palmerston North area. All maps have been supplied by Horizons Regional Council, based on modelling undertaken by Horizons. No modelling has been undertaken by KiwiRail/Stantec.</p>
Option 4	<p>Potential for flooding from local streams draining towards the site from the northeast. Proposed stormwater management approach for offsite drainage and the proposed perimeter road should provide sufficient protection in places. However, additional bunding may be required along the eastern boundary of the site. Any required bunding could potentially sit between the perimeter road and proposed diversion channel.</p> <p>Proposed mitigation options (bunding) are based on an assessment of 50-year ARI flood maps for the Mangaone Stream, 50-year ARI flood, 100-year ARI flood ,and 200 year ARI flood maps for the Oroua River, and 200 year ARI flood maps for the Palmerston North area. All maps have been supplied by Horizons Regional Council, based on modelling undertaken by Horizons. No modelling has been undertaken by KiwiRail/Stantec.</p>