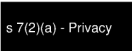


Tauranga City Council
PO Box 12-022
Tauranga Mail Centre
Tauranga 3143

Attention: 

Dear 

Tauranga City-wide Natural Hazards Risk Assessment

1 Introduction

Tonkin and Taylor Ltd (T+T) has recently completed a city-wide natural hazard risk assessment for Tauranga (2020b) using Appendix L of the Bay of Plenty Regional Council Regional Policy Statement BoPRC (2016) (hereinafter referred to as the RPS) on natural hazards. The intent of this work was to create a “baseline” of natural hazard risk which can be used to inform future updates to the City Plan, utilising the best currently available data.

In order to inform their update to the City Plan and its associated rules, supplementary to the above-mentioned report, Tauranga City Council (TCC) also engaged T+T to undertake additional risk assessments (that would be reported on separately) for liquefaction hazard and lateral spread for different Natural Hazard Zones (NHZs)¹ as listed below:

- Separate NHZs for the eastern and western parts of the city.
- The entire liquefaction hazard susceptibility area (HSA), excluding the areas that are also part of the coastal erosion and coastal inundation HSAs.
- The liquefaction vulnerability categories defined in accordance with the 2017 MBIE/MfE document *Planning and engineering guidance for potentially liquefaction-prone land* (MBIE/MfE Guidance (2017)).

These additional risk assessments are summarised in Section 2 of this letter report. This section should be read in conjunction with the Tauranga City-wide natural hazards risk assessment, dated April 2020, T+T ref 1008440.3000.v3. (T+T, 2020b).

This letter report also presents a case study using a hypothetical infill housing development example to establish whether the intended outcomes of the RPS risk assessment for liquefaction hazard are achieved through compliance with the New Zealand Building Code 2004 (NZBC). This case study has been developed with reference to the liquefaction-induced ground damage categories described in

¹ The NHZ is a zone defined by a regional, city or district plan as being the scale at which hazard risk assessment is to be undertaken for the purpose of developing appropriate risk management provisions in plans. A NHZ can be an entire HSA or (more likely) part of such an area, but it cannot be bigger than a HSA.

the MBIE/MfE Guidance (2017) if the dwelling is founded on a TC2 type waffle slab as described in the MBIE document *Repairing and rebuilding houses affected by the Canterbury earthquakes* MBIE Guidance (2012). T+T understands that TCC will also use this case study to inform their update to the City Plan and its associated rules. This case study is summarised in Section 3 of this letter report.

2 Risk assessment

Additional risk assessments as stated in Section 1 were undertaken for NHZs as specified by TCC. This section summarises the origin of the data and methodology that was used in conducting the risk assessment and presents the results of the risk assessment.

2.1 Liquefaction and lateral spread data

The datasets used to define the risk results in Section 2.3 for the liquefaction hazard for this study were the outputs of the 'Tauranga City Western Zone Liquefaction Hazard Assessment' undertaken by Aurecon (Aurecon, 2020) and the 'Liquefaction Analysis and Hazard Mapping for Eastern Zone' undertaken by T+T (T+T, 2020a). The RPS risk assessment has been undertaken in general accordance with the approach outlined in the 'Te Tumu Natural Hazard Risk Assessment – Liquefaction' (T+T, 2018).

The output from the T+T (2020a) liquefaction assessment covers approximately 5,800 ha of land east of the Tauranga City Central Business District (CBD). The output from the Aurecon (2020) liquefaction assessment covers 15,400 ha of land in the western portion of Tauranga City. The scope for both the T+T (2020a) and Aurecon (2020) studies included the following:

- Assessment for five return period events, including 0.1% AEP and 0.2% AEP levels of earthquake shaking.
- Consideration of the likely influence of 1.25 m of sea level rise on liquefaction-induced land damage.
- Consideration of the potential for lateral spreading as part of the assessment of liquefaction induced land damage.

2.2 Methodology

For a breakdown of the methodology please refer to the detailed approach in Section 2 in the Tauranga City-Wide Natural Hazards Assessment, by T+T, dated April 2020, T+T ref 1008440.3000.v3, (T+T, 2020b). The two scenarios for which the risk assessment has been conducted for are reiterated from (T+T, 2020b) and summarised in Section 2.2.1. Additional information in regards to determining consequence levels that has not been covered in (T+T, 2020b) is noted in section 2.2.2 below. The risk screening matrix used for the risk assessment is reiterated in section 2.3.1.

2.2.1 Scenarios

As stated in (T+T, 2020b) the following scenarios were used for the primary and secondary assessment for risk assessment in Section 2.3. Table 20 of Appendix L in the RPS recommends a 0.1% AEP event for the primary assessment and 0.2% and 0.033% AEP events for the secondary assessments. However, the T+T (2020a) and Aurecon (2020) data only estimate land damage for the 0.1% AEP event and a 0.2% AEP events and therefore only these events have been assessed. See Table 2.1 below.

Table 2.1: Liquefaction hazard events

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
All land in the TCC study extents that has been assessed in either the Aurecon (2020) or the T+T (2020a) data	Existing 0.1% AEP, no SLR	Existing 0.2% AEP, no SLR
	Future 0.1% AEP, 1.25 m SLR	Future 0.2% AEP, 1.25 m SLR

2.2.2 Additional information on consequence assessment

Consequence level	Built			Lifelines utilities	Health & safety
	Social/cultural	Buildings	Critical buildings		
Catastrophic	≥25% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	≥50% of buildings within hazard assessment area have functionality compromised.	≥25% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for > 1 month (affecting ≥ 20% of the town/city population) OR out for > 6 months (affecting < 20% of the town/city population).	>101 dead and/or >1001 injured
Major	11–24% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	21–49% of buildings within hazard assessment area have functionality compromised.	11–24% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 week – 1 month (affecting ≥ 20% of the town/city population) OR out for 6 weeks to 6 months (affecting < 20% of the town/city population).	11–100 dead and/or 101–1000 injured
Moderate	6–10% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	11–20% of buildings within hazard assessment area have functionality compromised.	6–10% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 day to 1 week (affecting ≥ 20% of the town/city population) OR out for 1 week to 6 weeks (affecting < 20% of the town/city population).	2–10 dead and/or 11–100 injured
Minor	1–5% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	2–10% of buildings within hazard assessment area have functionality compromised.	1–5% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 2 hours to 1 day (affecting ≥ 20% of the town/city population) OR out for 1 day to 1 week (affecting < 20% of the town/city population).	≤1 dead and/or 1–10 injured
Insignificant	No buildings of social/cultural significance within hazard assessment area have functionality compromised.	<1% of buildings within hazard assessment area have functionality compromised.	No damage within hazard assessment area, fully functional.	A lifeline utility service is out for up to 2 hours (affecting ≥ 20% of the town/city population) OR out for up to 1 day (affecting < 20% of the town/city population).	No dead No injured

NB for the purpose of Table 2.1:

- the term "town/city population" means the catchment of people within the hazard assessment area that is served by the lifeline utility, except that with respect to a lifeline utility that predominantly or exclusively serves a population outside the hazard assessment area, it means the population in the area served by the lifeline utility.
- the applicable consequence level will be the one that corresponds to the row that represents the highest measured or estimated consequence.

Figure 2.1: Consequence table with qualitative and quantitative descriptions (source BoPRC (2016))

For the risk assessment in Section 2.3, the number of functionally compromised buildings ('social/cultural', 'critical' and 'other') fall into percentages which may at times border between two consequence level categories. For example, where 5.3% of the social/critical buildings are functionally compromised, 5.3% would be rounded down to 5% and be categorised within the 'Minor' consequence level. If however 5.7% of social/critical buildings are functionally compromised, 5.7% would be rounded up to 6% and be categorised within the 'Moderate' consequence level. The borderline cases that had a material effect on the resultant risk level occurred in the following NHZs:

- Eastern Zone (current climate) – refer to Section 2.3.1.1.
- Western Zone (current climate) - refer to Section 2.3.1.3.
- Western Zone (future climate) – refer to Section 2.3.1.4.

2.2.3 Risk screening matrix

The risk assessment for liquefaction hazard is carried out using the risk screening matrix (Figure 2.2 below) recommended in Appendix L of the RPS.

Likelihood ⁵ (AEP %)	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
≥2	Low risk	Medium risk	Medium risk	High risk	High risk
<2-1	Low risk	Low risk	Medium risk	Medium risk	High risk
<1-0.1	Low risk	Low risk	Medium risk	Medium risk	High risk
<0.1-0.04	Low risk	Low risk	Low risk	Low risk	Medium risk
<0.04	Low risk	Low risk	Low risk	Low risk	Medium risk

Key

- High risk
- Medium risk
- Low risk

Figure 2.2: Risk screening matrix (source: BoPRC (2016))

2.3 Results

This section summarises the liquefaction hazard risk assessments based on three different sets of natural hazard zones as listed in Section 1.

The risk assessment for public safety and lifeline utilities has been undertaken using the same qualitative approach as described in Section 2.6 in T+T (2020b). A summary of consequence levels and risk ratings for public safety and lifeline utilities is summarised below:

Table 2.2: Summary of consequence and risk levels

	Consequence level	Risk level
Public safety*	Minor	Low
Lifeline utilities*	Catastrophic	High
Buildings	Refer to sections 2.3.1, 2.3.2, and 2.3.3	

The overall risk allocated to buildings is based on the highest consequence level associated with at least one building type ('critical', 'social/cultural', and 'other').

2.3.1 Eastern and Western zones

2.3.1.1 Eastern zone (current climate)

For the Eastern zone a total of 14 critical buildings, 207 social/cultural buildings and 23,756 'other' buildings located in the Eastern Zone HSA.

For the current climate scenario, the 0.1% AEP event (primary assessment) resulted in a consequence level of 'Major' and the 0.2% AEP event (secondary assessment) resulted in a consequence level of 'Moderate' based on the quantitative assessment of consequence to buildings. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.3: Building counts for liquefaction and lateral spread in the Eastern zone (current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	14	3	21.4%	1	7.1%		
Social/cultural buildings	207	11	5.3%	4	1.9%		
Other buildings	23,756	1,393	5.9%	645	2.7%		

Table 2.4: Liquefaction and lateral spread risk assessment results in the Eastern zone (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Major	Medium	Moderate	Medium		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.1.2 Eastern zone future climate

For the future climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of 'Catastrophic' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current climate scenario. The overall risk level assigned for both future events was 'High' based on the highest consequence level to both buildings and lifeline utilities.

Table 2.5: Building counts for liquefaction and lateral spread in the Eastern zone (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	14	4	28.6%	4	28.6%		
Social/cultural buildings	207	44	21.3%	25	12.1%		
Other buildings	23,756	6,044	25.4%	3,493	14.7%		

Table 2.6: Liquefaction and lateral spread risk assessment results in the Eastern zone (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Catastrophic	High	Catastrophic	High		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.1.3 Western zone (current climate)

For the Western Zone a total of 39 critical buildings, 592 social/cultural buildings and 40,056 'other' buildings were located in the HSA.

For the current climate scenario, the 0.1% AEP event (primary assessment) and the 0.2% AEP event (secondary assessment) resulted in a consequence level of 'Moderate' based on the quantitative assessment of consequence to buildings. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.7: Building counts for liquefaction and lateral spread in the Western zone (current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	39	2	5.1%	2	5.1%		
Social/cultural buildings	592	33	5.6%	33	5.6%		
Other buildings	40,056	2,160	5.4%	2,155	5.4%		

Table 2.8: Liquefaction and lateral spread risk assessment results in the Western zone (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Moderate	Medium	Moderate	Medium		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.1.4 Western zone future climate

For the future climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of 'Moderate' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current climate scenario. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.9: Building counts for liquefaction and lateral spread in the Western zone (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	39	2	5.1%	2	5.1%		
Social/cultural buildings	592	34	5.7%	34	5.7%		
Other buildings	40,056	2,306	5.8%	2,304	5.8%		

Table 2.10: Liquefaction and lateral spread risk assessment results in the Western zone (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Moderate	Medium	Moderate	Medium		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.2 HSA area excluding coastal erosion and inundation areas

The HSA for this section includes the entire TCC study area (i.e. both Eastern and Western Zones) excluding the coastal erosion and inundation HSAs. Refer to T +T, (2020b) for the extent of the coastal erosion and inundation HSAs. For this HSA, a total of 42 critical buildings, 739 social/cultural buildings and 60,290 'other' buildings were located in the HSA.

2.3.2.1 HSA area excluding coastal erosion and inundation areas (current climate)

For the current climate scenario, the 0.1% AEP event (primary assessment) and 0.2% (secondary assessment) resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from 'Minor' and 'Catastrophic' respectively. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.11: Building counts for liquefaction and lateral spread excluding coastal erosion and coastal inundation areas (current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	42	0	0.0%	0	0.0%		
Social/cultural buildings	739	19	2.6%	14	1.9%		
Other buildings	60,290	2,280	3.8%	1,572	2.6%		

Table 2.12: Liquefaction and lateral spread risk assessment results excluding coastal erosion and coastal inundation areas (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Minor	Low	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.2.2 HSA area excluding coastal erosion and inundation areas (future climate)

For the future climate scenario, the 0.1% AEP event (primary assessment) resulted in a consequence level of 'Moderate' and the 0.2% AEP event (secondary assessment) resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current scenario at 'Minor' and 'Catastrophic' respectively. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.13: Building counts for liquefaction and lateral spread excluding coastal erosion and coastal inundation areas (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	42	1	2.4%	0	0.0%		
Social/cultural buildings	739	50	6.8%	32	4.3%		
Other buildings	60,290	6,843	11.4%	4,422	7.3%		

Table 2.14: Liquefaction and lateral spread risk assessment results excluding coastal erosion and coastal inundation areas (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Moderate	Medium	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3 Liquefaction vulnerability categories

The key output of both the Aurecon (2020) and T+T (2020a) liquefaction vulnerability studies is the categorisation of land into one of the liquefaction vulnerability categories shown in Table 4.4 of the MBIE/MfE Guidance (2017) (refer Table 2.15 below).

Table 2.15: Table 4.4 from the MBIE/MfE Guidance (2017) - Performance criteria for determining the liquefaction vulnerability category

LIQUEFACTION CATEGORY IS UNDETERMINED			
A liquefaction vulnerability category has not been assigned at this stage, either because a liquefaction assessment has not been undertaken for this area, or there is not enough information to determine the appropriate category with the required level of confidence.			
LIQUEFACTION DAMAGE IS UNLIKELY There is a probability of more than 85 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking. At this stage there is not enough information to distinguish between Very Low and Low . More detailed assessment would be required to assign a more specific liquefaction category.		LIQUEFACTION DAMAGE IS POSSIBLE There is a probability of more than 15 percent that liquefaction-induced ground damage will be Minor to Moderate (or more) for 500-year shaking. At this stage there is not enough information to distinguish between Medium and High . More detailed assessment would be required to assign a more specific liquefaction category.	
Very Low Liquefaction Vulnerability There is a probability of more than 99 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking.	Low Liquefaction Vulnerability There is a probability of more than 85 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking.	Medium Liquefaction Vulnerability There is a probability of more than 50 percent that liquefaction-induced ground damage will be: Minor to Moderate (or less) for 500-year shaking; and None to Minor for 100-year shaking.	High Liquefaction Vulnerability There is a probability of more than 50 percent that liquefaction-induced ground damage will be: Moderate to Severe for 500-year shaking; and/or Minor to Moderate (or more) for 100-year shaking.

To reduce the number of HSAs and thereby simplify the results of the RPS risk assessment, each category (undetermined, unlikely, possible, very low, low, medium, and high) was regrouped into one of the following categories:

- Liquefaction category is undetermined.
- Liquefaction damage is unlikely.
- Liquefaction damage is possible.

This regrouping was undertaken as shown in Table 2.16.

Table 2.16: Summary of regrouping of liquefaction vulnerability categories for the purposes of this risk assessment

Reported liquefaction vulnerability category	Liquefaction vulnerability category for this risk assessment
Undetermined	Undetermined
Low	Unlikely
Very Low	Unlikely
Unlikely	Unlikely
High	Possible
Possible	Possible

Therefore if the assessment conducted by T+T (2020a) and Aurecon (2020) had liquefaction vulnerability categories ‘low’ or ‘very low’ this would now be re-categorized as ‘liquefaction damage is unlikely’. This was the same for liquefaction vulnerability category ‘high’ this would now be re-categorized as ‘liquefaction damage is possible’ for the purposes of this assessment. If the liquefaction vulnerability categories were classed as ‘undetermined,’ ‘unlikely’ or ‘possible’ in the

assessment conducted by T+T (2020a) and Aurecon (2020) there would be no change to the categorization for this assessment.

2.3.3.1 Liquefaction vulnerability category 'liquefaction category is undetermined' (current climate)

Where the liquefaction vulnerability was defined as 'liquefaction category is undetermined,' a total of 0 critical buildings, 4 social/cultural buildings and 221 'other' buildings were located in the HSA.

For the current climate scenario, the 0.1% AEP (primary assessment) and 0.2% AEP event (secondary assessment) resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged and are 'Minor' and 'Catastrophic' respectively. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.17: Building counts for liquefaction vulnerability category 'liquefaction damage is undetermined' current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	0	n/a	n/a	0	n/a		
Social/cultural buildings	4	0	0.00%	0	0.00%		
Other buildings	221	3	1.36%	3	1.36%		

Table 2.18: Risk assessment results for liquefaction vulnerability category 'liquefaction damage is undetermined' (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Minor	Low	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3.2 Liquefaction vulnerability category 'liquefaction category is undetermined' (future climate)

For the future climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged and are 'Minor' and 'Catastrophic' respectively. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.19: Building counts for liquefaction vulnerability category 'liquefaction damage is undetermined' (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	0	n/a	n/a	0	n/a		
Social/cultural buildings	4	0	0.00%	0	0.00%		
Other buildings	221	3	1.36%	3	1.36%		

Table 2.20: Risk assessment results for liquefaction vulnerability category 'liquefaction damage is undetermined' (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Minor	Low	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3.3 Liquefaction vulnerability category 'liquefaction damage is unlikely' (current climate)

Where the liquefaction vulnerability was defined as 'liquefaction category is unlikely,' a total of 36 critical buildings, 552 social/cultural buildings and 37,626 'other' buildings were located in the HSA.

For the current climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current climate scenario and are 'Minor' and 'Catastrophic' respectively.

For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.21: Building counts for liquefaction vulnerability category 'Liquefaction damage is unlikely' (current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	36	0	0.0%	0	0.0%		
Social/cultural buildings	552	9	1.63%	9	1.63%		
Other buildings	37,626	650	1.73%	650	1.73%		

Table 2.22: Risk assessment results for liquefaction vulnerability category 'Liquefaction damage is unlikely' (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Minor	Low	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3.4 Liquefaction vulnerability category 'liquefaction damage is unlikely' (future climate)

For the future climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current climate scenario at 'Minor' and 'Catastrophic' respectively. For the two events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.23: Building counts for liquefaction vulnerability category ‘liquefaction damage is unlikely’ (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	36	0	0.00%	0	0.00%		
Social/cultural buildings	552	9	1.63%	9	1.63%		
Other buildings	37,626	653	1.74%	648	1.72%		

Table 2.24: Risk assessment results for liquefaction vulnerability category ‘liquefaction damage is unlikely’ (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Minor	Low	Minor	Low		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3.5 Liquefaction vulnerability category ‘liquefaction damage is possible’ (current climate)

Where the liquefaction vulnerability was defined as ‘liquefaction category is possible,’ a total of 17 critical buildings, 243 social/cultural buildings and 25,965 ‘other’ buildings were located in the HSA.

For the current climate scenario, the 0.1% AEP event (primary assessment) and the 0.2% AEP event (secondary assessment) resulted in a consequence level of ‘Major’ based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged at ‘Minor’ and ‘Catastrophic’ respectively. For the two events assessed, an overall risk level of ‘High’ was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.25: Building counts for liquefaction vulnerability category ‘liquefaction damage is possible’ (current climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	17	4	23.53%	2	11.76%		
Social/cultural buildings	243	34	13.99%	28	11.52%		
Other buildings	25,965	2,899	11.17%	2,145	8.26%		

Table 2.26: Risk assessment results for liquefaction vulnerability category ‘liquefaction damage is possible’ (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Major	Medium	Major	Medium		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

2.3.3.6 Liquefaction vulnerability category ‘liquefaction damage is possible’ (future climate)

For the future climate scenario, the 0.1% AEP event (primary assessment) and 0.2% AEP event (secondary assessment) both resulted in a consequence level of ‘Catastrophic’ based on the quantitative assessment of consequence to buildings. The consequence to public safety and lifeline utilities remain unchanged from the current climate scenario at ‘Minor’ and ‘Catastrophic’ respectively. For the two events assessed, an overall risk level of ‘High’ was assigned for the current climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level).

Table 2.27: Building counts for liquefaction vulnerability category ‘liquefaction damage is possible’ (future climate)

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	17	5	29.41%	5	29.41%		
Social/cultural buildings	243	68	27.98%	50	20.58%		
Other buildings	25,965	7,692	29.62%	5,144	19.81%		

Table 2.28: Risk assessment results for liquefaction vulnerability category ‘liquefaction damage is possible’ (future climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		n/a	
Likelihood	0.1% AEP		0.2% AEP			
	Consequence	Risk Level	Consequence	Risk Level		
Buildings	Catastrophic	High	Catastrophic	High		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

3 Case study

As discussed in Section 1, this case study was developed to understand whether the intended outcomes of the RPS risk assessment for liquefaction hazard are likely to be achieved through compliance with the NZBC.

In this section, a hypothetical example of a 2 storey duplex dwelling (“duplex”) founded on a TC2 waffle slab has been used as a case study to test if the intended outcomes of the RPS risk assessment for liquefaction hazard are likely to be achieved through compliance with the NZBC for the following degrees of liquefaction-induced land damage:

- None to minor.
- Minor to moderate.
- Moderate to severe (without lateral spreading).
- Moderate to severe (with lateral spreading).

3.1 Key assumptions

In the development of this case study we have made the following key assumptions:

- TC2 waffle slab using Option 4 in Part A, Section 5.3 of MBIE Guidance (2012) i.e. an enhanced foundation slab constructed over the existing soil and the duplexes constructed using light-weight frame, lightweight cladding, and a light-weight roof (e.g. timber frame and cladding and a steel roof).²
- The building is of a uniform rectangular or square shape and the building footprint is no more than 400m² (for both dwellings that comprise the duplex).³ The maximum length of the building footprint is no more than 40m (for both dwellings that comprise the duplex).⁴
- Degrees of liquefaction-induced land damage are as defined in Table 2.2 of MBIE/MfE Guidance (2017) (see Column 1 of Table 3.1)⁵. Categories of lateral stretch of the ground across the building footprint are as defined in Table 12.4 of the MBIE Guidance (2012) (see Column 3 of Table 3.1).
- The representative curves presented in Section 3.4 of this report have been developed with consideration of the ground shaking seismic hazard assuming a Vs30 of 180m/s as estimated using the method described in the Bradley Seismic Limited (BSL) report *Regional ground motion hazard for liquefaction and landslide assessment, Tauranga City* (BSL, 2019). The Peak Ground Acceleration (PGA) and mean magnitude for each return period and the equivalent AEP are presented in Table 3.2.

If these assumptions do not apply, it may impact on the validity of this case study and the process should be revisited with more or specific detail about the scenario under consideration.

² This assumption is important because it minimises the weight of the building. Experience in Christchurch following the Canterbury Earthquake Sequence (CES) showed that under the same ground conditions, heavier buildings are more likely than lightweight buildings to sustain damage by settling into the ground either uniformly or differentially. A guiding principle of the MBIE Guidance (2012) is that "...to mitigate the effects of liquefaction...it is preferable to build using lightweight materials rather than heavy materials."

³ This assumption is important because larger buildings with larger footprints are more susceptible to the effects of lateral stretch than smaller buildings with relatively small footprints. This is because the comparatively large area of a larger building means that a larger magnitude of lateral stretch is likely to occur across the building footprint. As a result, it is more likely for significant cracking to occur within the foundation of a larger building in ground where lateral stretching occurs.

⁴ This assumption is important because a building with a larger length to width aspect ratio has the potential to be subjected to more lateral stretch within the building footprint.

⁵ The MBIE Guidance (2012) refers to "vertical settlement" values when establishing tolerance levels for a TC2 waffle slab whereas the MBIE/MfE Guidance (2017) refers to "differential settlement" values in the description of the degrees of liquefaction-induced land damage. Technically these terms refer to different consequences associated with liquefaction however for the purposes of this assessment we have used the ranges of "differential settlement" to estimate values of "vertical settlement" when developing column 2 of

Table 3.1. This is considered reasonable because at relatively small degrees of "vertical settlement" (<100 mm as considered in this case study) recorded vertical and differential settlement are typically similar. It is only when larger settlements (e.g. >500mm) are sustained that the values tend to diverge.

Table 3.1: Assumed relationship between land damage, nominal vertical settlement and lateral stretch

Land damage	Vertical settlement (mm)	Lateral stretch (mm)
None to minor	0 – 25	0
Minor to moderate	25 - 100	0
Moderate to severe with minor lateral stretch	> 100	0 - 100
Moderate to severe with moderate lateral stretch	> 100	100 - 200
Moderate to severe with major lateral stretch	> 100	200 - 500
Moderate to severe with severe lateral stretch	> 100	> 500

Table 3.2: Estimated ground seismic hazard using the BSL Report (2019) by return period and AEP

Return period (years)	AEP (%)	PGA (g)	Mean magnitude
25	4%	0.07	6.0
500	0.2%	0.20	6.2
1,000	0.1%	0.25	6.2
3,030	0.033%	0.33	6.3

3.2 NZBC assessment

Table 3.3 presents the tolerance limits for vertical settlement and lateral stretch in accordance with the NZBC for a TC2 waffle slab based on the assumptions listed in Section 0. The tolerance limits for the vertical settlement were obtained from Table 3.1 in Part A, Section 3 of MBIE Guidance (2012) for a TC2 type foundation. The tolerance limits for lateral stretch were obtained from Table 15.6, in Part C, Section 15 for a TC2 type foundation of MBIE Guidance (2012).

The NZBC specifies two design cases: Serviceability Limit State (SLS) and Ultimate Limit State (ULS). The SLS design case represents a level of earthquake load on a building below which the building can continue to be used as originally intended without repair. The ULS design case represents a level of earthquake load on a building below which there will be a very low risk of:

- Structural collapse.
- Failure of parts and elements which would be life threatening to people within or around the building.
- Failure of parts or elements whose function is critical for the safe evacuation of people from the building.

For the duplex considered in this case study the return periods for SLS and ULS are 25 and 500 years respectively (i.e. importance level 2).

Table 3.3: TC2 waffle slab vertical settlement and lateral stretch tolerances for NZBC criteria

Design case	Return period	AEP (%)	Vertical settlement (mm)	Lateral stretch (mm)
SLS	25 years	4%	50	50
ULS	500 years	0.2%	100	100

Using the information provided in Table 3.1 and Table 3.3 compliance or non-compliance the NZBC for each design case and each degree of land damage can be evaluated as follows:

- 1 Identify land damage category for the design case (e.g. none to minor for SLS).
- 2 Identify the corresponding vertical settlement associated with the land damage category for the design case (e.g. none to minor corresponds to 0-25mm vertical settlement).
- 3 Compare the value obtained in step 2 to the maximum threshold value in the NZBC as shown in Table 3.3 and evaluate whether or not the vertical settlement for the land damage is “within” or “exceeds” the vertical settlement tolerance limits (e.g. for SLS, land damage category none to minor, assign ‘within’ as vertical settlement 0-25mm < 50mm).
- 4 Repeat steps 1-4 above for lateral stretch.
- 5 If either vertical settlement or lateral stretch tolerances are exceeded, then overall the design criteria for that design case at that degree of land damage has been exceeded.

Table 3.4 presents a summary of the NZBC assessment for each design case and each degree of liquefaction-induced land damage for this case study.

Table 3.4: NZBC assessment summary

Design case		SLS			ULS		
Likelihood		4% AEP (25 years)			0.2% AEP (500 years)		
Tolerance test		Vertical Settlement	Lateral stretch	Overall	Vertical Settlement	Lateral stretch	Overall
Degree of liquefaction-induced land damage	None to minor	Within	Within	Within	Within	Within	Within
	Minor to moderate	Exceeds	Within	Exceeds	Within	Within	Within
	Moderate to severe with minor lateral stretch	Exceeds	Exceeds	Exceeds	Exceeds	Within	Exceeds
	Moderate to severe with moderate lateral stretch	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds
	Moderate to severe with major lateral stretch	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds
	Moderate to severe with severe lateral stretch	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds

3.3 RPS risk assessment

As discussed in T+T (2020b) compliance or non-compliance with the RPS is dependent on the overall risk level being categorised as 'low.' The risk level is dependent on the consequence level and return period. For liquefaction hazard, the return periods for the assessment are defined and are summarised in Section 2.2, Table 2.1 of this report.

To relate liquefaction-induced land damage to the risk assessment outlined in the RPS, vertical settlement and lateral stretch associated with each degree of liquefaction-induced land damage (refer to Table 3.1), have been correlated with the building consequence levels in the RPS as described in Figure 2.1. These correlations are shown in Table 3.5 and have been developed with reference to previous work undertaken by T+T (refer to Section 8.4.3 of T+T (2018) and Section 3.1.5 of T+T (2019)).

Table 3.5: Correlation between land damage and consequence level

Land damage	Consequence level
None to minor	Insignificant
Minor to moderate	Minor
Moderate to severe with minor lateral stretch	Moderate to major
Moderate to severe with moderate lateral stretch	Moderate to major
Moderate to severe with major lateral stretch	Catastrophic
Moderate to severe with severe lateral stretch	Catastrophic

Using the correlations provided in Table 3.6 and the risk matrix presented in the RPS (refer to Figure 2.2) the risk level for each of the primary and secondary assessments can be evaluated. The results are summarised in Table 3.6.

Table 3.6: RPS risk assessment

Degree of liquefaction-induced land damage	Primary Assessment		Secondary Assessment		Secondary Assessment		Overall risk
	0.1% AEP		0.2% AEP		0.033% AEP		
	Consequence	Risk level	Consequence	Risk level	Consequence	Risk level	
None to minor	Insignificant	Low	Insignificant	Low	Insignificant	Low	Low
Minor to moderate	Minor	Low	Minor	Low	Minor	Low	Low
Moderate to severe with minor lateral stretch	Moderate to major	Med	Moderate to major	Med	Moderate to major	Low	Med
Moderate to severe with moderate lateral stretch	Moderate to major	Med	Moderate to major	Med	Moderate to major	Low	Med
Moderate to severe with major lateral stretch	Catastrophic	High	Catastrophic	High	Catastrophic	Med	High
Moderate to severe with severe lateral stretch	Catastrophic	High	Catastrophic	High	Catastrophic	Med	High

3.4 Comparison between NZBC and RPS

A comparison of the results between the NZBC and RPS assessments are summarised in Table 3.7 below. For our case study example of a 2 storey duplex founded on a TC2 waffle slab, the following conclusions can be made:

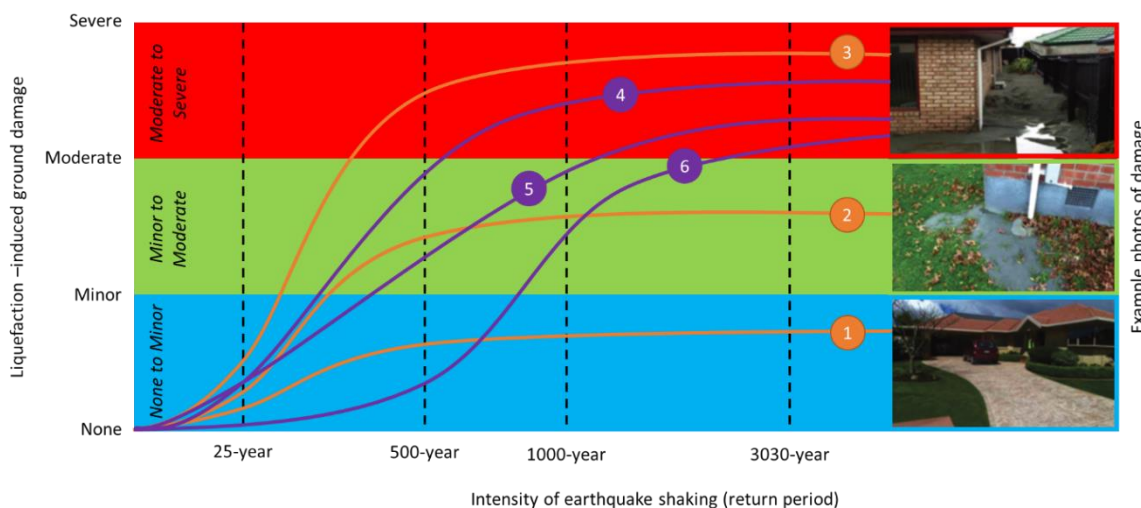
- For the SLS design case no worse than none to minor land damage can be sustained
- For the ULS design case no worse than minor to moderate land damage can be sustained
- To satisfy the RPS's requirements no worse than minor to moderate land damage can be sustained.

Table 3.7: Summary table comparing results between NZBC and RPS assessments

Scenario	NZBC SLS	NZBC ULS	RPS
Likelihood	4% AEP	0.2% AEP	Overall
None to minor	Within	Within	Low
Minor to moderate	Exceed	Within	Low
Moderate to severe with minor lateral stretch	Exceed	Exceed	Medium
Moderate to severe with moderate lateral stretch	Exceed	Exceed	Medium
Moderate to severe with major lateral stretch	Exceed	Exceed	High
Moderate to severe with severe lateral stretch	Exceed	Exceed	High

Figure 3.1 presents the above data through six representative conceptual curves showing the degree of liquefaction-induced ground damage at different strengths of earthquake shaking. As shown in the conceptual curves the relationship between earthquake shaking and ground damage is highly non-linear which is a key characteristic of liquefaction as described in the MBIE/MfE Guidance (2017).⁶ Note that the moderate to severe land damage category includes all categories of lateral stretch described in Table 3.1.

⁶ Refer to Section 4.3.2 in the MBIE/MfE Guidance (2017) for further details on ground damage response curves.



Note that the moderate to severe land damage category includes all categories of lateral stretch described in Table 3.1

Figure 3.1: Example conceptual response curves for the case study (2 storey duplex on a TC2 type waffle slab) adopted and modified from Figure 4.3 in the MBIE/MfE Guidance (2017).

While the curves shown in Figure 3.1 are conceptual, based on T+T's understanding of the ground conditions and seismic hazard in Tauranga they are consistent with modelled ground damage response curves in Tauranga as described in T+T (2020). The key features of these response curves are as follows:

- For all ground conditions encountered in Tauranga no worse than none to minor land damage is anticipated at 25 year return period levels of earthquake shaking
- At 500, 1,000 and 3,030 year return period levels of earthquake shaking none to minor or minor to moderate or moderate to severe land damage is anticipated. For constant levels of earthquake shaking, the likelihood of each category of land damage being sustained at a given site is primarily a function of the ground conditions encountered at that site

Table 3.8 presents the information conveyed in the curves in Figure 3.1 in a tabulated format, it shows in what situations compliance/non-compliance with the NZBC and the RPS occurs (based on the findings of Section 3.2 and 3.3) and whether compliance with the NZBC is coincident with compliance of the intended outcomes of the RPS. Curves 1-3 show cases where compliance with the NZBC is coincident with compliance with the intended outcomes of the RPS. Curves 4-6 show cases where the NZBC and RPS are not coincident with the intended outcomes of the RPS.

While there are cases where the two tests are consistent, this hypothetical case study indicates that the intended outcomes of the RPS risk assessment for liquefaction hazard are not necessarily achieved through compliance with the Building Code 2004. Note that this conclusion is relevant for the specific conditions in Tauranga and in other parts of New Zealand where the ground conditions and seismic hazard may be different a different conclusion may be reached.

Table 3.8: Summary of land damage for each conceptual response curves and assessment of compliance/non-compliance with the NZBC and RPS

Curve	Intensity of earthquake shaking (return period)				NZBC and RPS compliance		
	25	500	1000	3030	NZBC	RPS	NZBC = RPS
1	N-M	N-M	N-M	N-M	Yes	Yes	Yes
2	N-M	M-M	M-M	M-M	Yes	Yes	Yes
3	N-M	M-S	M-S	M-S	No	No	Yes
4	N-M	M-M	M-S	M-S	Yes	No	No
5	N-M	M-M	M-M	M-S	Yes	No	No
6	N-M	N-M	M-M	M-S	Yes	No	No

N-M = none to minor land damage, M-M = minor to moderate land damage and M-S = moderate to severe land damage

4 Conclusions

4.1 RPS risk assessment

T+T has undertaken a high-level city wide natural risk hazard assessment for Tauranga in accordance with the BoPRC RPS' requirements for natural hazards. These results provide a "baseline" of natural hazard risk to inform future updates to the City Plan and against which further options may be compared.

Table 4.1 presents a summary for separate Natural Hazard Zones for the eastern and western parts of the city.

Table 4.1: Summary table for eastern and western zones for the 0.1% and 0.2% AEP events

	Eastern (current)	Eastern (future)	Western (current)	Western (future)
Buildings	Medium	High	Medium	Medium
Lifeline utilities	High	High	High	High
Public safety	Low	Low	Low	Low
Overall risk level	High			

Table 4.2 presents a summary for the entire liquefaction hazard susceptibility area (HSA), excluding the areas that are part of the coastal erosion and coastal inundation HSAs.

Table 4.2: Summary table HSA area for the 0.1% and 0.2% AEP events excluding the areas that are part of the coastal erosion and coastal inundation HSAs

	Current	Future
Buildings	Medium	Low
Lifeline utilities	High	High
Public safety	Low	Low
Overall risk level	High	

Table 4.3 presents a summary for the HSA separated into the liquefaction vulnerability categories as defined in accordance with the 2017 MBIE/MfE document Planning and engineering guidance for potentially liquefaction-prone land (MBIE, 2017).

Table 4.3: Summary table HSA area for the 0.1% and 0.2% AEP events

	Liquefaction vulnerability category					
	Undetermined (Current)	Undetermined (Future)	Unlikely (Current)	Unlikely (Future)	Possible (Current)	Possible (Future)
Buildings	Low	Low	Low	Low	Medium	High
Lifeline utilities	High	High	High	High	High	High
Public safety	Low	Low	Low	Low	Low	Low
Overall risk level	High		High		High	

The results summarised above have been produced utilising the latest available natural hazard information. This study provides an assessment framework that can be updated by TCC as more recent and/or accurate natural hazard information becomes available.

4.2 Case study

T+T has developed a hypothetical case study to establish whether the intended outcomes of the RPS risk assessment for liquefaction hazard are achieved through compliance with the NZBC. This case study has been developed with reference to the liquefaction-induced ground damage categories described in the MBIE/MfE Guidance (2017) if the dwelling is founded on a TC2 type waffle slab as described in the MBIE Guidance (2012). The case study is also based on T+T's understanding of the ground conditions and seismic hazard in Tauranga as described in T+T (2020).

While there are cases where the two tests are consistent, this case study indicates that the intended outcomes of the RPS risk assessment for liquefaction hazard are not necessarily achieved through compliance with the NZBC.

5 Limitations

There are differences in the output of the risk results between the Eastern and Western zones. This was due to the work being carried out by different consultants (Aurecon, 2020) and (T+T, 2020a).

The case study is based on key assumptions listed in section 3.1 and based on T+T's understanding of the ground conditions and seismic hazard in Tauranga. If the assumptions differ, it may impact on the validity of the case study and the process should be revisited with more detail about the scenario under consideration.

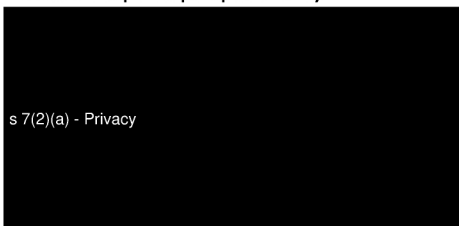
6 Applicability

This letter report has been prepared for the exclusive use of our client Tauranga City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

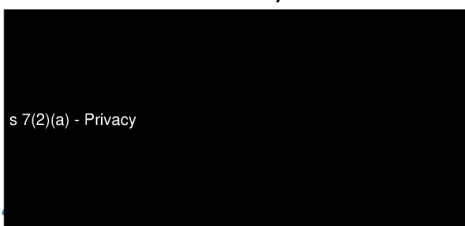
Environmental and Engineering Consultants

Letter Report prepared by:



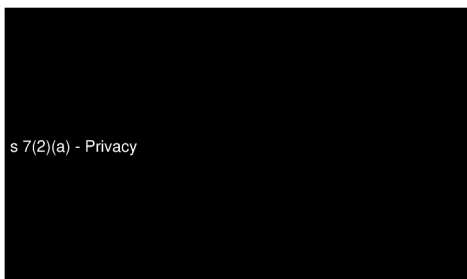
Disaster Risk Reduction Consultant

Technical Review by:



Senior Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:



Project Director

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