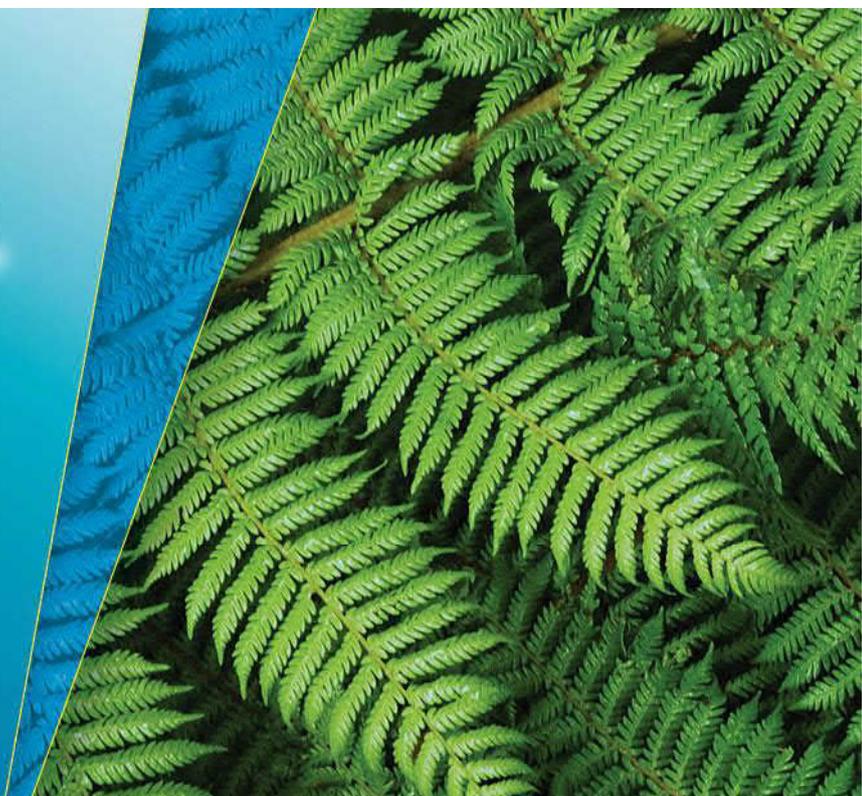
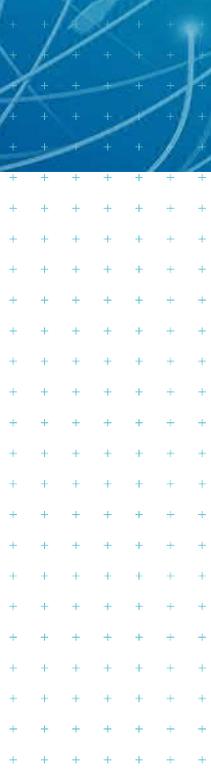


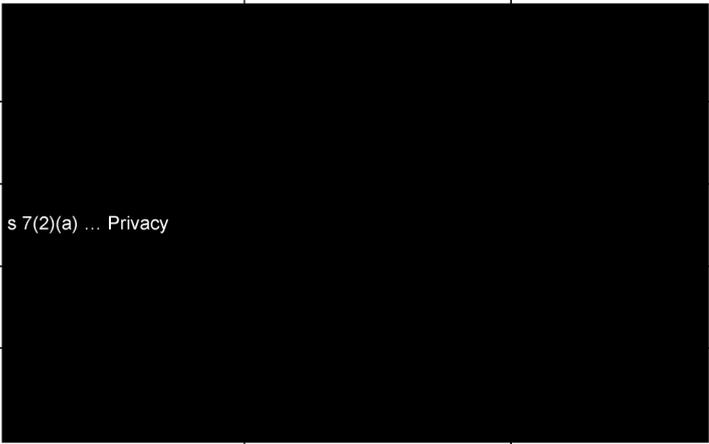


# Tauranga City-wide Natural Hazards Risk Assessment

**Prepared for**  
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## Executive summary

Tonkin & Taylor Ltd (T+T) have been engaged by Tauranga City Council (TCC) to undertake a high level city-wide natural hazard risk assessment for Tauranga. The risk assessment was carried out in accordance with Appendix L of the Bay of Plenty Regional Council (BoPRC) Regional Policy Statement (RPS) on natural hazards (BoPRC, 2016a). The intent of this work is to create a “baseline” of natural hazard risk which can be used to inform future city planning, utilising the best currently available data. This study utilises existing models and datasets to undertake city-wide risk assessments for the following natural hazards:

- Coastal inundation
- Coastal erosion
- Tsunami
- High groundwater
- Liquefaction and lateral spread
- Slope instability

The table below presents a summary of the results of the city-wide risk assessment.

Hazard	Current climate	Future climate
Coastal inundation	High risk	High risk
Coastal erosion – inner harbour	Medium risk	High risk
Coastal erosion – open coast	Low risk	Medium risk
Tsunami	Medium risk	High risk
High groundwater	Medium risk	High risk
Liquefaction and lateral spread	High risk	High risk
Slope instability	Low risk	n/a

The policy direction associated with these levels of natural hazard risk are set out in Policy NH 3B of the BoPRC RPS. Policy NH 6B states that where natural hazard risk is classified as ‘High’ the RPS requires a response (i.e. risk mitigation) to reduce the level of risk to ‘Medium’ (and lower if reasonably practicable). Where natural hazard risk is classified as ‘Medium’ (considered tolerable but not desirable in the RPS) opportunities to reduce risk should be taken where practicable. To comply with the RPS any land use management decisions made by TCC as part of planning processes should seek to mitigate risk where it is ‘High’ or ‘Medium’ and not increase the risk level where it is ‘Low’.

This study provides an assessment framework that can incorporate newer and/or more accurate natural hazard information as it becomes available.

## Glossary

**Annual Individual Fatality Risk (AIFR)** – the probability of fatality from a particular hazard for an individual over the period of a year.

**Hazard Susceptibility Area (HSA)** - the spatial extent of a potential hazard event identified by susceptibility mapping.

**Functionally compromised** - means the building cannot continue to be used for its intended use immediately after the event.

**LiDAR (Light Detection and Ranging)** - a surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Often used to identify ground levels over very large areas.

**Primary assessment** – the event likelihood that should be used in the initial risk assessment (differs depending on hazard).

**Regional Policy Statement (RPS)** - a directive policy document in relation to regional and district plans and the consideration of resource consents. It highlights regionally significant issues with resource management and sets out what needs to be achieved (objectives) and how it will be achieved (policies and methods).

**Secondary assessment** – assessment of other hazard events of higher and/or lower frequency to the primary assessment that need to be assessed when the primary assessment is not high risk to determine the event of maximum risk.

# 1 Introduction

## 1.1 Scope

Tonkin & Taylor Ltd (T+T) have been engaged by Tauranga City Council (TCC) to undertake a high level city-wide natural hazard risk assessment for Tauranga. The risk assessment was carried out in accordance with Appendix L of the Bay of Plenty Regional Council (BoPRC) Regional Policy Statement (RPS) on natural hazards (BoPRC, 2016a). The intent of this work is to create a “baseline” of natural hazard risk which can be used to inform future city planning, utilising the best currently available data. It provides an assessment framework that can incorporate newer and/or more accurate natural hazard information becomes available. This study utilises existing models and datasets to undertake city-wide risk assessments for the following natural hazards:

- Coastal inundation
- Coastal erosion
- Tsunami
- High groundwater
- Liquefaction and lateral spread
- Slope instability

Volcanic hazard and fault rupture from an earthquake (also mentioned in Appendix L) have not been assessed as part of this study. Flooding from intense rainfall events has also not been included in the scope of this study as it has been addressed in a separate study by AWA (refer Section 1.3.3). High groundwater, while not explicitly mentioned in the RPS, has been included in this study as it is an emerging hazard in Tauranga with effects on the built environment becoming more evident as sea levels rises.

## 1.2 Purpose

Tauranga City is projected to grow by approximately 78,500 residents over the 50 years from 2013 to 2063. This will require approximately 49,300 new dwellings to be constructed over the same period. To meet the demand for housing in Tauranga, TCC are currently planning the development and delivery of two new large urban growth areas: Te Tumu in the east (7,000 forecast dwellings) and Tauriko West in the west (3,000 forecast dwellings) with development planned to start in 2023. To meet demand beyond these two new growth areas, TCC are looking to facilitate additional infill and intensification opportunities within the existing urban areas of Tauranga. This is mainly through a range of planning projects, specifically providing for residential intensification generally across the city within existing residential and commercial areas, and through wider spatial planning providing for a more focused intensification change.

In order to give effect to the BoPRC RPS (BoPRC, 2016a), a risk management approach is required for these planning processes (and other associated planning work, and future plan changes). This is to ensure that more intensive development does not increase the level of natural hazard risk, and that risk is reduced over time.

The purpose of this report is therefore to undertake a high level natural hazard risk assessment utilising existing datasets held by TCC (for their jurisdictional areas) to demonstrate compliance with the BoPRC RPS. This risk assessment establishes the existing level of risk based on current development for both current climate as well as future climate.

## 1.3 Background

### 1.3.1 Bay of Plenty Regional Council Regional Policy Statement (RPS)

The BoPRC RPS is a statutory policy document that provides an overview of the region's significant resource management issues and it sets out how regional, city and district councils need to manage these resources. It must be given effect to by the region's city and district councils when developing their city/district plans.

A revision to the RPS - Change 2 (Natural Hazards) - was approved by BoPRC on 2 June 2016 and inserts natural hazards provisions into the operative BoPRC RPS. The change guides those preparing regional, city and district plans and considering resource consent applications in managing land use and associated activities based on the level of natural hazard risk they are subject to. The natural hazards covered by Proposed Change 2 include volcanic, earthquake, tsunami, coastal erosion, coastal inundation, landslip and flooding hazards. Appendix L of Change 2 (BoPRC, 2016a) provides guidance for how practitioners should undertake assessments of natural hazard risk and is the basis of the methodology used in this study.

### 1.3.2 Existing natural hazard datasets

The following models and datasets have been utilised as part of this study:

- Coastal inundation – T+T, in conjunction with NIWA, have recently completed a coastal inundation/storm surge assessment of Tauranga Harbour for BoPRC, Western Bay of Plenty District Council (WBoPDC) and TCC that covers the inner-harbour coastal margins. This assessment produced coastal inundation maps for the inner-harbour for a range of return period events and sea level rise estimates. NIWA's report 'Tauranga Harbour Inundation Modelling' (NIWA, 2019) provides a summary of the assessment.
- Coastal erosion – Recently T+T have recently completed two coastal erosion hazard assessments for Tauranga City. One is the Tauranga Harbour erosion assessment for BoPRC, WBoPDC and TCC that covers the inner-harbour coastal margins and the other is the Mount Maunganui to Te Tumu erosion assessment that includes the open coast Both studies involved producing coastal erosion hazard lines for a 'likely' scenario and 'very unlikely' scenario for a 50 year event horizon and 100 year horizon and several different sea level rise scenarios (resulting in nine maps in total). Summaries of each of the assessments are provided in T+T (2019) and T+T (2020b).
- Tsunami – T+T have an existing model that was created for TCC to model tsunami inundation in Tauranga for a range of return period events and sea level rise scenarios. This tsunami model has been utilised for various projects such as TCC's tsunami evacuation zones and to inform future urban development in Papamoa and Te Tumu. T+T's report 'Tauranga Tsunami Inundation Modelling' (T+T, 2013) provides a summary of the model build.
- High groundwater – T+T have assisted TCC to develop a network of groundwater monitoring stations around Tauranga. Currently there are 88 groundwater monitoring locations established with a record of up to four years. T+T were commissioned by TCC in early 2017 to use the data to produce an inferred 95<sup>th</sup> percentile groundwater table across low lying areas in the city both for current and future sea levels. T+T's report 'Tauranga Groundwater Monitoring – June 2017 results' (T+T, 2017) provides a summary of methodology used to produce the city-wide inferred groundwater table.
- Liquefaction and lateral spread – the risk assessment for liquefaction and lateral spread hazard had initially been undertaken using the the outputs of the Microzoning for Earthquake Hazards Report prepared by Opus (2003) for the Western Bay of Plenty. However this has now been revised and the risk assessment results presented in Section 3.5 of this report have been

developed using data from 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 risk assessment has been undertaken in general accordance with the approach outlined in the 'Te Tumu Natural Hazard Risk Assessment – Liquefaction' (T+T, 2018).

- Slope instability – the assessment of risk associated with slope instability have been developed using the slope angle information available on the TCC Geospatial Portal. The theoretical derivation of the slope angle information is described in Richards (2001).

### **1.3.3 Risk assessment for rainfall induced flooding**

A city-wide flood risk assessment (AWA, 2019) was carried out to meet the natural hazards provisions of the RPS. The assessment (AWA, 2019) divided the city into 19 different hazard assessment zones based on catchment boundaries and found that all catchments had a risk level of 'High' due to flooding caused by intense rainfall events. It is noted that there are several differences in methodology for the flood risk assessment compared to the risk assessments undertaken as part of this study (e.g. methodology for inferring floor level). While the results of the AWA study are included in the appended hazard maps (refer Figures B16-B19 in Appendix B), no assessment has been undertaken for flooding as part of this study.

## 2 Methodology

The Tauranga city-wide natural hazard risk assessment has been undertaken in accordance with Appendix L of the operative BoPRC RPS (refer Section 1.3.1). While adherence to Appendix L is not mandatory, it sets out Regional Council's expectation about how the RPS risk assessment can be undertaken. For aspects of the methodology on which Appendix L does not provide guidance, engineering judgement has been used.

This study is concerned with establishing the baseline (i.e. existing) natural hazard risk based on current development for both current climate as well as future climate to 2130 for the following natural hazards:

- Coastal inundation
- Coastal erosion (open coast and inner harbour)
- Tsunami
- High groundwater
- Liquefaction and lateral spread
- Slope instability

All natural hazards have been assessed for both current and future climate scenarios. The future climate scenarios include sea level rise (SLR) of 1.25 m (except for liquefaction and lateral spread which has SLR of 1 m as this is the only available information for future climate). This sea level rise assumption is based on the predicted sea level rise for the RCP8.5 median projection to 2130 relative to Moturiki Vertical Datum (MVD) (NIWA, 2019).

In terms of spatial scale, this study assesses the risk level for the entire Hazard Susceptibility Area (HSA) for each hazard, at a citywide scale. Therefore, the natural hazard zone is considered to be the entire HSA for each hazard.

Section 2.1 below gives details of the methodology that applies across all hazards while the hazard-specific methodologies are summarised in Section 2.2 to Section 2.7.

### 2.1 General approach

#### 2.1.1 Likelihood

The risk screening matrix in Appendix L assigns a risk level based on consequence (refer Section 2.1.2) and likelihood. In risk management terminology, the word "likelihood" is used to refer to the chance of something happening, whether determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability (e.g. Annual Exceedance Probability (AEP)) or a frequency over a given time period).

For hazards such as flooding, tsunami and coastal inundation, the hazard is triggered by a discrete event such as an earthquake (tsunami), low pressure system and wind (coastal inundation) or rainfall (flooding) and an AEP for that event can be readily determined. For events which continue to act over a long period of time, such as high groundwater level and coastal erosion, an AEP cannot directly be attributed to the hazard. In these cases qualitative judgements of likelihood have been made in the risk assessment.

#### 2.1.2 Consequence assessment

The consequence level of each hazard event was assessed using Table 21 of Appendix L of the RPS (shown in Figure 2.1). Table 21 gives quantitative measures for assigning appropriate consequence level for buildings, lifeline utilities and public safety impacts of a hazard. The overall consequence for

a given hazard event is determined by taking the highest consequence level calculated for all assessed return periods.

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 21:

- 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 (2016a))

### 2.1.2.1 Consequence to buildings

The RPS process considers three categories of building:

- Critical buildings – buildings occupied by agencies assisting the public in times of emergency e.g. Local council offices, fire stations, police stations, hospitals, emergency medical centres, civil defence centres etc.
- Buildings of social or cultural significance – e.g. educational facilities, places of worship, museums, marae, libraries, community centres etc.
- All ‘other’ buildings.

Google Maps was used to determine building usage to identify critical and social/cultural buildings for this study. Publically available data from the Ministry of Education was also used to locate education facilities such as schools and early childhood education centres. Table 2.1 below summarises how many buildings were identified in each category.

Table 2.1: Summary of building categorisation for Tauranga

Category	Total number of buildings
Critical buildings	53
Social/cultural buildings	799
Other buildings	63,949

To assign a consequence level for damage to buildings the number of “functionally compromised” buildings needs to be assessed. The BoPRC RPS defines functionally compromised as when a building cannot continue to be used for its intended use immediately after a hazard event. The actual criteria

by which this is assessed differs depending on the hazard types. Section 2.2 to Section 2.7 below gives the functionally compromised criteria used in this study for each hazard.

In order to undertake the natural hazard consequence assessments for tsunami, flooding and coastal inundation building floor levels were required to determine which buildings may be inundated and functionally compromised.

TCC have surveyed building floor levels for approximately 10,000 buildings that were identified as being potentially susceptible to flooding in response to extreme rainfall events. Aside from recording floor levels of each of the buildings, the foundation type (piles or concrete) and building use (dwelling, garage, commercial, industrial etc.) were also identified. TCC hold a spatial building footprints layer without any floor level information for the remaining buildings in Tauranga. Surveyed floor level information for buildings was used where available. Where surveyed floor level information was unavailable, floor level was inferred by adding a 150 mm offset to the minimum underlying LiDAR derived Digital Elevation Model (DEM) level. The rationale behind this approach is discussed further in Appendix A. Note that this approach to estimate building floor level (in the absence of surveyed information) differs from the approach adopted by AWA in their undertaking of the natural hazard risk assessment for flooding.

Building footprints less than 20 m<sup>2</sup> were excluded from the total count of functionally compromised buildings as these were likely to be garden sheds or other structures that have not been considered as 'buildings'. Garages or other minor dwellings larger than 20 m<sup>2</sup> that are not attached to the main dwelling will count as a separate building in the consequence assessment.

### **2.1.2.2 Consequence to lifeline utilities**

Lifeline utilities include transport (road, rail), energy (electricity, gas), water (wastewater, potable water), communications and infrastructure networks that are fundamental to New Zealand's communities and economy. The consequence assessment criteria for lifeline utilities are quantified in Figure 2.1 in terms of duration of outage time and population affected. Estimating utility outage times and the population affected requires a detailed assessment which is outside the scope of this study. For the purposes of this study, high level qualitative estimates have been made for consequence to lifeline utilities.

### **2.1.2.3 Consequences relating to public safety**

Consequence to public safety is quantified in Table 21 (Figure 2.1) in terms of number of fatalities and injuries. Quantitative methods for assessing public safety consequences were used where available (e.g. tsunami – refer Section 2.4). Where quantitative methods did not exist, or where it was clear that fatalities/injuries would likely not result from a hazard, a qualitative judgement of public safety consequence was made.

## **2.2 Coastal inundation**

For hazard risk assessment purposes coastal inundation is defined as the combination of storm tide and wave setup plus any allowance for future sea-level rise.

Coastal inundation modelling for the Tauranga Harbour is summarised by NIWA (2019). The NIWA study used a calibrated flexible mesh hydrodynamic model (using DelftFM) forced by tidal water levels, annual average river flows, wind, and air pressure (inverse barometer effect). The model calculated storm tide around the entire harbour shoreline and dynamically mapped the water depth overland.

Table 2.2 below summarises the event scenarios that were used for the primary and secondary assessment for coastal inundation. A 1% AEP event was used for the primary assessment and a 2%

and 0.2% AEP event was used for the secondary assessment in accordance with Table 20 of Appendix L (BoPRC, 2016a).

**Table 2.2: Coastal inundation hazard events**

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
Inundation extent for a 0.2% Annual Exceedance Probability (AEP), 2130	<b>Existing</b> 1% AEP, 2020 <sup>1</sup>	<b>Existing</b> 2% AEP, 2020 0.2% AEP, 2020
	<b>Future</b> 1% AEP, 2130	<b>Future</b> 2% AEP, 2130 0.2% AEP, 2130

The HSA for coastal inundation was based on the inundation extent of a 0.2% AEP, 2130 event. The HSA for coastal inundation is shown in Figure B1 of Appendix B. For the primary and secondary assessments, a building was considered as functionally compromised if coastal inundation level at the building footprint was shown to exceed the respective building floor level (either surveyed or inferred).

The risk assessment results for coastal inundation are presented in Section 3.1.

## 2.3 Coastal erosion

For hazard risk assessment purposes, coastal erosion refers to a shift in the position of the shoreline over a given period, together with an assessment of associated slope instability. Coastal erosion is an episodic process that acts “cumulatively” so likelihood is best assessed based on the probability of exceedance over a longer period than a year.

Two coastal erosion assessments have been undertaken by T+T over the 2018-2020 period. One of the assessments covers 32 selected sites around Tauranga Harbour (T+T, 2019) and the other assessment covers the open coast between Mauao and Te Tumu (T+T, 2020b). Both studies applied a probabilistic approach to map the coastal erosion hazard with two probabilistic scenarios – a “likely” scenario (P66%) and a “very unlikely” (P5%) scenario.

It is noted that the studies ignore existing coastal protection structures on stretches of coastline that were assessed. While these structures can mitigate the impacts of coastal erosion, they do not address the cause of erosion. Hence they are only a temporary measure, requiring continuous maintenance and renewal if to be considered a long-term solution. If a structure is adequately maintained, repaired and upgraded as necessary, then it is likely that the erosion hazard areas would be minimal. Conversely, if the structure were to fail or be removed, then the shoreline may rapidly regress dependent on the adjacent shoreline and fronting foreshore level. There were some stretches of the harbour coast that weren’t assessed on the basis that there were coastal protection structures that would be well maintained, repaired and upgraded as necessary due to their economic importance. This includes the shoreline around Port of Tauranga.

Table 2.3 below summarises the event scenarios that were used for the primary and secondary assessment for coastal inundation. A P66% erosion scenario (i.e. there is a 66% chance of an erosion distance being exceeded in that timeframe) was used for the primary assessment and a P5% erosion scenario was used for the secondary assessment. These scenarios differ from the guidance in Table 20 of Appendix L (BoPRC, 2016a) but were considered to be appropriate as coastal erosion is a hazard

<sup>1</sup> 2020 was the “present day” scenario assessed in NIWA (2019).

that should be assessed on a long term basis. It is noted that a P66% scenario is analogous to a 1% AEP as there is a 66% chance of a 1% AEP event occurring within a 100 year planning horizon (refer Figure 2.2). Similarly the P5% scenario is analogous to a 0.05% AEP event.

**Table 2.3: Coastal erosion hazard events**

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
Erosion hazard line for a P5% erosion scenario, 2130	<b>Existing</b> P66% erosion scenario, 2030 <sup>2</sup>	<b>Existing</b> P5% erosion scenario, 2030
	<b>Future</b> P66% erosion scenario, 2130	<b>Future</b> P5% erosion scenario, 2130

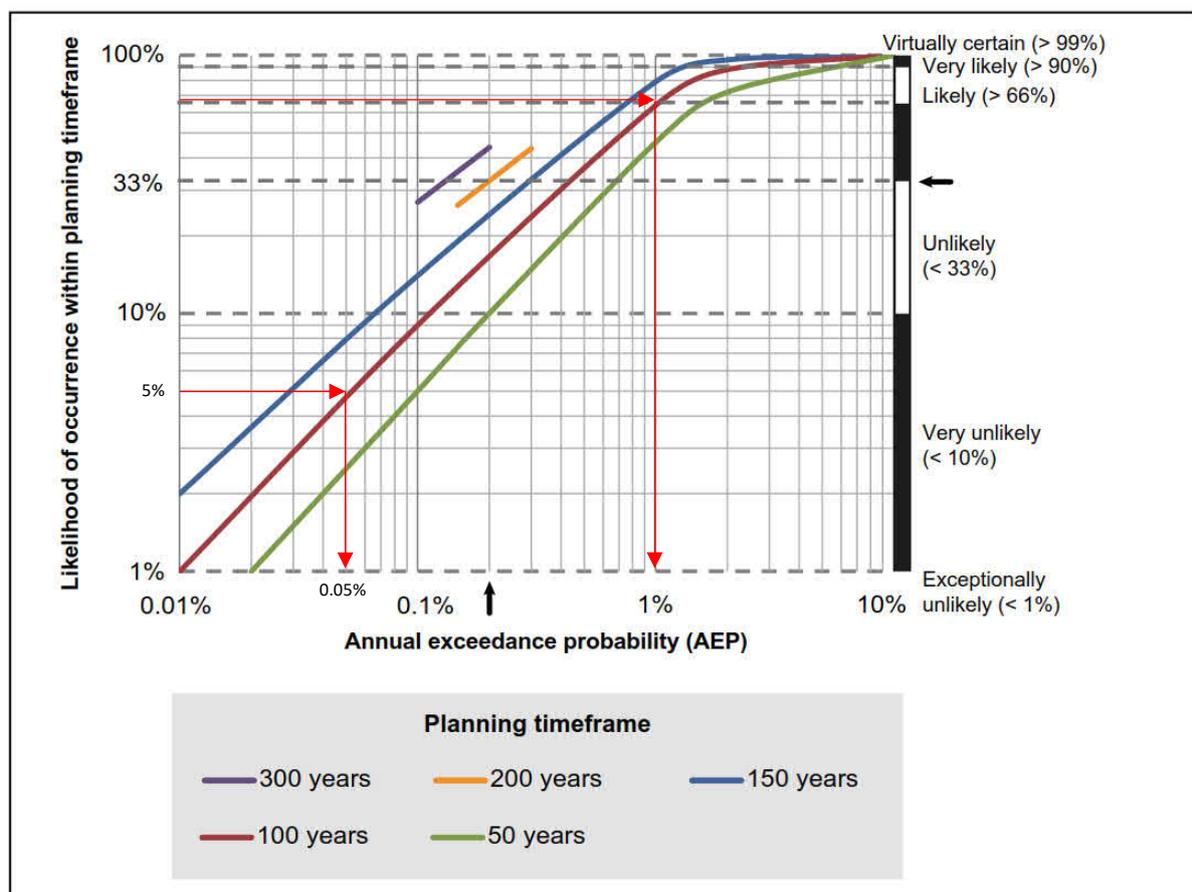


Figure 2.2: Annual exceedance probability and likelihood of occurrence within a range of planning timeframes (source: BoPRC (2016b))

The HSA for coastal erosion was based on P5%, 2130 erosion scenario. The HSA for coastal erosion is shown in Figure B5 of Appendix B. For the primary and secondary assessment a building was considered functionally compromised if the erosion hazard line intersected, or was more landward than the building footprint.

The risk assessment results for coastal erosion are presented in Section 3.2.

<sup>2</sup> 2030 was the “current” planning timeframe assessed in T+T (2019).

## 2.4 Tsunami

A tsunami is a natural phenomenon consisting of a series of waves generated when a large volume of water in the sea is rapidly displaced due to an event such as an earthquake, landslide or volcanic eruption.

T+T developed a tsunami model for Tauranga that represents likely tsunami inundation extents and depths for both present day and future sea levels for a 0.1% AEP event, 0.2% AEP event, 0.04% AEP event and a maximum credible event (T+T, 2013).

Table 2.4 below summarises the event scenarios used for the primary and secondary assessment for tsunami. A 0.1% AEP event was used for the primary assessment and a 0.2% and 0.04% AEP event was used for the secondary assessment in accordance with Table 20 of Appendix L (BoPRC, 2016a).

**Table 2.4: Tsunami hazard events**

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
Inundation extent for a maximum credible event with 1.25 m of sea level rise (SLR)	<b>Existing</b> 0.1% AEP, no SLR	<b>Existing</b> 0.2% AEP, no SLR 0.04% AEP, no SLR
	<b>Future</b> 0.1% AEP, 1.25 m SLR	<b>Future</b> 0.2% AEP, 1.25 m SLR 0.04% AEP, 1.25 m SLR

The HSA for tsunami was based on a maximum credible event with 1.25 m SLR. For the primary and secondary assessment a building was considered functionally compromised if tsunami inundation level exceeded the respective building floor level (either surveyed or inferred) or if depth-velocity product exceeded 1 m<sup>2</sup>/s within the building footprint. The HSA for tsunami is shown in Figure B8 of Appendix B. The depth-velocity product threshold is based on work undertaken by Smith et. al (2016) which identified 1 m<sup>2</sup>/s as the point at which all building types are considered vulnerable to structural damage and some building types are vulnerable to failure.

Calculation of Annual Individual Fatality Risk (AIFR) was required for tsunami hazard in accordance with Appendix L (BoPRC, 2016a) due to the risk level not being 'High' based on the initial consequence assessment (i.e. consequence to buildings, lifeline utilities and public safety).

AIFR refers to the probability of fatality from a particular hazard for an individual over the period of a year and is calculated using the following formula:

$$AIFR = (D \times P)/N$$

Where:

*D* = number of estimated fatalities from the event

*N* = population exposed to hazard (i.e. max number of people in the hazard assessment area at any point in time over a 24 hour period)

*P* = annual exceedance probability of the hazard event

The AIFR assessment needs to be undertaken both for the total population within the hazard assessment area as well as the population in care (i.e. people in hospitals, aged care facilities, schools and early childhood education). The total number of people within the hazard assessment area was estimated based on the number of buildings within the HSA. The average occupancy rate of dwellings in Tauranga is 2.53 people per dwelling (2013 according to Statistics NZ). Therefore the number of buildings in the HSA for tsunami multiplied by the average occupancy rate provides an approximation of the total population exposed to tsunami hazard in their homes (refer Table 2.5). This would simulate something similar to a "night time" scenario, when the vast majority of people are inside their homes.

**Table 2.5: Total population within the HSA for tsunami hazard**

Number of dwellings within the HSA	18,365
Estimated population within the HSA	46,463

The population in care was determined using using statistics from Ministry of Health and Ministry of Education and is summarised in Table 2.6 below. It is recognised that there is some potential for double accounting, depending on where the person in care resides, although we consider this to be insignificant for the purposes of the region-wide risk assessment.

**Table 2.6: Population in care within the HSA for tsunami hazard**

Facility type	Total population in HSA
Schools <sup>1</sup>	4,757
Early childhood education (ECE) centres <sup>2</sup>	1,314
Hospitals	0
Rest homes <sup>3</sup>	153
<b>Total</b>	<b>6,224</b>

<sup>1</sup>Includes primary, intermediate and secondary schools. Based on 2018 roll data from <https://www.educationcounts.govt.nz/>

<sup>2</sup>Includes all ECE facilities (daycare, kindergartens, play centre, home care etc.). Based on 2018 data from <https://www.educationcounts.govt.nz/>

<sup>3</sup>Only includes rest homes certified with the Ministry of Health. Population in retirement villages without assisted living not included. Based on 2019 data from <https://www.health.govt.nz/your-health/certified-providers/aged-care>

The estimated number of fatalities was derived for both AIFR assessments using the same model used in Beban et. al. (2011) for assessing tsunami risk in Papamoa/Te Tumu, where:

$$\text{Number of fatalities} = \text{number of people exposed} \times \text{tsunami inundation depth (m)} \times 0.04$$

Therefore, the total number of estimated fatalities was derived by determining the tsunami inundation depth at each building footprint and population in care facility. This fatality model was also used to quantitatively assess public safety consequences. It is recognised that there are alternative and more detailed methodologies for estimating injuries and fatalities, although for the purposes of a city-wide risk assessment, the approach is reasonable.

The risk assessment results for tsunami, including the results of the AIFR assessments, are presented in Section 3.3.

## 2.5 High groundwater

For hazard risk assessment purposes, high groundwater refers to the interaction of sea levels with groundwater levels in low lying coastal areas, and its potential effects on structures and infrastructure both above and below the ground surface. As groundwater levels in low lying coastal areas rise in response to rising sea levels, surface ponding is likely in some areas and more extensive flooding is likely after heavy rain. A higher groundwater level can also damage roads, pipes, cables, and the foundations of buildings. This should not be confused with groundwater flooding which is a hazard in its own right (irrespective of coastal influence) and has not been considered as part of this study.

T+T developed an inferred 95<sup>th</sup> percentile groundwater level across low lying areas of the city both for current and future sea levels (T+T, 2017). The results of the 2017 study were used for the hazard assessment.

Table 2.7 below summarises the event scenarios that were used for the primary and secondary assessment for high groundwater. High groundwater was not included in Table 20 of Appendix L (BoPRC, 2016a), but was included in the current study as it is an emerging hazard with effects on the built environment becoming more evident as sea levels rise. No secondary assessment was undertaken as a 95<sup>th</sup> percentile groundwater level was the only scenario that has currently been mapped for entire city as part of the previous work and the methodology for mapping groundwater levels is due to change in upcoming studies.

**Table 2.7: High groundwater hazard events**

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
95 <sup>th</sup> percentile groundwater table with 1.25 m SLR. HSA extent is where groundwater depth < 0.5 m	<b>Existing</b> 95 <sup>th</sup> percentile groundwater table, no SLR	<b>Existing</b> n/a
	<b>Future</b> 95 <sup>th</sup> percentile groundwater table, 1.25 m SLR	<b>Future</b> n/a

The HSA for high groundwater level was based on building footprints where depth to groundwater (below ground level rather than below building floor level), was less than 0.5 m for a 95<sup>th</sup> Percentile groundwater table with 1.25 m SLR. The HSA for high groundwater is shown in Figure B12 of Appendix B. For the primary assessment a building was considered functionally compromised if depth to groundwater was less than 0 m (i.e. groundwater level projected to be at, or above, ground).

The risk assessment results for high groundwater are presented in Section 3.4.

## 2.6 Liquefaction and lateral spread

Liquefaction is the process by which earthquake shaking increases the water pressure in the ground in sandy and silty soil layers resulting in temporary loss of soil strength. Liquefaction can give rise to significant land and building damage through the following mechanisms:

- Ejection of sediment to the ground surface.
- Differential settlement of the ground due to volume loss in liquefied soil.
- Lateral movement of the ground (known as lateral spreading).

The factors that influence the vulnerability of land to liquefaction-related damage are the strength and composition of the soils, the depth of the groundwater surface and the strength of earthquake shaking sustained.

The datasets used to define 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.

While the scope of works for the Western Zone and Eastern Zone studies were identical, as would be expected when work of this nature is undertaken by different consultants, there are differences in the methodology applied. Therefore there are also likely to be differences outputs even in areas where the ground conditions are similar.

The T+T (2020a) and Aurecon (2020) data has been applied to the entirety of the Tauranga area.

Table 2.8 below defines the the event scenarios that were used for the primary and secondary assessment for liquefaction. Table 20 of Appendix L (BoPRC, 2016a) 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 for the 0.1% AEP event and a 0.2% AEP events and therefore only these events have been assessed.

**Table 2.8: 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	<b>Existing</b> 0.1% AEP, no SLR	<b>Existing</b> 0.2% AEP, no SLR
	<b>Future</b> 0.1% AEP, 1.25 m SLR	<b>Future</b> 0.2% AEP, 1.25 m SLR

We note that the level of earthquake shaking associated with the 0.1% AEP is sufficiently high that it provides an indication of the level of liquefaction induced land damage that would be expected for the 0.033% AEP. However, unlike the previous iterations of this assessment, it is not sufficiently high that it should be considered “effectively equivalent” to the 0.033% AEP. This is because recent revisions to the understanding of seismic hazard, that have been incorporated into the T+T (2020a) and Aurecon (2020) studies, indicate that the previously available information for longer return period events was over estimating seismic hazard by up to 30%.

For the liquefaction risk assessment the HSA, for the T+T (2020a) and Aurecon (2020) data is defined as all land within the TCC land area that has been assessed in the respective studies. The HSA for liquefaction is shown in Figure B14 of Appendix B.

For this assessment, a functionally compromised building is considered to be synonymous with the definition of “loss of amenity” as defined by the MBIE guidance document “Repairing and rebuilding houses affected by the Canterbury earthquakes” (MBIE, 2012). One of the key performance measures in the definition of loss of amenity is the concept of “readily repairable.” The MBIE guidance document defines this as “...repairable without relocation of occupants for more than four weeks...” (refer to Section 8.2.3 and Table 8.1 of the MBIE (2012) guidance document).

Based on review of the building floor survey information presented in Appendix A, the prevalent building foundation types found in the Tauranga area are either piled foundations or slab on grade.

This survey data was used to infer the proportion of each of these foundation types within each Area Unit<sup>3</sup> within the Tauranga land area.

Table 2.9 shows the assumed percentage of buildings that are assumed to be functionally compromised based on the land damage categories for the prevalent building foundation types within the HSA. The values presented in Table 2.9 have been developed based on engineering judgement informed by experience from the 2010 – 2011 Canterbury Earthquake Sequence. Particular consideration has been given to the following factors:

- The likely spatial variation in liquefaction-induced land damage within a given category.
- The likely variation in building performance in response to the liquefaction-induced land damage within a given category.

These values have been applied to the building count in each location to derive the results of the risk assessment as shown in Section 3.5.

**Table 2.9: Percentage of buildings that are assumed to be functionally compromised based on the land damage categories for the prevalent building foundation types**

Land damage category	Piled foundations functionally compromised	Slab on grade functionally compromised
<i>None to minor</i>	1%	2.5%
<i>Minor to moderate</i>	10%	15%
<i>Moderate to severe</i>	50%	50%

Note that the nature of the methodology applied means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 is estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

The risk assessment results for liquefaction and lateral spread are presented in Section 3.5 below.

## 2.7 Slope instability

Slope instability occurs where either soil and/or rock move downslope under gravity. Typically, slope instability occurs on relatively steep slopes in response to an external trigger such as heavy rainfall or earthquake shaking. Slope instability typically causes damage to the built environment in the form of either “evacuation” of the land underlying structures or “inundation” of structures with the debris generated.

Following a series of rainfall induced landslide events that caused significant property damage in the 1980s and 1990s, a number of studies were undertaken to better understand the factors that influence slope instability in the Tauranga region. These studies include Houghton & Hegan (1980), T+T (1980), Bird (1981), WBoPDC (1992) and Oliver (1997). The findings of these studies indicate that the evacuation zone of the landslip typically occurs above a line projected at approximately 1V:2H from the toe of a slope and the run-out distance of the landslip debris typically falls within a line projected at about 1V:4H from the headscarp of the slip (Richards, 2001).

<sup>3</sup> Area Unit boundaries are defined by Statistics NZ and is approximately equivalent to suburbs. The current Area Unit boundaries can be accessed digitally through the Statistics NZ website (Stats NZ, 2019)

To understand which parts of Tauranga may be susceptible to slope instability, these conditions have been mapped across Tauranga using geospatial tools. An additional projection line of 1V:3H from the toe of the slope was also mapped as part of this process. The spatial area covered by these projection lines can be accessed on the TCC Map Viewer<sup>4</sup>. This data set has been utilised to undertake a preliminary qualitative risk assessment of rainfall induced slope instability. Refer to Figure 2.3 for a schematic representation of these lines projected onto a slope typically found in the Tauranga region.

The risk assessment has been limited to qualitative consideration of only the 1% AEP rainfall induced scenario because the available hazard information does not support further more detailed analysis. The primary reasons for this are as follows:

- The factors that influence seismic induced slope instability are not captured in the available dataset and there is no recent historic precedent with which to calibrate the results.
- There is significant uncertainty associated with the influence of rainfall intensity and climate change on slope instability. Therefore, it is not meaningful to consider secondary assessments or future climate scenarios based on the current information available.

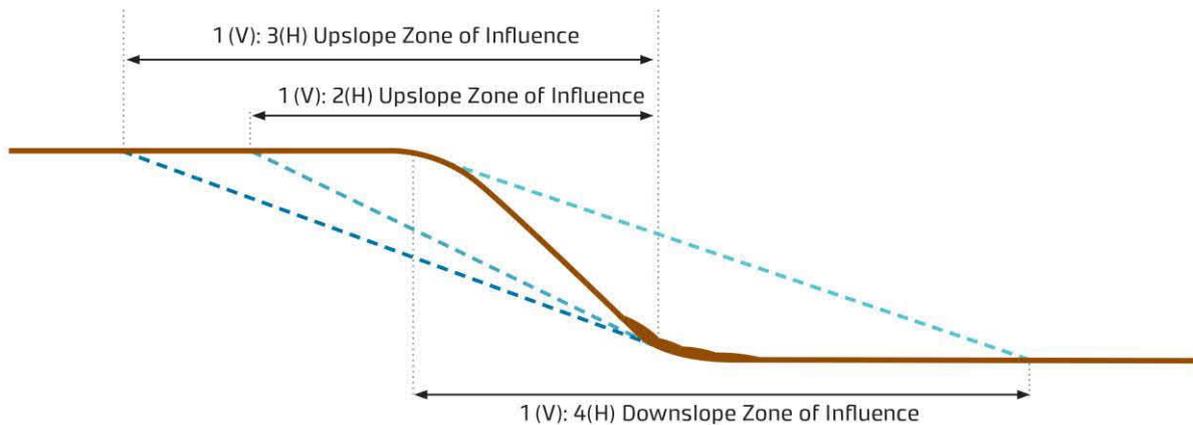


Figure 2.3: Schematic representation of typical slope in Tauranga showing 1(V):2(H) upslope, 1(V):3(H) upslope and 1(V):4(H) downslope projection lines

Table 2.10 below defines the HSA and the event scenarios that have been used for this rainfall induced slope instability risk assessment.

**Table 2.10: Rainfall induced slope instability hazard events**

Hazard susceptibility area (HSA)	Primary assessment	Secondary assessment
All land within the spatial extent of the 1(V):2(H) upslope, 1(V):3(H) upslope and 1(V):4(H) downslope projection lines	<b>Existing</b> 1% AEP rainfall event, no SLR	<b>Existing</b> n/a
	<b>Future</b> n/a	<b>Future</b> n/a

The HSA is defined as all land within the spatial extent of the 1(V):2(H) upslope, 1(V):3(H) upslope and 1(V):4(H) downslope projection lines. The HSA for slope instability is shown in Figure B15 of

<sup>4</sup> Available at <https://mapi.tauranga.govt.nz/Html5/index.html?viewer=Mapi>

Appendix B. The same definition of functionally compromised as was assumed for the liquefaction assessment has been assumed for this slope instability risk assessment (refer Section 2.6).

Table 2.11 shows the assumed percentage of buildings that will likely be functionally compromised in a 1% AEP rainfall induced landslide event by building slope location. The values presented in Table 2.11 have been developed based engineering judgement informed by local experience and review of case history information described above. Particular consideration has been given to the following factors:

- The likely spatial distribution of rainfall induced landsliding within a given slope location during a 1% AEP event
- The likely variation in building performance in response to the rainfall induced landsliding within a given slope location during a 1% AEP event

These values have been applied to the building count in each location to derive the results of the risk assessment as shown in Section 3.6.

**Table 2.11: Percentage of buildings functionally compromised in a 1% AEP rainfall induced landslide event by building slope location**

Building slope location	Percentage buildings functionally compromised
1(V):3(H) upslope	1%
1(V):2(H) upslope and 1(V):3(H) upslope	5%
1(V):2(H) upslope, 1(V):3(H) upslope and 1(V):4(H) downslope	10%
1(V):4(H) downslope	2.5%

Note that the nature of the methodology applied means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 is estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

### 3 Risk assessment results

This section presents the results of the likelihood and consequence assessment undertaken for each hazard and the subsequent assessment of hazard risk. Figure 3.1 below is the risk screening matrix recommended in Appendix L of the BoPRC RPS that has been used in assigning the level of risk for each hazard.

Likelihood <sup>5</sup> (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 3.1: Risk screening matrix (source: BoPRC (2016a))

For each of the six hazards assessed as part of this study, as well as flood hazard assessed by AWA (2019), maps of the HSAs and hazard extents have been produced and are presented in Appendix B. For some hazards, the available hazard data did not cover the entire city. These areas are indicated by the hatched red areas where applicable.

#### 3.1 Coastal inundation

The hazard extent for coastal inundation is shown in Figures B2-B4 in Appendix B. A total of 11 critical buildings, 60 social/cultural buildings and 3,583 'other' buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.1 and the risk assessment results are presented in Table 3.2.

For the current climate scenario, the 1% AEP event (primary assessment) resulted in a consequence level of 'Major' based on the quantitative assessment of consequence to buildings, while the 2% AEP event and 0.2% AEP event (secondary assessments) resulted in consequence levels of 'Moderate' and 'Catastrophic', respectively. We note that while coastal inundation may cause buildings to be functionally compromised, the functionality of these buildings will likely be able to be reinstated once inundation has subsided. This differs from hazards such as coastal erosion where compromised functionality may also mean complete destruction of a building.

For public safety consideration, the consequence for all events was classified as 'Insignificant' (no fatalities, no injuries). Even with high coastal inundation exposure, fatality rates are typically low due to advanced warning of weather systems, community preparedness and other interventions (Ishiguro & Yano, 2015). Flooding associated with coastal inundation is generally low velocity (compared with fluvial flooding) and lifeline utilities are typically restored relatively quickly once

flooding has receded (New Zealand Lifelines Council, 2017). Therefore consequence to lifeline utilities was classified as 'Moderate' (out of service for one day to one week where it affects  $\geq 20\%$  of the city or one week to six weeks where it affects  $< 20\%$  of the city) for all three events assessed.

For the three events assessed, an overall risk level of 'High' was assigned for the current climate scenario based on consequence to buildings (as this yielded the highest consequence level), with the 0.2% AEP event producing the maximum level of risk.

**Table 3.1: Building counts for coastal inundation (current climate)**

Building type	Total number of buildings in HSA	Primary Assessment 1% AEP, 2020		Secondary Assessment 2% AEP, 2020		Secondary Assessment 0.2% AEP, 2020	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	11	0	0.0%	0	0.0%	3	27.3%
<b>Social/cultural buildings</b>	60	10	16.6%	5	8.3%	25	41.7%
<b>Other buildings</b>	3,583	541	15.1%	348	9.7%	1,443	40.3%

**Table 3.2: Coastal inundation risk assessment results (current climate)**

Scenario	Primary Assessment 1% AEP, 2020		Secondary Assessment 2% AEP, 2020		Secondary Assessment 0.2% AEP, 2020	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Likelihood</b>	1% AEP		2% AEP		0.2% AEP	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Buildings</b>	Major	Medium	Moderate	Medium	Catastrophic	High
<b>Lifeline utilities</b>	Moderate	Medium	Moderate	Medium	Moderate	Medium
<b>Public safety</b>	Insignificant	Low	Insignificant	Low	Insignificant	Low
<b>Scenario risk level</b>	Medium		Medium		High	
<b>Hazard risk level</b>	High					

The quantity of buildings functionally compromised for the future climate scenario are presented in Table 3.3 and the risk assessment results is presented in Table 3.4. For the future climate scenario, the majority of all types of buildings would be functionally compromised resulting in a consequence level of 'Catastrophic' for all three return period events. While sea level rise will increase inundation exposure, it is unlikely to be a rapid change that increases consequence to public safety or lifeline utilities. Therefore the consequence levels for all events remained unchanged from the current climate scenario.

The overall risk level assigned for the future climate scenario was 'High' based on the consequence to buildings (as this yielded the highest consequence level), with the 2% AEP event producing the maximum level of risk.

**Table 3.3: Building counts for coastal inundation (future climate)**

Building type	Total number of buildings in HSA	Primary Assessment 1% AEP, 2130		Secondary Assessment 2% AEP, 2130		Secondary Assessment 0.2% AEP, 2130	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	11	9	81.8%	7	63.6%	11	100.0%
<b>Social/cultural buildings</b>	60	48	80.0%	42	70.0%	60	100.0%
<b>Other buildings</b>	3,583	2,803	78.2%	2,586	72.2%	3,406	95.1%

**Table 3.4: Coastal inundation risk assessment results (future climate)**

Scenario	Primary Assessment 1% AEP, 2130		Secondary Assessment 2% AEP, 2130		Secondary Assessment 0.2% AEP, 2130	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Likelihood</b>	1% AEP		2% AEP		0.2% AEP	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Buildings</b>	Catastrophic	High	Catastrophic	High	Catastrophic	High
<b>Lifeline utilities</b>	Moderate	Medium	Moderate	Medium	Moderate	Medium
<b>Public safety</b>	Insignificant	Low	Insignificant	Low	Insignificant	Low
<b>Scenario risk level</b>	High		High		High	
<b>Hazard risk level</b>	High					

## 3.2 Coastal erosion

Separate risk assessments have been undertaken for coastal erosion occurring within the inner harbour and on the open coast (i.e. between Mount Maunganui and Te Tumu). Te Tumu has been assessed as part of a separate risk assessment study as there are currently no buildings or infrastructure located there. The hazard extent for coastal erosion in both areas is shown in Figures B6 and B7 in Appendix B.

### 3.2.1 Inner harbour

A total of 7 social/cultural buildings and 699 'other' buildings were found to be located within the coastal erosion HSA within the inner harbour. No critical buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.5 and the risk assessment results are presented in Table 3.6.

For the current climate scenario, the P66% scenario (primary assessment) resulted in a consequence level of 'Moderate' based on the quantitative assessment of consequence to buildings. Only one secondary assessment – the P5% scenario (i.e. lower likelihood) was undertaken, and this resulted in a consequence level of 'Major' for consequence to buildings. The number of buildings estimated to be functionally compromised, assumes that coastal erosion will occur in a manner by which the entire coastline will erode to the coastal hazard extent for a given probability. In reality, erosion processes will occur with some degree of spatial variability. Therefore at a given point in time, some parts of the coast may have eroded more than others (i.e. in 100 years time some parts of the coast

may have eroded to the P66% erosion hazard line while others may have eroded to the P5% erosion hazard line). We also note that for coastal erosion hazard, buildings that are functionally compromised may not be able to have their functionality restored (i.e. buildings will be completely destroyed). This differs from other hazards such as coastal inundation, where a buildings functionality may be able to be restored some time after the inundation has subsided.

While the consequence to public safety as a result of erosion of beach shorelines (i.e. shallow angle shorelines) is likely to be 'Insignificant', erosion of cliff shorelines (i.e. steep angle shorelines) could pose a threat to human life where dwellings are situated in close proximity to the hazard. Therefore consequence to public safety has been classified as 'Moderate' (2-10 fatalities and/or 11-100 injuries) for both events assessed. The coastal erosion HSA is a relatively small area of the city, and lifeline utilities within the HSA are generally limited to water and wastewater networks and roads that serve a small number of houses. Therefore, the consequence level for lifeline utilities was classified as 'Moderate' (out of service for more than one day to one day week it affects  $\geq 20\%$  of the city or one week to six weeks where it affects  $< 20\%$  of the city) for both events assessed.

The P66% event has a 66% chance of occurring over a 100 year planning timeframe. This is the same probability of a 1% AEP event occurring within a 100 year period so a 1% AEP likelihood was used in the risk screening matrix to determine risk level. Similarly, the P5% has the same probability of occurrence as a 0.05% AEP event in a 100 year period, so a 0.05% AEP likelihood was used to assign risk level for this event. For the two events assessed an overall risk level of 'Medium' was assigned for the current climate scenario with the P66% event producing the maximum level of risk.

**Table 3.5: Building counts for inner harbour coastal erosion (current climate)**

Building type	Total number of buildings in HSA	Primary Assessment P66%, 2030		Secondary Assessment P5%, 2030		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	0	-	-	-	-		
<b>Social/cultural buildings</b>	7	0	0.0%	1	14.3%		
<b>Other buildings</b>	699	90	12.9%	306	43.4%		

**Table 3.6: Inner harbour coastal erosion risk assessment results (current climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	P66%, 2130		P5%, 2130		n/a	
Likelihood	66% chance of occurring in the next 100 years - analogous to 1% AEP		5% chance of occurring in the next 100 years - analogous to 0.05% AEP			
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
Buildings	Moderate	Medium	Major	Low		
Lifeline utilities	Moderate	Medium	Moderate	Low		
Public safety	Moderate	Medium	Moderate	Low		
Scenario risk level	Medium		Low			
Hazard risk level	Medium					

The quantity of buildings functionally compromised for the future climate scenario is presented in Table 3.7 and the risk assessment results are presented in Table 3.8. For the future climate scenario, both the primary and secondary assessment resulted in a consequence of 'Catastrophic' based on the quantitative assessment of consequence to buildings. For the secondary assessment 100% of buildings were functionally compromised as the hazard event is the same as that used to define the coastal erosion HSA.

Consequence levels for public safety and lifeline utilities would remain unchanged from the current climate scenario as the increase in hazard extent between the current climate and future climate scenario is relatively small. Using the same rationale for likelihood as described for the current climate scenario above, a risk level of 'High' was assigned for the future climate scenario based on consequence to buildings (as this yielded the highest consequence level), with the P66% scenario producing the maximum level of risk .

**Table 3.7: Building counts for inner harbour coastal erosion (future climate)**

Building type	Total number of buildings in HSA	Primary Assessment P66%, 2130		Secondary Assessment P5%, 2130		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	0	-	-	-	-		
Social/cultural buildings	7	6	85.7%	7	100.0%		
Other buildings	699	470	67.2%	699	100.0%		

**Table 3.8: Inner harbour coastal erosion risk assessment results (future climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	P66%, 2130		P5%, 2130		n/a	
Likelihood	66% chance of occurring in the next 100 years - analogous to 1% AEP		5% chance of occurring in the next 100 years - analogous to 0.05% AEP			
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
Buildings	Catastrophic	High	Catastrophic	Medium		
Lifeline utilities	Moderate	Medium	Moderate	Low		
Public safety	Moderate	Medium	Moderate	Low		
Scenario risk level	High		Medium			
Hazard risk level	High					

### 3.2.2 Open coast

A total of 186 'other' buildings were found to be located within the coastal erosion HSA for the open coast (i.e. between Mount Maunganui and Te Tumu). No critical or social/cultural buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.9 and the risk assessment results are presented in Table 3.10.

For the current climate scenario, both the primary (P66%) and secondary (P5%) assessments resulted in a consequence level of 'Insignificant' based on the quantitative assessment of consequence to buildings. The open coast consists only of beach shorelines (i.e. shallow angle shorelines) and therefore the consequence to public safety has been classified as 'Insignificant'. The coastal erosion extent for the current climate scenario generally does not extend beyond beach-front properties into the road corridor and so would likely not result in outages of any lifeline utilities. Therefore the consequence to lifeline utilities was classified as 'Insignificant'. Subsequently, for the two events assessed an overall risk level of 'Low' was assigned for the current climate scenario.

**Table 3.9: Building counts for open coast erosion (current climate)**

Building type	Total number of buildings in HSA	Primary Assessment		Secondary Assessment		Secondary Assessment	
		P66%, 2030		P5%, 2030		n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	-	-	-	-	-		
Social/cultural buildings	-	-	-	-	-		
Other buildings	186	0	0.00%	0	0.00%		

**Table 3.10: Open coast erosion risk assessment results (current climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	P66%, 2130		P5%, 2130		n/a	
<b>Likelihood</b>	66% chance of occurring in the next 100 years - analogous to 1% AEP		5% chance of occurring in the next 100 years - analogous to 0.05% AEP			
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Buildings</b>	Insignificant	Low	Insignificant	Low		
<b>Lifeline utilities</b>	Insignificant	Low	Insignificant	Low		
<b>Public safety</b>	Insignificant	Low	Insignificant	Low		
<b>Scenario risk level</b>	Low		Low			
<b>Hazard risk level</b>	Low					

The quantity of buildings functionally compromised for the future climate scenario is presented in Table 3.11 and the risk assessment results are presented in Table 3.12. For the future climate scenario the primary assessment resulted in a consequence of 'Minor' and the secondary assessment resulted in a consequence of 'Catastrophic' based on the quantitative assessment of consequence to buildings. As with the inner harbour erosion, this is because 100% of the buildings were functionally compromised as the hazard event is the same as that used to define the coastal erosion HSA.

While the consequence for lifeline utilities remained unchanged from the current climate scenario for the primary assessment, the consequence for the secondary assessment was classified as 'Moderate'. This is because the coastal erosion extent for the secondary assessment with future climate extends into the road corridor, particularly near Mount Main Beach so has the potential to result in outages to lifeline utilities. The consequence level for public safety remains unchanged from the current climate scenario. An overall risk level of 'Medium' was assigned for the future climate scenario based on the consequence to buildings (as this yielded the highest consequence level), with the P5% scenario producing the maximum level of risk.

**Table 3.11: Building counts for open coast erosion (future climate)**

Building type	Total number of buildings in HSA	Primary Assessment		Secondary Assessment		Secondary Assessment	
		P66%, 2130		P5%, 2130		n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	-	-	-	-	-		
<b>Social/cultural buildings</b>	-	-	-	-	-		
<b>Other buildings</b>	186	3	1.61%	186	100.00%		

**Table 3.12: Open coast erosion risk assessment results (future climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	P66%, 2130		P5%, 2130		n/a	
<b>Likelihood</b>	66% chance of occurring in the next 100 years - analogous to 1% AEP		5% chance of occurring in the next 100 years - analogous to 0.05% AEP			
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Buildings</b>	Minor	Low	Catastrophic	Medium		
<b>Lifeline utilities</b>	Insignificant	Low	Moderate	Low		
<b>Public safety</b>	Insignificant	Low	Insignificant	Low		
<b>Scenario risk level</b>	Low		Medium			
<b>Hazard risk level</b>	Medium					

### 3.3 Tsunami

The hazard extent for tsunami is shown in Figures B9-B11 in Appendix B. A total of 9 critical buildings, 107 social/cultural buildings and 19,061 ‘other’ buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.13 and the risk assessment results are presented in Table 3.13.

For the current climate scenario, the 0.1% AEP event (primary assessment) resulted in a consequence level of ‘Insignificant’ based on the quantitative assessment of consequence to buildings, while the 0.2% AEP event and 0.04% AEP event (secondary assessments) resulted in consequence levels of ‘Insignificant’ and ‘Minor’, respectively. We note that these building consequence levels are lower than other hazards such as coastal inundation despite the fact a greater number of buildings are functionally compromised. This is due to the fact that in the RPS methodology consequence to buildings is determined by the percentage of buildings within the HSA that are functionally compromised and there are a larger number of buildings within the tsunami HSA. For more discussion on this point refer Section 4.

In determining consequence to public safety, the number of fatalities for each tsunami event was quantified using the approach described in Section 2.4. This involved estimating the number of fatalities at each dwelling in the HSA by assuming average occupancy of 2.53 and multiplying by tsunami inundation depth (in metres) and a fatality factor of 0.04 (Beban et. al., 2011). Injuries were not considered in the consequences to public safety as the model used to quantify injuries in Beban et. al. (2011) does not result in a significantly larger amount of injuries, and the consequence level is insensitive to relatively small changes in injury numbers. The estimated number of fatalities for each event was used to assign a consequence level using the thresholds in Table 21 of Appendix L of the RPS (refer Figure 2.1). The resulting public safety consequence levels for the 0.1% AEP event, 0.2% AEP event and 0.04% AEP event were ‘Moderate’, ‘Minor’ and ‘Major’, respectively.

The consequence to lifeline utilities was qualitatively considered for tsunami hazard. The New Zealand Lifeline Council compiled the following summary of potential tsunami damage to life utilities from Horspool & Fraser (2016) in their 2017 Infrastructure Vulnerability Assessment (New Zealand Lifelines Council, 2017):

- Transportation networks will likely be damaged by even small tsunami (tsunami depths ~1 m) due to scouring and deposition of debris.

- Wastewater and potable water networks are particularly vulnerable to tsunami at their facility buildings and pipe intake and outflow sites. Contamination of drinking water supplies or sewerage containment ponds can occur with even small amounts of intrusion of seawater from a tsunami.
- Telecommunications networks will most likely be disrupted locally due to damage to buildings and electrical equipment at exchanges and failure of cellular sites.
- Energy networks, particularly electricity, will be impacted due to shorting of buried cables if they become exposed to the water and have pre-existing casing damage. Also, overhead lines are susceptible to failure by toppling of poles, which can be damaged by debris strikes. Petroleum and gas terminals, often located in coastal areas may suffer damage to their pipe networks and tank farms in tsunami depths of 2 m or greater.
- Back-up services, such as generators, are often located on the ground outside of buildings, on ground floors or in basements, putting them at risk.
- Bridges are a lifeline component that are vulnerable to tsunami and often have co-location of other lifeline services, which if damaged can cause failure of these other lifeline services.

While it is difficult to make a judgement on likely recovery time for lifeline utilities after a tsunami without a detailed assessment (as discussed in Section 2.1.2.2), we consider it unlikely that the consequence level would be higher than 'Moderate' for the 0.1% AEP event and 0.2% AEP event given the limited spatial extent of the hazard. A consequence level of 'Moderate' is defined as a lifeline utility being out of service for one day to one week where it affects  $\geq 20\%$  of the city or one week to six weeks where it affects  $< 20\%$  of the city. For the 0.04% AEP tsunami event we consider it likely that the consequence level will be 'Major' (out of service for one week to one month where it affects  $\geq 20\%$  of the city or six weeks to six months where it affects  $< 20\%$  of the city) given the higher inundation depth and hazard extent. The potential consequences of tsunami hazard on lifeline utilities was considered to be more severe than coastal inundation given that water velocities and debris flows are likely to be higher for tsunami hazard.

For the three events assessed a risk level of 'Medium' was assigned for the current climate scenario based on consequence to public safety and lifeline utilities (as these yielded the highest consequence level), with the 0.1% AEP event producing the maximum level of risk .

An assessment of AIFR and AIFR<sup>PIC</sup> was conducted as the risk level based on consequence to buildings, public safety and lifeline utilities did not yield a risk level of 'High'. The assessment of AIFR and AIFR<sup>PIC</sup> is based on the number of estimated fatalities and the return period of the hazard event to give the probability of fatality from a particular hazard for an individual over the period of a year. The methodology for the AIFR and AIFR<sup>PIC</sup> assessment is described in more detail in Section 2.4. Given that the AIFR and AIFR<sup>PIC</sup> for all events was less than  $1 \times 10^{-4}$ , the risk level remained as 'Medium' for the current climate scenario as per the risk assessment methodology given in Appendix L (BoPRC, 2016a).

**Table 3.13: Building counts and fatality risk for tsunami (current climate)**

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP		Secondary Assessment 0.2% AEP		Secondary Assessment 0.04%	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	9	0	0.0%	0	0.0%	0	0.0%
<b>Social/cultural buildings</b>	107	0	0.0%	0	0.0%	1	1.0%
<b>Other buildings</b>	19,061	129	0.7%	11	0.1%	554	2.9%
Annual Individual Fatality Risk (AIFR)							
<b>Estimated fatalities</b>	5		<1		65		
<b>AIFR</b>	$1.2 \times 10^{-7}$		$6.1 \times 10^{-9}$		$5.6 \times 10^{-7}$		
<b>Estimated fatalities for people in care</b>	0		0		4		
<b>AIFR<sup>PIC</sup></b>	-		-		$2.3 \times 10^{-7}$		

**Table 3.14: Tsunami risk assessment results (current climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP		0.2% AEP		0.04% AEP	
Likelihood	0.1% AEP		0.2% AEP		0.04% AEP	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
<b>Buildings</b>	Insignificant*	Low	Insignificant*	Low	Minor*	Low
<b>Lifeline utilities</b>	Moderate	Medium	Moderate	Medium	Major	Low
<b>Public safety</b>	Moderate	Medium	Minor	Low	Major	Low
<b>Scenario risk level</b>	Medium		Medium		Low	
<b>Hazard risk level</b>	Medium					

\*Consequence level is based on the portion of buildings within the HSA that are functionally compromised. The consequence levels for buildings using the RPS methodology comes out low due to the high number of buildings within the HSA and does not reflect the potential consequences to buildings in absolute terms.

The quantity of buildings functionally compromised for the future climate scenario is presented in Table 3.15 and the risk assessment results are presented in Table 3.16. For the future climate scenario, the 0.1% AEP event (primary assessment) resulted in a consequence level of 'Major' based on the quantitative assessment of consequence to buildings, while the 0.2% AEP event and 0.04% AEP event (secondary assessments) resulted in consequence levels of 'Moderate' and 'Catastrophic', respectively. These building consequence levels are determined by social/cultural buildings and critical buildings rather than the number of 'other' buildings.

Based on the estimated fatalities for each event the consequence to public safety for the 0.1% AEP event, 0.2% AEP event and 0.04% AEP event was classified as 'Major', 'Major' and 'Catastrophic',

respectively. For lifeline utilities the consequence level for all three events was classified as 'Catastrophic' (out of service for more than one month where it affects  $\geq 20\%$  of the city or six months where it affects  $< 20\%$  of the city). Therefore a risk level of 'High' was assigned for the future climate scenario based on consequence to lifeline utilities (as this yielded the highest consequence level), with the 0.2% AEP event producing the maximum level of risk .

**Table 3.15: Building counts and fatality risk for tsunami (future climate)**

Building type	Total number of buildings in HSA	Primary Assessment 0.1% AEP, 1.25 m SLR		Secondary Assessment 0.2% AEP, 1.25 m SLR		Secondary Assessment 0.04%, 1.25 m SLR	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	9	1	12.5%	0	0.0%	3	37.5%
Social/cultural buildings	107	12	11.2%	11	10.3%	22	20.6%
Other buildings	19,061	633	3.3%	472	2.5%	1,734	9.1%
Annual Individual Fatality Risk (AIFR)							
Estimated fatalities	59		29		208		
AIFR	$1.3 \times 10^{-6}$		$1.2 \times 10^{-6}$		$1.8 \times 10^{-6}$		
Estimated fatalities for people in care	5		3		81		
AIFR <sup>PIC</sup>	$7.8 \times 10^{-7}$		$1.1 \times 10^{-6}$		$5.2 \times 10^{-6}$		

**Table 3.16: Tsunami risk assessment results (future climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	0.1% AEP, 1.25 m SLR		0.2% AEP, 1.25 m SLR		0.04% AEP, 1.25 m SLR	
Likelihood	0.1% AEP		0.2% AEP		0.04% AEP	
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
Buildings	Major	Medium	Moderate	Medium	Catastrophic	Medium
Lifeline utilities	Catastrophic	High	Catastrophic	High	Catastrophic	Medium
Public safety	Major	Medium	Major	Medium	Catastrophic	Medium
Scenario risk level	High		High		Medium	
Hazard risk level	High					

### 3.4 High groundwater

The hazard extent for high groundwater is shown in Figure B13 in Appendix B. A total of 4 critical buildings, 84 social/cultural buildings and 7,703 'other' buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.17 and the risk assessment results are presented in Table 3.18.

For the current climate scenario, the 95<sup>th</sup> Percentile groundwater level (primary assessment) resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. No secondary assessment was undertaken for high groundwater. High groundwater is a hazard that primarily affects buildings and infrastructure so the consequence to public safety has been classified as 'Insignificant'. For lifeline utilities, high groundwater may affect the operation of underground infrastructure such as pipes or cables or the foundations of above ground infrastructure like roads or utility buildings. While it is difficult to determine likely damage to utilities without a detailed assessment, we consider it unlikely that the consequences level would be higher than 'Moderate' (out of service for more than one day to one week where it affects  $\geq 20\%$  of the city or one weeks to six weeks where it affects  $< 20\%$  of the city). For all three events assessed, the consequence to lifeline utilities has been classified as 'Minor' to 'Moderate'.

The 95<sup>th</sup> percentile groundwater level is the groundwater level which is exceeded for 5% of the period of record (i.e. 18 days a year on average). While it is difficult to determine an equivalent AEP to this assessment, we have assumed it to be greater than a 2% AEP (the highest likelihood considered in the risk screening matrix) for the purposes of the RPS risk assessment process. A risk level of 'Medium' was assigned for the current climate scenario based on consequence to buildings and lifeline utilities.

**Table 3.17: Building counts for high groundwater (current climate)**

Building type	Total number of buildings in HSA	Primary Assessment 95 <sup>th</sup> Percentile		Secondary Assessment n/a		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	4	0	0.0%				
<b>Social/cultural buildings</b>	84	4	4.8%				
<b>Other buildings</b>	7,703	166	2.1%				

**Table 3.18: High groundwater risk assessment results (current climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	95 <sup>th</sup> percentile		n/a		n/a	
Likelihood	>2% AEP					
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
Buildings	Minor	Medium				
Lifeline utilities	Minor-Moderate	Medium				
Public safety	Insignificant	Low				
Scenario risk level	Medium					
Hazard risk level	Medium					

The quantity of buildings functionally compromised for the future climate scenario is presented in Table 3.19 and the risk assessment results are presented in Table 3.20. For the future climate scenario, the primary assessment resulted in a consequence of 'Catastrophic' based on the quantitative assessment of consequence to buildings. Consequence levels for public safety and lifeline utilities would remain unchanged from the current climate scenario. Using the same rationale for likelihood as described for the current climate scenario above, a risk level of 'High' was assigned for the future climate scenario based on consequence to buildings.

**Table 3.19: Building counts for high groundwater (future climate)**

Building type	Total number of buildings in HSA	Primary Assessment 95 <sup>th</sup> Percentile, 1.25m SLR		Secondary Assessment n/a		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
Critical buildings	4	3	75.0%				
Social/cultural buildings	84	52	61.9%				
Other buildings	7,703	3,228	41.9%				

**Table 3.20: High groundwater risk assessment results (future climate)**

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	95 <sup>th</sup> percentile		n/a		n/a	
Likelihood	>2% AEP					
	Consequence	Risk Level	Consequence	Risk Level	Consequence	Risk Level
Buildings	Catastrophic	High				
Lifeline utilities	Minor-Moderate	Medium				
Public safety	Insignificant	Low				
Scenario risk level	Medium					
Hazard risk level	High					

### 3.5 Liquefaction and lateral spread

The risk assessment results for liquefaction and lateral spread are presented in Table 3.22 (current climate) and Table 3.24 (future climate). A total of 53 critical buildings, 799 social/cultural buildings and 63,812 'other' buildings were found to be located in the HSA.

For the current climate scenario, the 0.1% AEP event (primary assessment) resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. The 0.2% AEP event (secondary assessment) resulted in a consequence level of 'Moderate' based on the quantitative assessment of consequence to buildings.

Consequence to lifeline utilities and public safety were qualitatively considered for liquefaction and lateral spread hazard. Despite the potential to cause significant damage to buildings and other infrastructure, the experience in the Christchurch area following the Canterbury Earthquake Sequence (CES) is that liquefaction and lateral spreading do not pose a significant risk to life. While 185 people lost their lives as a result the February 2011 earthquake, 130 of these fatalities occurred as a result of the collapse of two office buildings due to structural failure induced by severe ground shaking. The remaining fatalities were as a result of either collapsed walls, falling masonry or falling rocks. None of these fatalities were associated with either liquefaction or lateral spreading. We note that there are multi-storey buildings founded on land that is susceptible to liquefaction in Tauranga City. If these buildings have not been designed to accommodate the effects of liquefaction and lateral spreading, there is the potential for building collapse to occur. Such collapse would pose a significant risk to life such that the thresholds for 'Major' or 'Catastrophic' consequence levels (refer to Figure 2.1) could be reached. However, for this qualitative assessment, we have assumed that these multi-storey buildings meet the requirements of The Building (Earthquake-prone Buildings) Amendment Act 2016, and therefore collapse is unlikely and there is no associated significant risk to life. Based on this knowledge, and our understanding of the mechanisms through which the consequences of liquefaction manifest, we consider the public safety consequence level for liquefaction to be 'Minor' for both of the events assessed.

Liquefaction and lateral spreading has the potential to cause significant damage to lifelines utilities including the following:

- Damage to road, rail and port infrastructure through settlement, cracking, sinkholes and ejecta.
- Underground services can be damaged due to ground deformation and blocked due to sedimentation.
- Deformation of embankments and bridge abutments can cause damage to bridge foundations and the super structure.
- Settlement and cracking of flood stopbanks and disruption to stormwater drainage can result in significant increase in flooding frequency and severity.

All of these consequences were observed during the CES. Based on this experience, and our understanding of the mechanisms through which the consequences of liquefaction manifest, we consider the lifeline utility consequence level for liquefaction and lateral spreading to likely be 'Catastrophic' for both events assessed. 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), with the 0.2% AEP event producing the maximum level of risk.

**Table 3.21: Building counts for liquefaction and lateral spread (current climate)<sup>5</sup>**

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.	%
<b>Critical buildings</b>	53	4	7.5%	1	1.9%		
<b>Social/cultural buildings</b>	779	42	5.3%	35	4.4%		
<b>Other buildings</b>	63,812	3,552	5.6%	2,797	4.4%		

<sup>5</sup> Note that the nature of the methodology applied means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 is estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

**Table 3.22: Liquefaction and lateral spread risk assessment results (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	Moderate	Medium		
Lifeline utilities	Catastrophic	High	Catastrophic	High		
Public safety	Minor	Low	Minor	Low		
Scenario risk level	High		High			
Hazard risk level	High					

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), with the 0.2% AEP event producing the maximum level of risk.

**Table 3.23: Building counts for liquefaction and lateral spread (future climate)<sup>6</sup>**

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	53	5	9.4%	5	9.4%		
Social/cultural buildings	799	76	9.5%	57	7.1%		
Other buildings	63,812	8,348	13.1%	5,794	9.1%		

<sup>6</sup> Note that the nature of the methodology applied means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 is estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

**Table 3.24: Liquefaction and lateral spread risk assessment results (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					

### 3.6 Slope instability

No hazard extent has been mapped for slope instability. Due to the nature of the information available, only a qualitative primary assessment based on the current climate was able to be undertaken. A total of 13 critical buildings, 96 social/cultural buildings and 10,648 other buildings were found to be located in the HSA. The quantity of buildings functionally compromised for the current climate scenario is presented in Table 3.25 and the risk assessment results are presented in Table 3.26.

The assessment resulted in a consequence level of 'Minor' based on the quantitative assessment of consequence to buildings. Due to the nature of both the consequences of slope instability and the hazard data available, we consider that it is not feasible to undertake an assessment (either qualitative or quantitative) of consequence to lifeline utilities or public safety. Therefore, a risk level of 'Low' was assigned for the current climate scenario based on the consequence to buildings.

Table 3.25: Building counts for slope instability (current climate)<sup>7</sup>

Building type	Total number of buildings in HSA	Primary Assessment 1% AEP		Secondary Assessment n/a		Secondary Assessment n/a	
		Buildings functionally compromised					
		No.	%	No.	%	No.	%
<b>Critical buildings</b>	13	<1	3.4%				
<b>Social/cultural buildings</b>	96	3	2.7%				
<b>Other buildings</b>	10,648	334	3.1%				

Table 3.26: Slope instability risk assessment results (current climate)

Scenario	Primary Assessment		Secondary Assessment		Secondary Assessment	
	1% AEP		n/a		n/a	
<b>Likelihood</b>	1% AEP					
	<b>Consequence</b>	<b>Risk Level</b>	<b>Consequence</b>	<b>Risk Level</b>	<b>Consequence</b>	<b>Risk Level</b>
<b>Buildings</b>	Minor	Low				
<b>Lifeline utilities</b>	N/A	N/A				
<b>Public safety</b>	N/A	N/A				
<b>Scenario risk level</b>	Low					
<b>Hazard risk level</b>	Low					

<sup>7</sup> Note that the nature of the methodology applied means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 is estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

## 4 Limitations

We note the following limitations of the results of this study:

- The hazard result layers used to assess consequence and risk level for each of the hazards, were sourced from other studies regarded as the best available information at time of writing. Each of these studies has its own set of limitations in the methodology and underlying source data, which are documented in the referenced reports and should be referred to for further information. Some of these studies were spatially limited so results were not available across the entire city (refer HSA maps in Appendix B) and some were limited in terms of how many different likelihoods had been mapped for use in this study. The current study has been undertaken in a way to enable an update of results as more recent/accurate hazard information becomes available.
- The RPS defines the HSA as the “maximum spatial extent of a hazard” and does not give any guidance on which return period event should be used to determine this. Therefore the events used for the HSA were based on available hazard data and commonly accepted “upper bound” events. Given that building consequence levels are based on the percentage of buildings within the HSA that are functionally compromised, the definition of the HSA can have a large effect on the consequence level, and therefore risk level, for a given hazard. In some cases this results in building consequence levels that are lower for a certain hazard, despite the fact that a greater number of buildings would be functionally compromised than for another hazard.
- Not all hazards have likelihoods that are able to be quantified in terms of AEP. In some cases, such as coastal erosion, high groundwater and slope instability, judgement had to be used in how to apply the risk assessment framework which is based on AEP rather than qualitative measures of likelihood.
- Data on building floor levels and foundation types was limited only to properties which had previously been surveyed by TCC. The available data provided a large sample from which we could make inferences regarding floor levels for unsurveyed buildings and is considered appropriate for the purposes of a high level risk assessment. However, inferred floor levels are not accurate enough to identify hazard prone buildings down to a property scale assessment.
- Future climate scenarios provide a useful understanding of how climate change and sea level rise may impact the hazard susceptibility of different areas of the city. However, the future scenarios used do not consider the interaction with other hazards and natural processes that may change over time (e.g. coastal inundation extents are based on the present day land form which may change as coastal erosion acts in low lying areas).
- The results of this study are based on high level qualitative estimates for consequence to lifeline utilities. These estimates were based on observations of the consequence to lifeline utilities from previous hazard events. No Tauranga-specific assessment of lifeline utility locations in relation to hazard extents was undertaken as part of this study.
- The nature of the methodology applied to the assessment of liquefaction and slope instability risk means that it is not possible to identify which buildings in the HSA will be functionally compromised. This is because the method relies on estimating a percentage of properties within the HSA rather than identifying specific properties that will likely be functionally compromised. Further, when there is only a small number of buildings in the HSA, a number less than 1 can be estimated for the functionally compromised building count. In these cases the building count is presented as <1 rather than presenting a decimal value.

## 5 Conclusions and recommendations

T+T has undertaken a high level city-wide natural hazard risk assessment for Tauranga in accordance with the BoPRC RPS on natural hazards. Table 5.1 below presents a summary of the results of the city-wide risk assessment. These results provide a “baseline” of natural hazard risk to inform future city planning and against which further options may be compared.

**Table 5.1: Summary of risk assessment results**

Hazard	Current climate	Future climate
Coastal inundation	High risk	High risk
Coastal erosion (inner harbour)	Medium risk	High risk
Coastal erosion (open coast)	Low risk	Medium risk
Tsunami	Medium risk	High risk
High groundwater	Medium risk	High risk
Liquefaction and lateral spread	High risk	High risk
Slope instability	Low risk	n/a

The policy direction associated with these levels of natural hazard risk are set out in Policy NH 3B of the BoPRC RPS. Policy NH 6B states that where natural hazard risk is classified as ‘High’, the RPS requires a response (i.e. risk mitigation) to reduce the level of risk to ‘Medium’ (and lower if reasonably practicable). The RPS acknowledges that this response may potentially need to occur over a long timeframe, especially where risk reduction relies on land development/redevelopment processes that relate to the design life of buildings and infrastructure. Where natural hazard risk is classified as ‘Medium’ (considered tolerable but not desirable in the RPS), opportunities to reduce risk should be taken where practicable. To comply with the RPS any land use management decisions made by TCC as part of planning processes should seek to mitigate risk where it is ‘High’ or ‘Medium’ and not increase the risk level where it is ‘Low’.

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.

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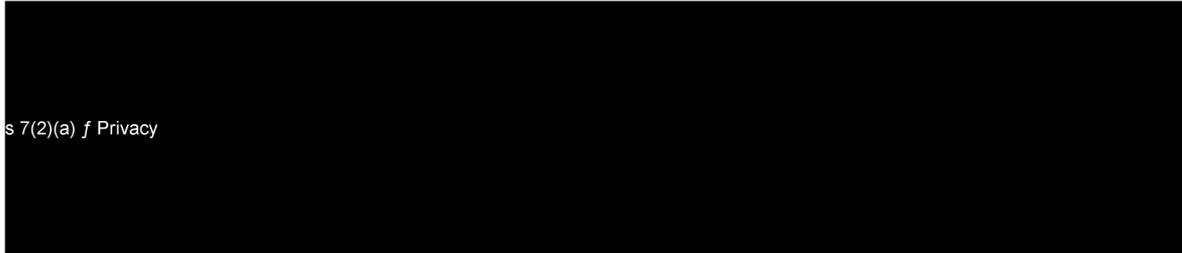
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## 7 Applicability

This 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.

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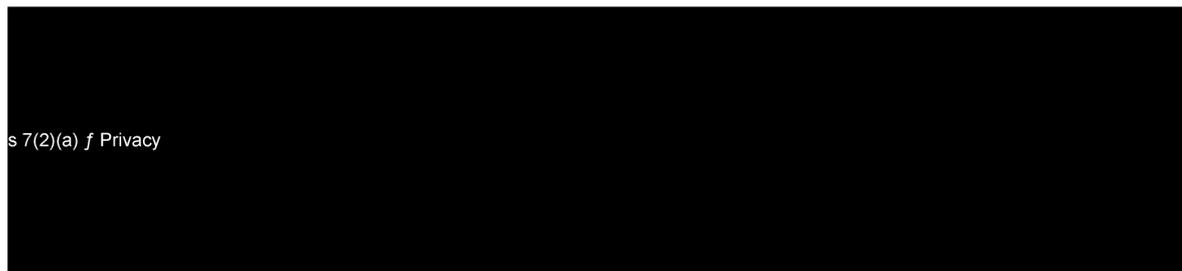
Report prepared by:



Water Resources Engineer

Senior Geotechnical Engineer

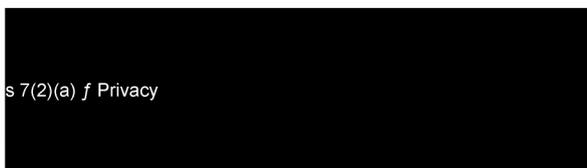
Technical review by:



Senior Water Resources Engineer

Senior Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:



Project Director

JTIH

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## **Appendix A: Summary of building floor level analysis**

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## Summary of building floor level analysis

TCC have surveyed building floor levels for approximately 10,000 buildings that were identified as being potentially susceptible to flooding in response to extreme rainfall events. Aside from recording floor levels of each of the buildings, the foundation type (piles or concrete) and building use (dwelling, garage, commercial, industrial etc.) were also identified. Figure 1 below shows how many buildings were surveyed for each foundation type and building use.

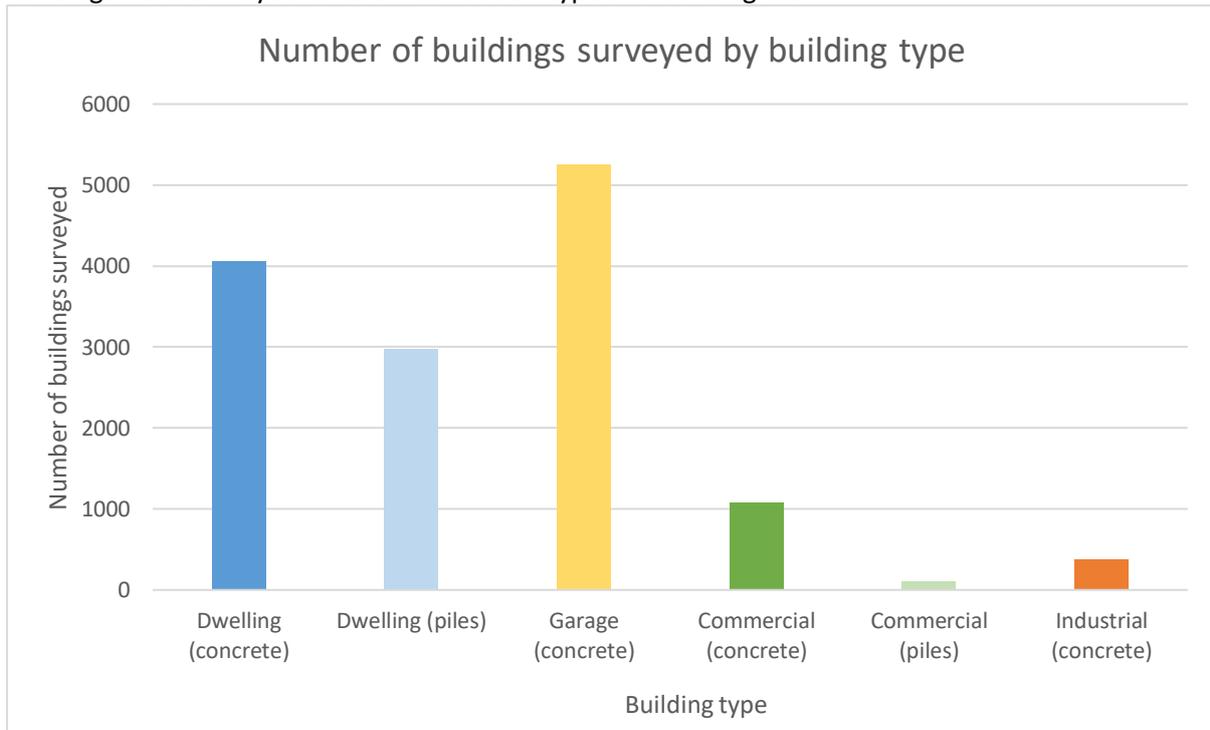


Figure 1: Summary of surveyed floor level types

The existing Tauranga City Council (TCC) surveyed floor level data has been analysed to determine a suitable methodology for inferring floor levels of buildings that have not been surveyed based on relative vertical offsets to adjacent ground levels. The adjacent ground levels were based on a Digital Elevation Model (DEM) based on the TCC 2019 LiDAR data. It is noted that DEM levels within building footprints are interpolated from LiDAR levels surrounding building footprints when creating the DEM (because above-ground features such as buildings have been removed from the processed DEM).

Minimum DEM level was chosen as the basis for the inferred floor levels as actual minimum floor levels of a building were considered to more likely to correlate with the ground level of the downslope side of a building. This is demonstrated in the example in Figure 2 below.

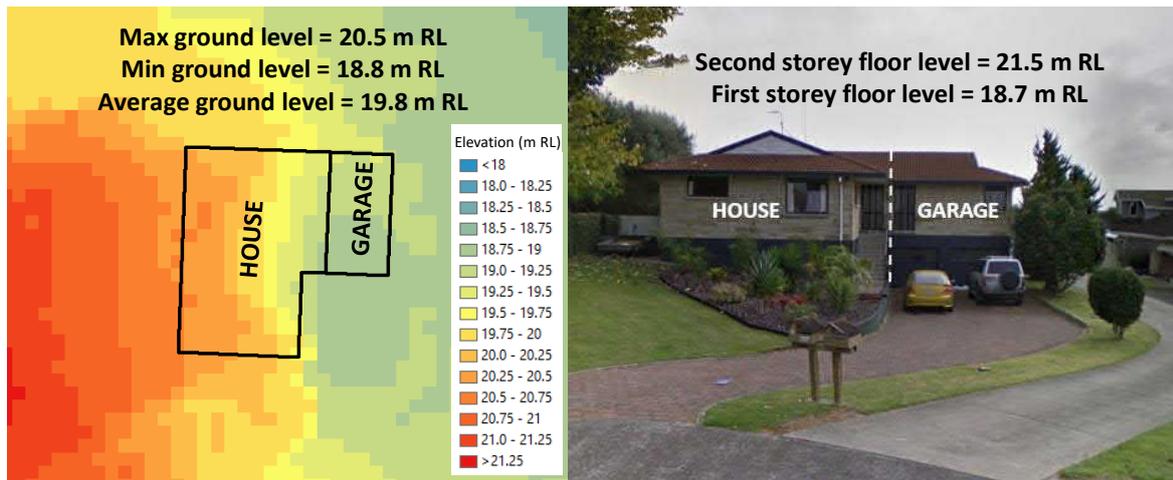


Figure 2: Example of surveyed floor levels and DEM levels for a house on a slope

Comparing minimum underlying DEM level with surveyed floor levels for each building type resulted in a spread of observed floor level offsets centred about an average. This is illustrated in the histograms of floor level offsets included as Figure 3 to Figure 8 below. Table 1 below presents the median floor level offset for each building type. Generally buildings on piles were approximately 800 mm above minimum DEM level while buildings on concrete foundations were approximately 200-300 mm above minimum DEM level. Garages were generally only 130 mm above minimum DEM level.

**Table 1: Median floor level offsets by building type**

Building type (with foundation type)	Number of surveyed buildings	Median floor level offset (mm) (from minimum LiDAR level)
Dwelling (piles)	2971	820
Dwelling (concrete)	4064	250
Garage (concrete)	5252	130
Commercial (concrete)	1072	240
Commercial (piles)	101	760
Industrial (concrete)	376	200

Based on this data floor levels for all unsurveyed buildings was inferred by adding a 150 mm offset to the minimum underlying DEM level. This value is primarily based on the observed floor level offset for garages due to fact that the majority of dwellings in Tauranga have attached garages, even in older parts of Tauranga. For this study if an attached garage is inundated in a natural hazard event then the entire dwelling is considered functionally compromised, therefore this offset best represents the level at which attached garages (and therefore dwellings) will first become inundated. This assumed floor level also correlates well with the observed floor levels offset for all buildings with concrete floors (residential, commercial and industrial). This assumption is slightly conservative especially for dwellings that are on piles with no attached garage. However from the data available it appears these cases are relatively rare, especially in areas of Tauranga developed after 1980-1990 which compromise a large proportion of the city.

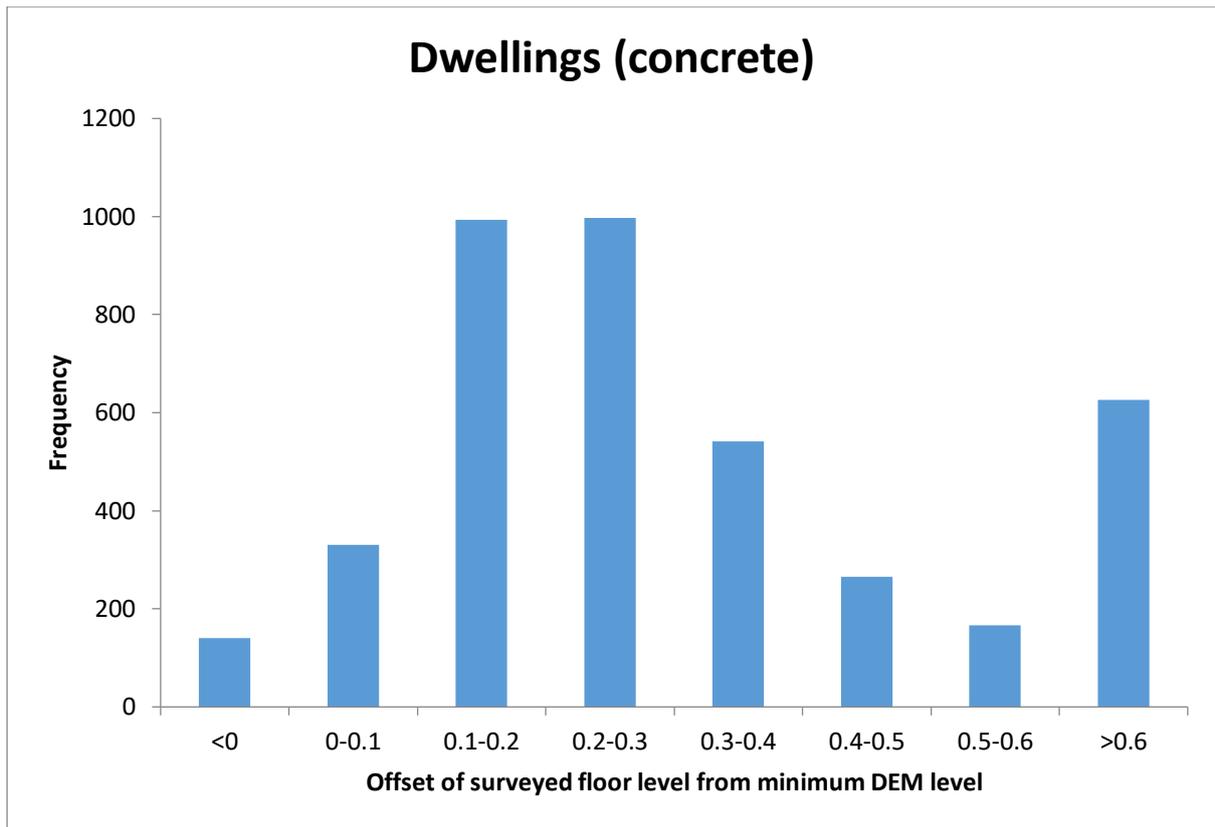


Figure 3: Offset of surveyed floor level from minimum DEM level – Dwellings on concrete foundations

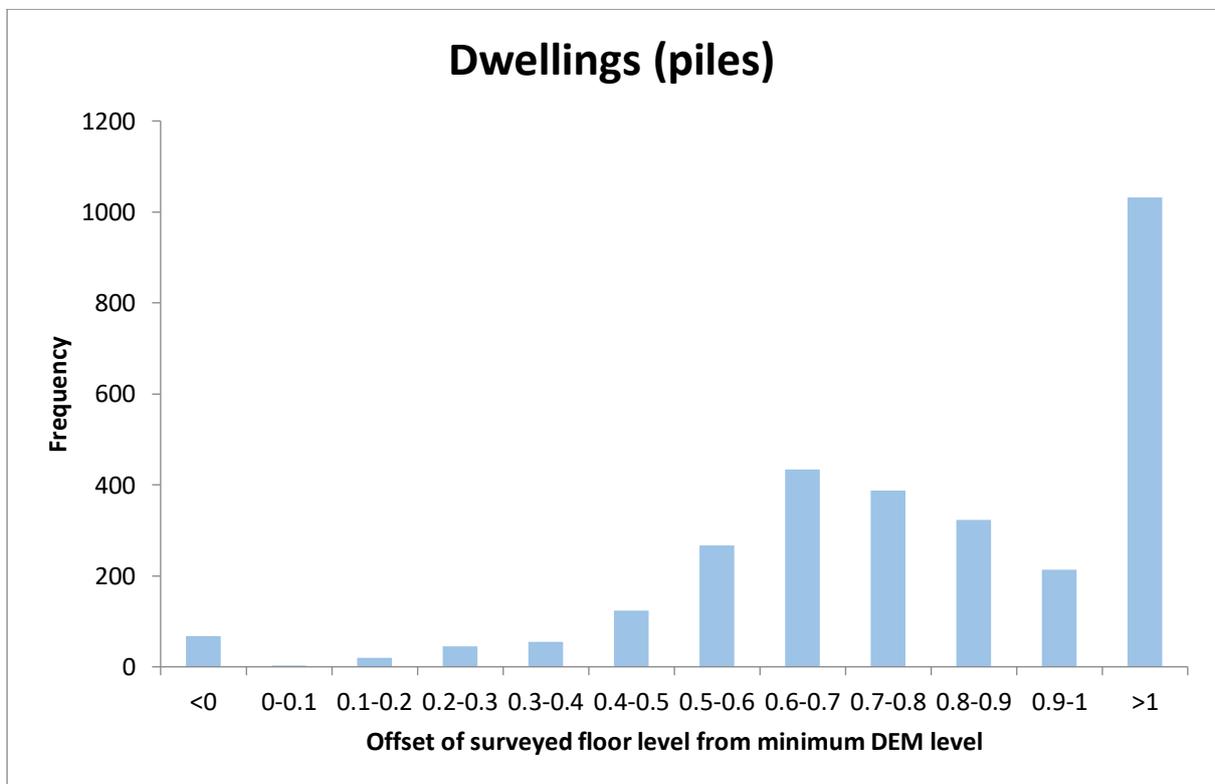


Figure 4: Offset of surveyed floor level from minimum DEM level – Dwellings on piled foundations

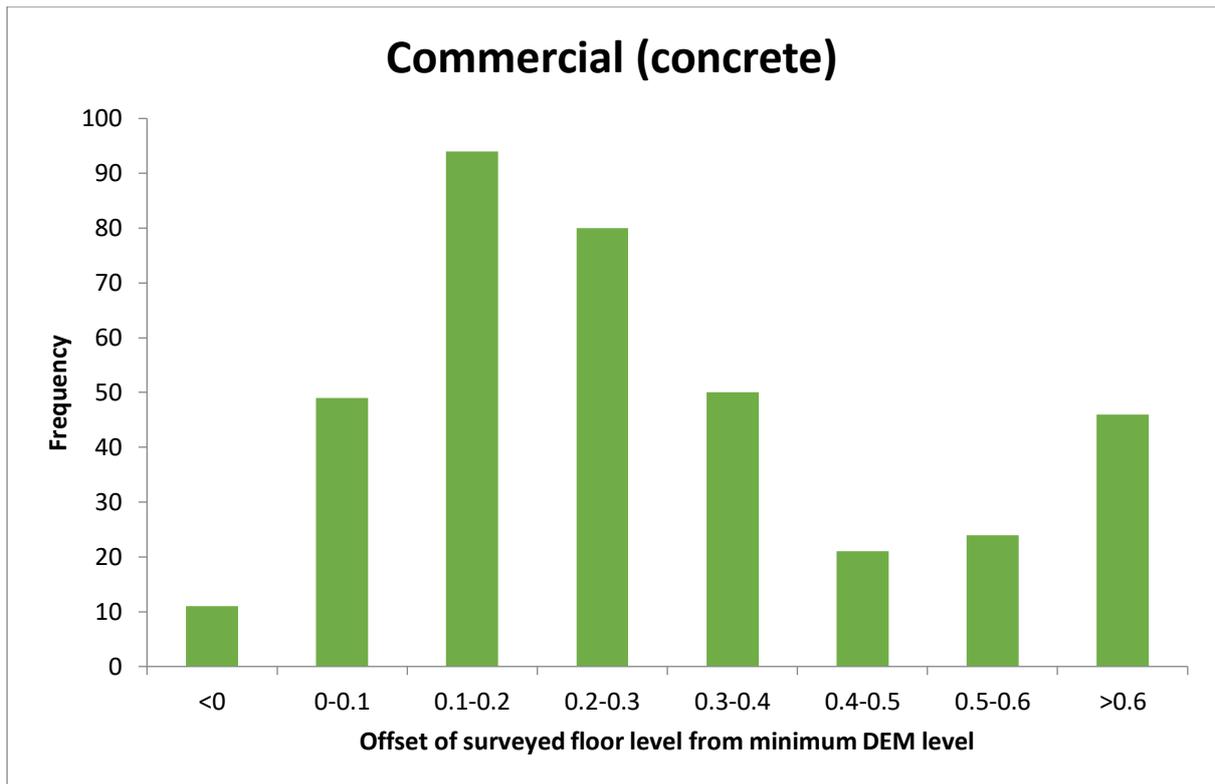


Figure 5: Offset of surveyed floor level from minimum DEM level – Commercial buildings on concrete foundations

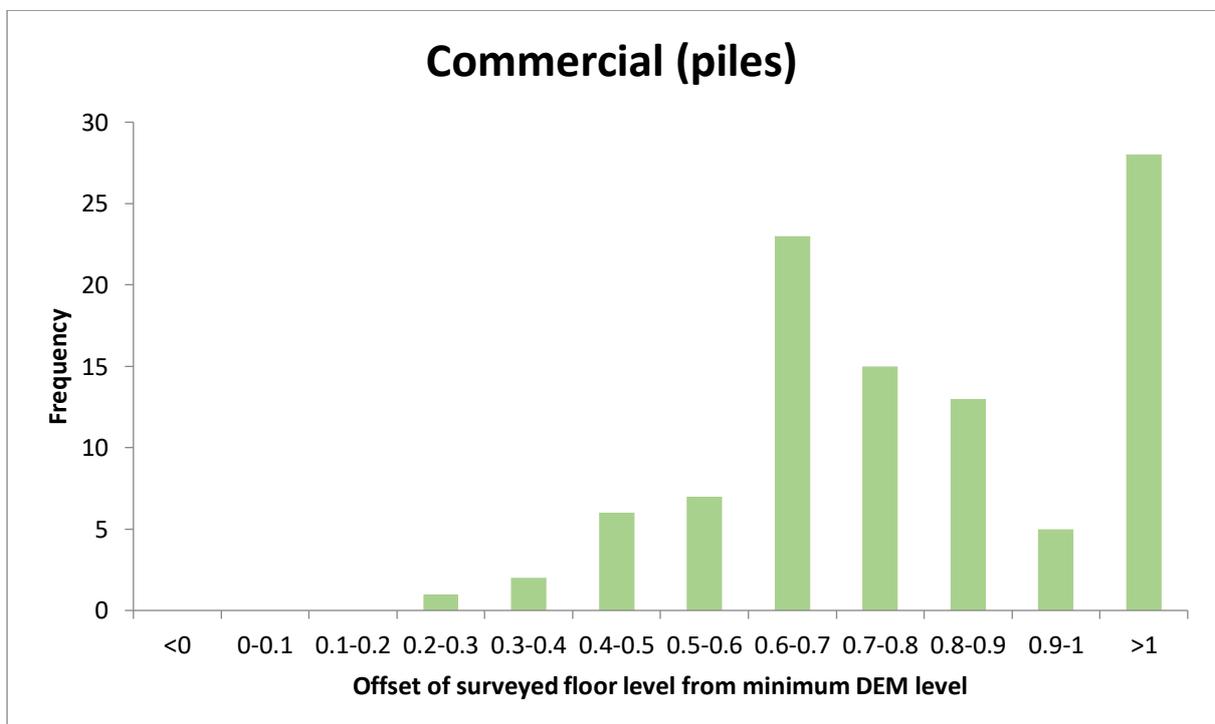


Figure 6: Offset of surveyed floor level from minimum DEM level – Commercial buildings on piled foundations

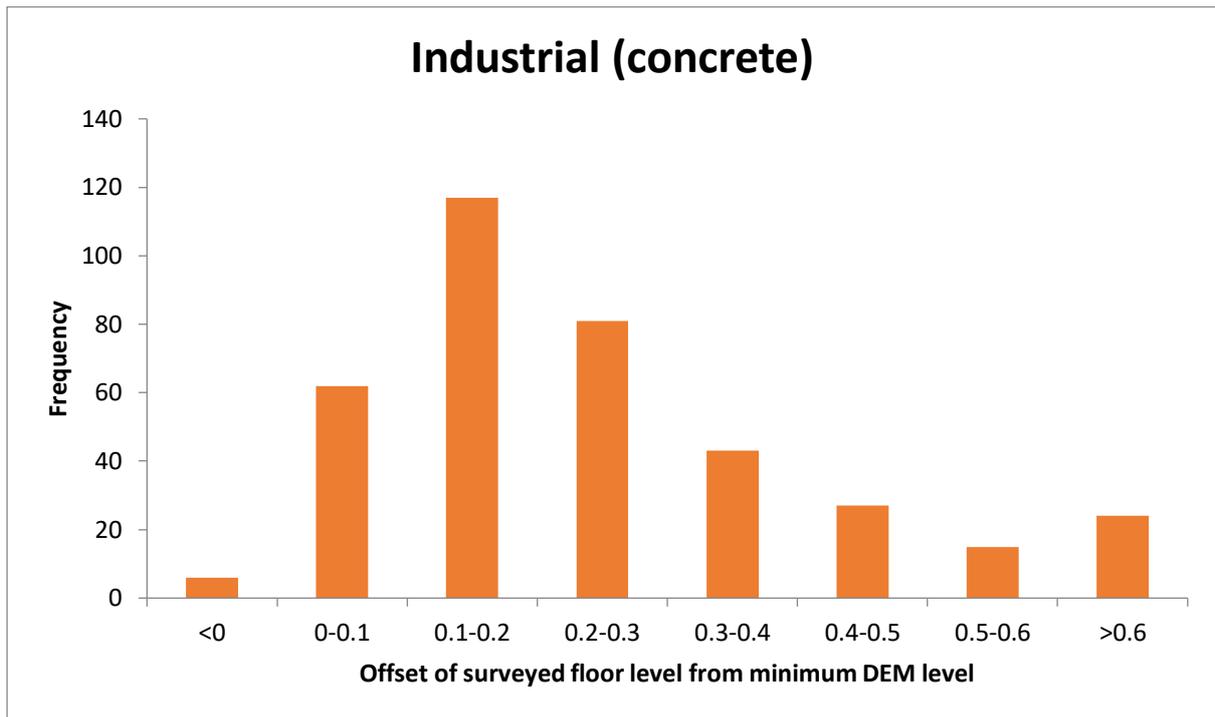


Figure 7: Offset of surveyed floor level from minimum DEM level – Industrial buildings on concrete foundations

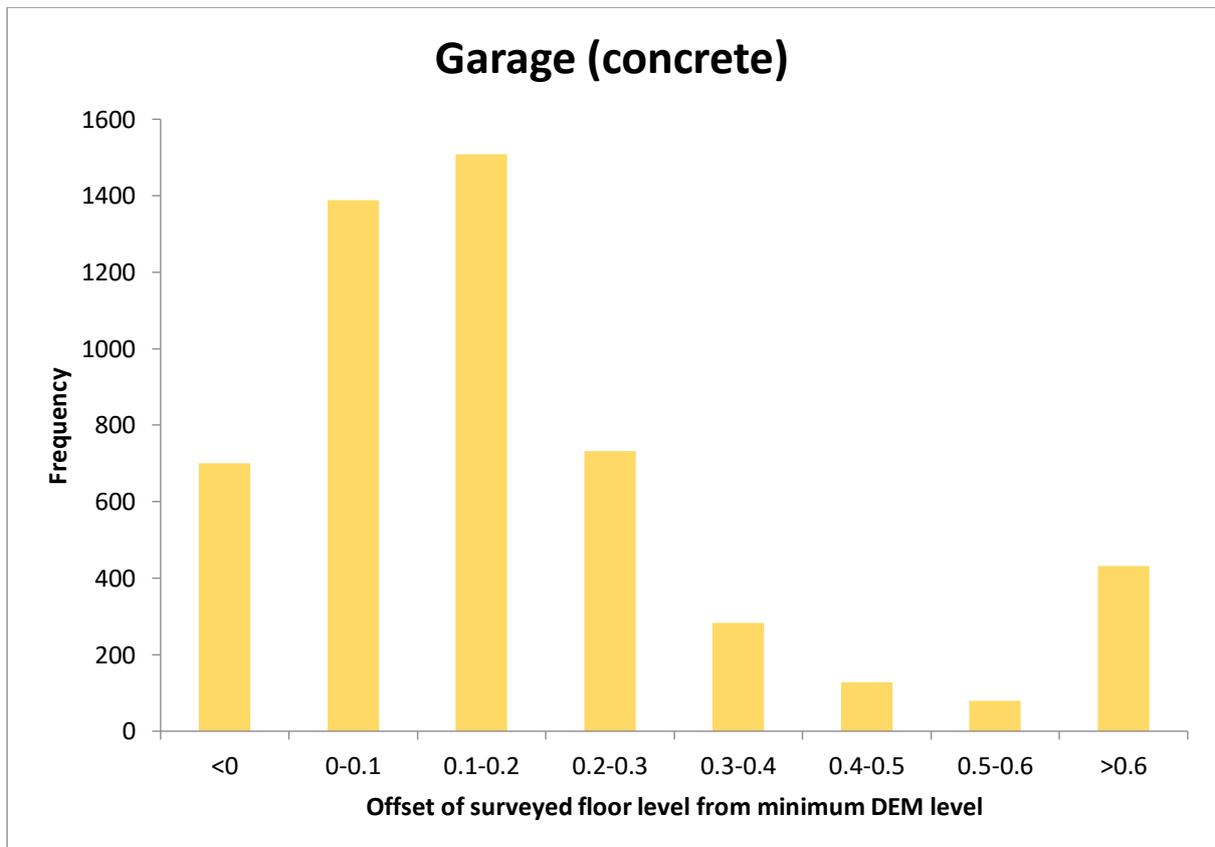
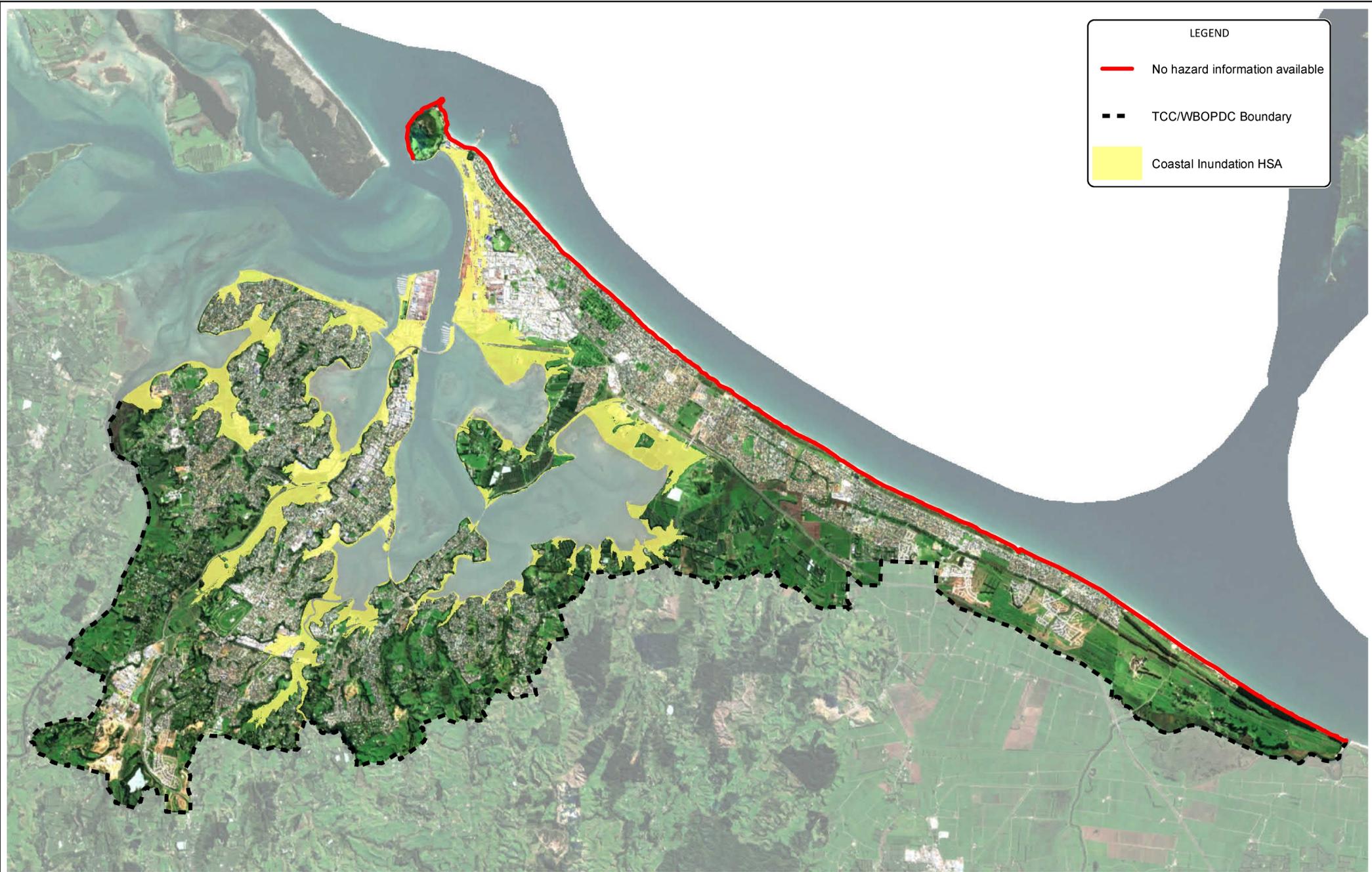


Figure 8: Offset of surveyed floor level from minimum DEM level – Garages on concrete foundations

## **Appendix B: Hazard maps**

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- **Figure B1 – Coastal Inundation HSA**
- **Figure B2 – Coastal Inundation (2% AEP)**
- **Figure B3 – Coastal Inundation (1% AEP)**
- **Figure B4 – Coastal Inundation (0.2% AEP)**
- **Figure B5 – Coastal Erosion HSA**
- **Figure B6 – Coastal Erosion (P66% Scenario)**
- **Figure B7 – Coastal Erosion (P5% Scenario)**
- **Figure B8 – Tsunami HSA**
- **Figure B9 – Tsunami (0.2% AEP)**
- **Figure B10 – Tsunami (0.1% AEP)**
- **Figure B11 – Tsunami (0.04% AEP)**
- **Figure B12 – High Groundwater HSA**
- **Figure B13 – High Groundwater (95<sup>th</sup> Percentile)**
- **Figure B14 – Liquefaction and Lateral Spread HSA**
- **Figure B15 – Slope Instability HSA**
- **Figure B16 – Rainfall Induced Flooding HSA**
- **Figure B17 – Rainfall Induced Flooding (2% AEP)**
- **Figure B18 – Rainfall Induced Flooding (1% AEP)**
- **Figure B19 – Rainfall Induced Flooding (0.2% AEP)**

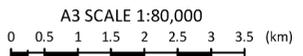


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- Coastal Inundation HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for coastal inundation is based on the 0.2% AEP, 2130 event. Refer NIWA's report 'Tauranga Harbour Inundation Modelling' dated June 2019 (NIWA report no: 2018269HN) for further information.  
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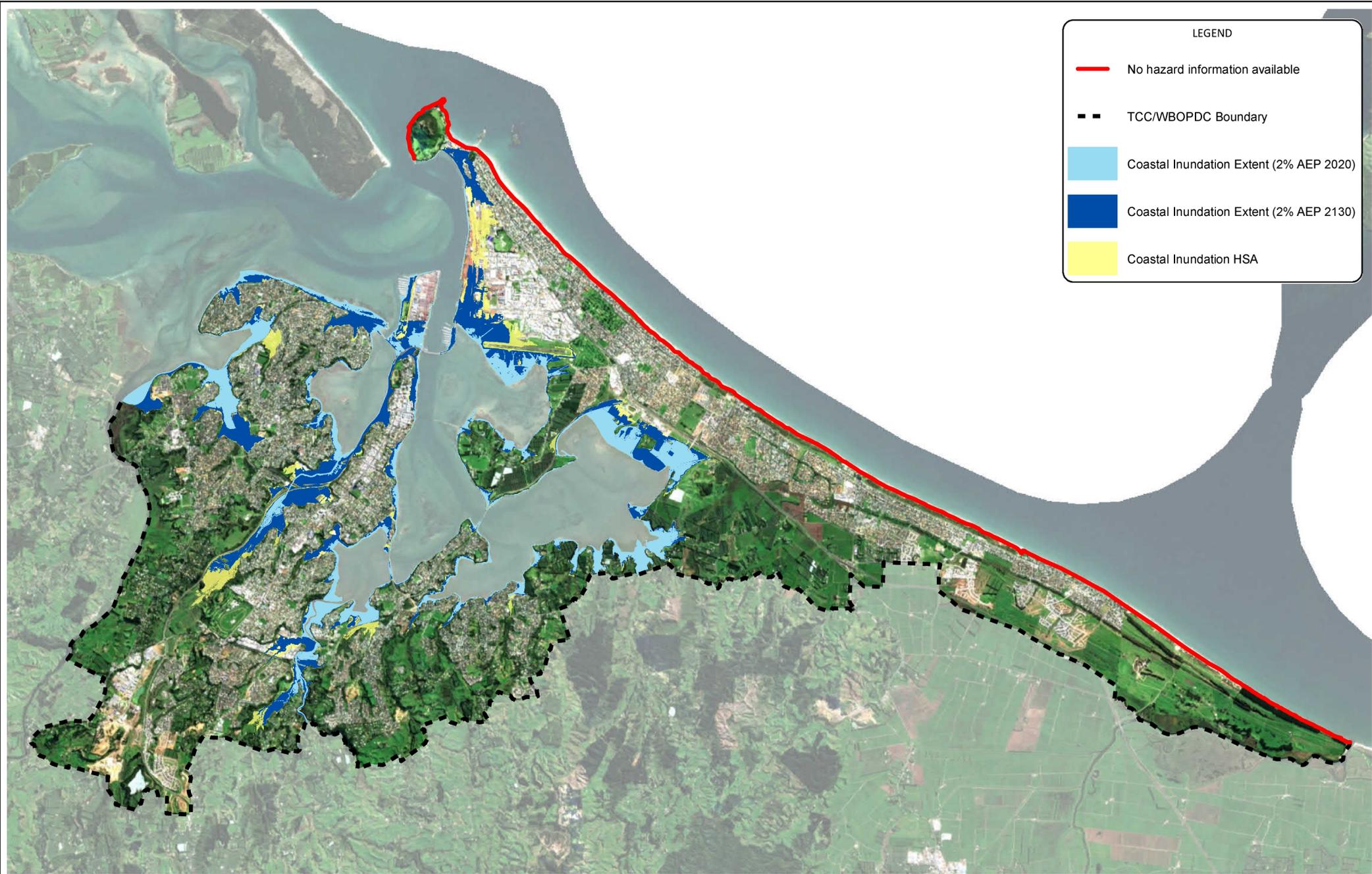


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**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**  
 Coastal Inundation HSA

FIGURE No. **Figure B1** Rev. **0**

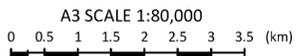


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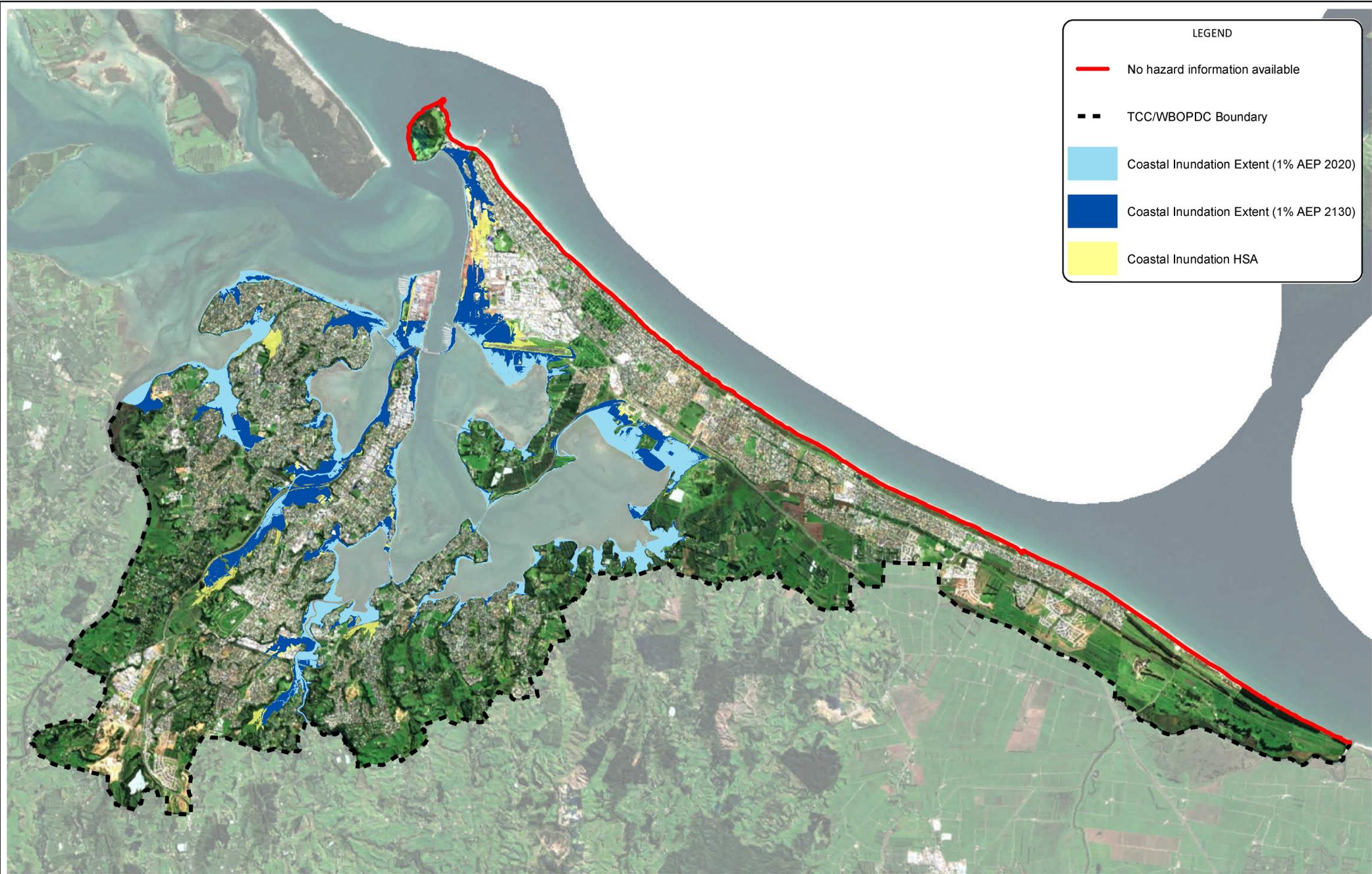
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 Coastal Inundation (2% AEP)

FIGURE No. **Figure B2** Rev. **0**

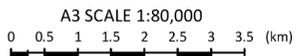
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- Coastal Inundation Extent (1% AEP 2130)
- Coastal Inundation HSA

**Notes:**  
 -Hazard susceptibility area (HSA) for coastal inundation is based on the 0.2% AEP, 2130 event. Refer NIWA's report 'Tauranga Harbour Inundation Modelling' dated June 2019 (NIWA report no: 2018269HN) for further information.  
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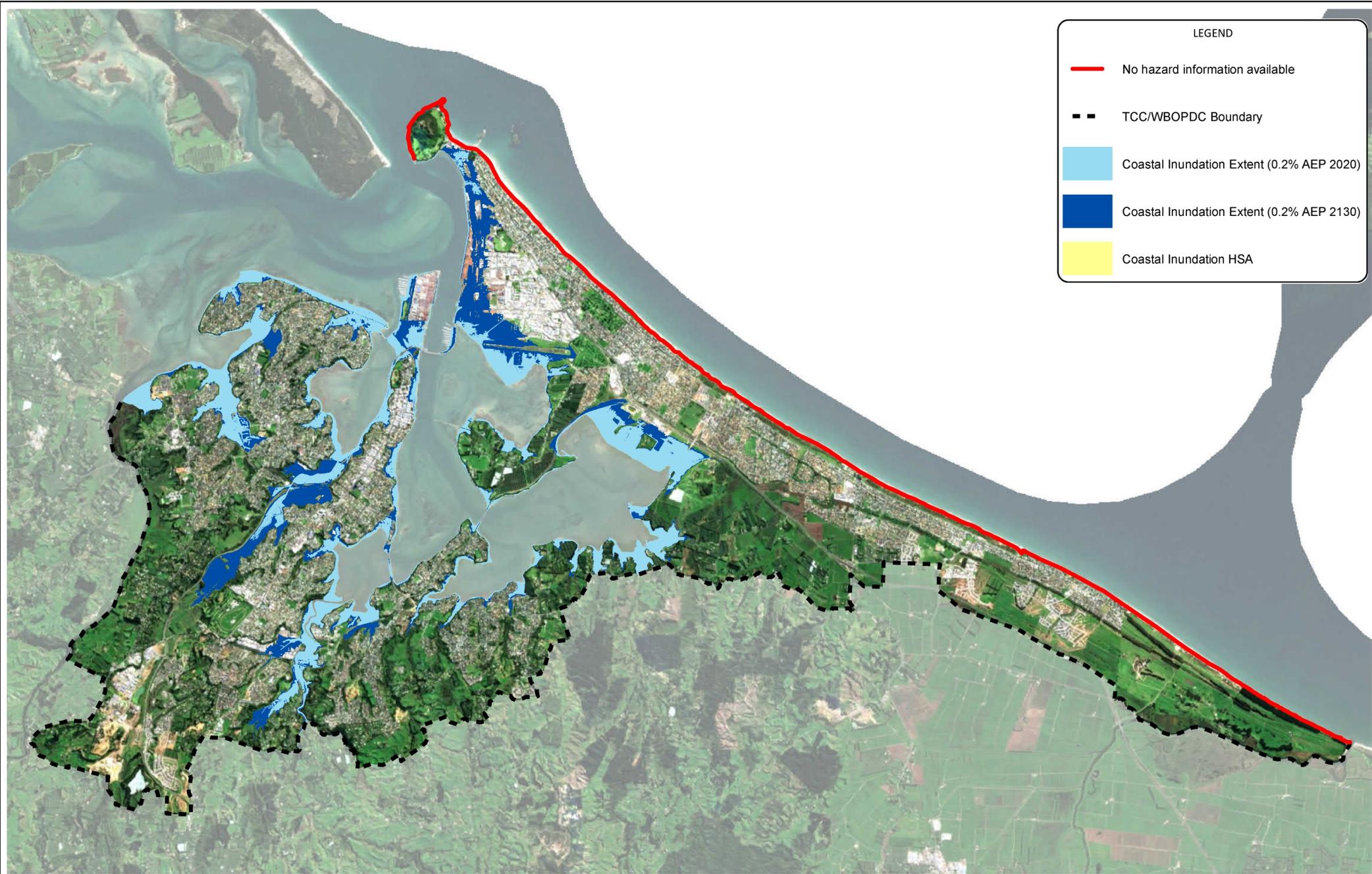
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 Coastal Inundation (1% AEP)

FIGURE No. **Figure B3**

Rev. **0**

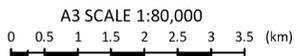


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 Coastal Inundation (0.2% AEP)

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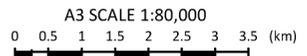
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**LEGEND**

- TCC/WBOPDC Boundary
- Coastal Erosion HSA

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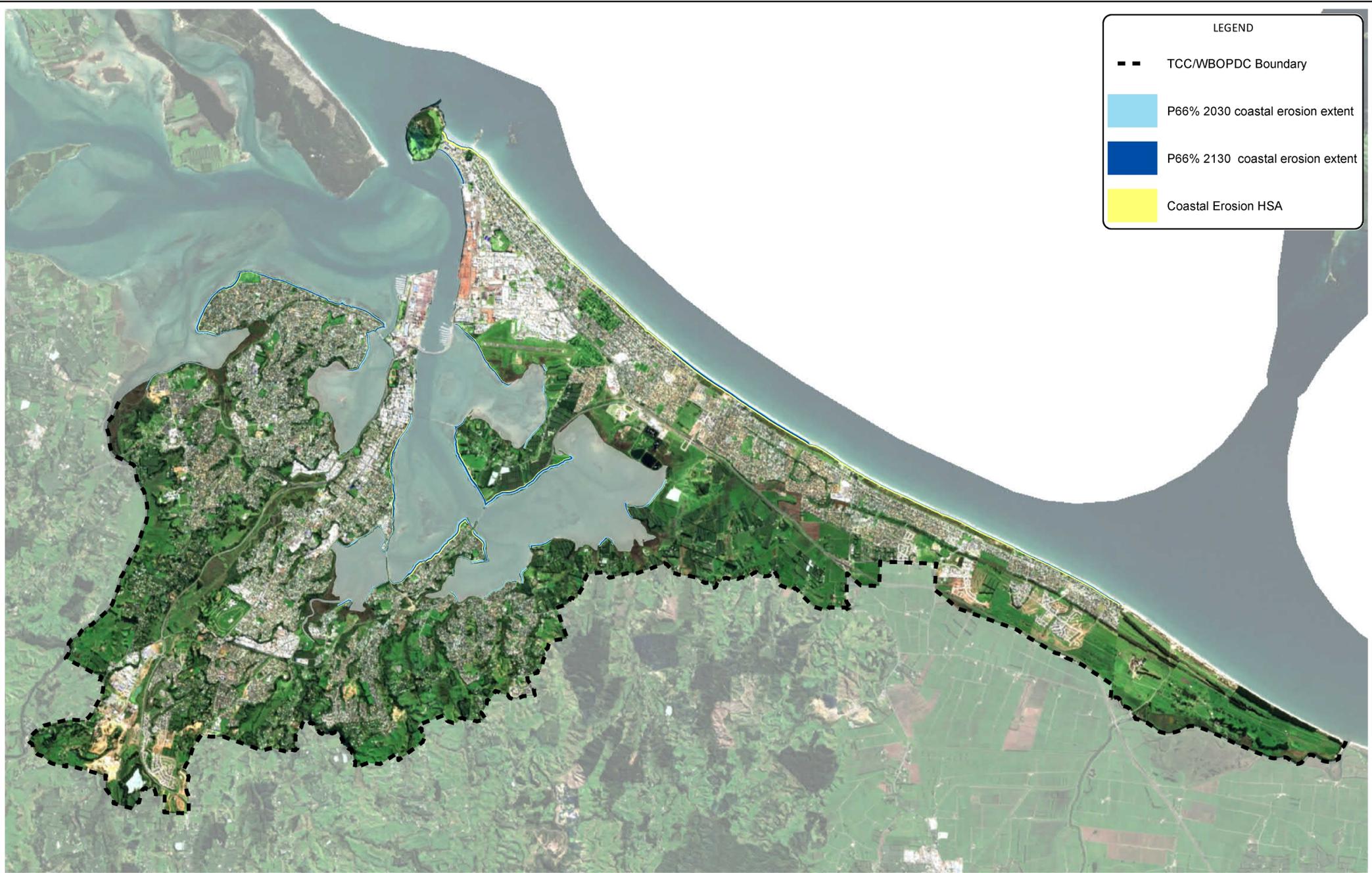
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 Coastal Erosion (HSA) - Inner Harbour and Open Coast

FIGURE No. **Figure B5**

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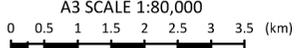
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-  P66% 2130 coastal erosion extent
-  Coastal Erosion HSA

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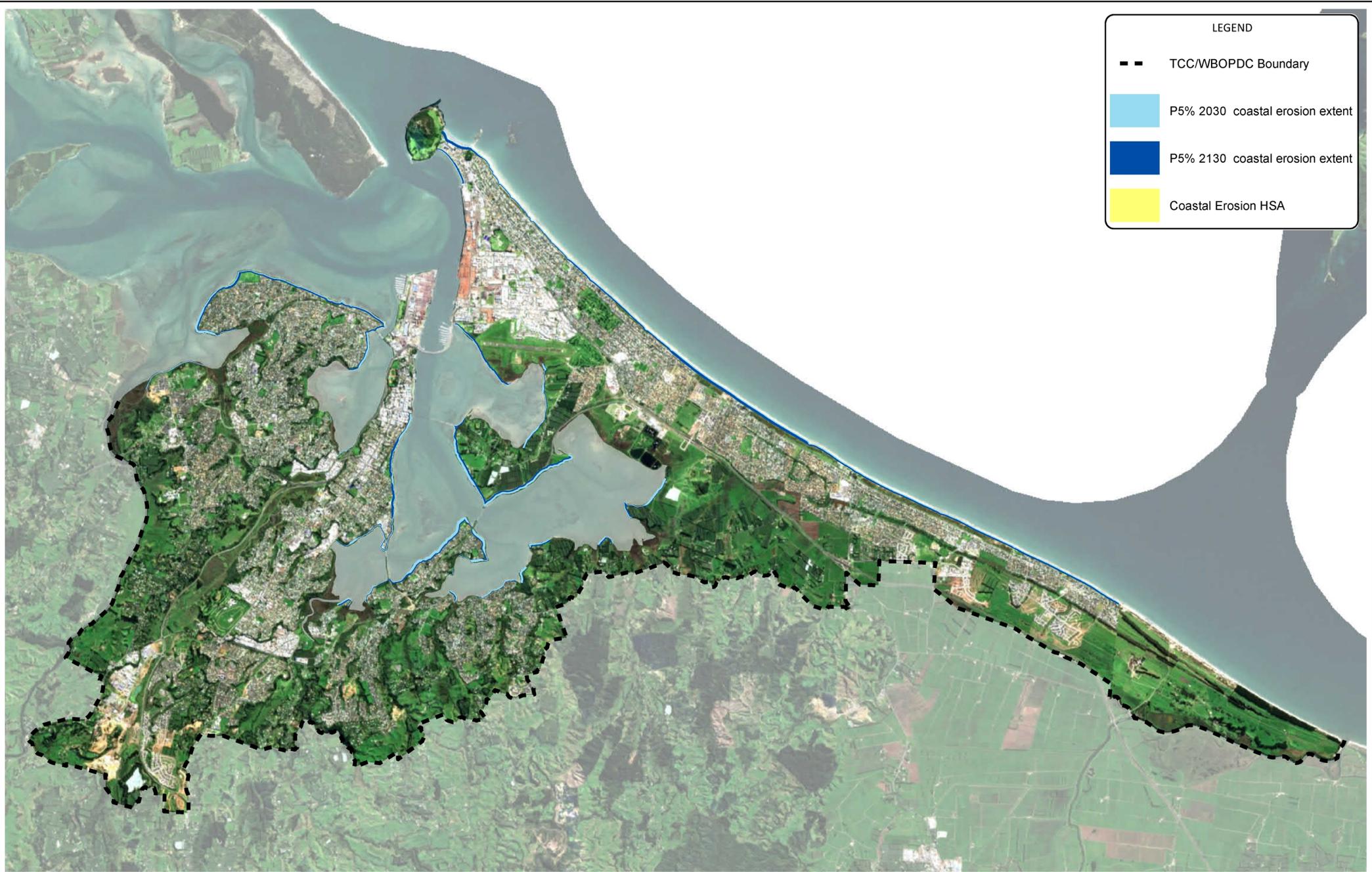
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 Coastal Erosion (P66% Scenario) -  
 Inner Harbour and Open Coast

FIGURE No. **Figure B6** Rev. **0**

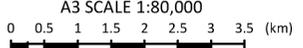
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**LEGEND**

-  TCC/WBOPDC Boundary
-  P5% 2030 coastal erosion extent
-  P5% 2130 coastal erosion extent
-  Coastal Erosion HSA

**Notes:**  
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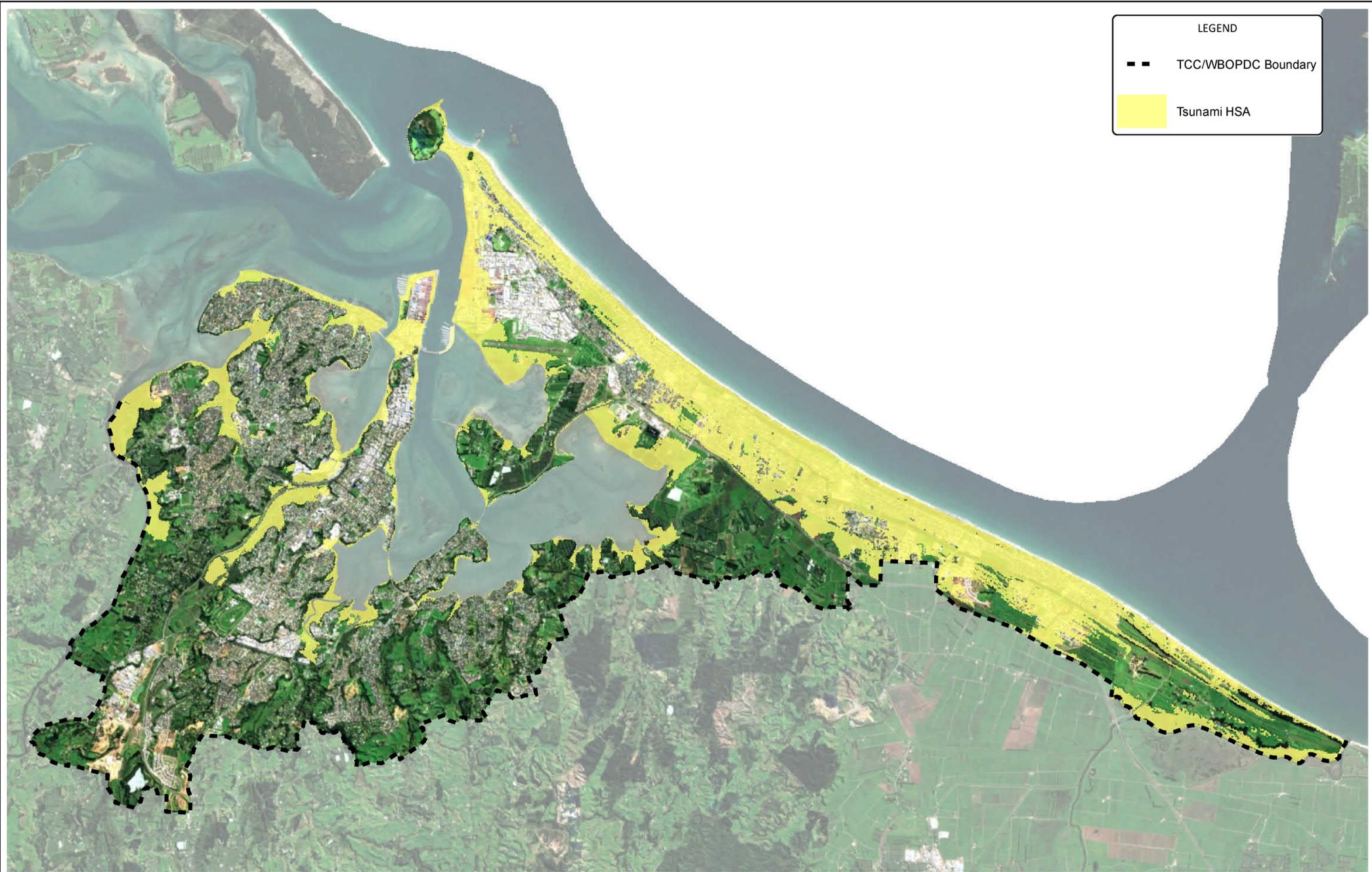



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 TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT  
 Coastal Erosion (P5% Scenario) -  
 Inner Harbour and Open Coast

FIGURE No. **Figure B7** Rev. **0**

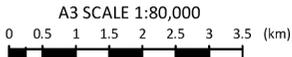


LEGEND

- TCC/WBOPDC Boundary
- Tsunami HSA

Path: T:\Tauranga\Projects\1008440\WorkingMaterial\Reporting\HSA\_maps\Tsunami\Tsunami\_HSA.mxd Date: 13/01/2020 Time: 12:34:52 PM

**Notes:**  
 -Hazard susceptibility area (HSA) for tsunami is based on the 2130 maximum credible event. Refer T+T's report 'Tauranga Tsunami Inundation Modelling' dated Nov 2013 (T+T Ref 28757.v4) for more information.  
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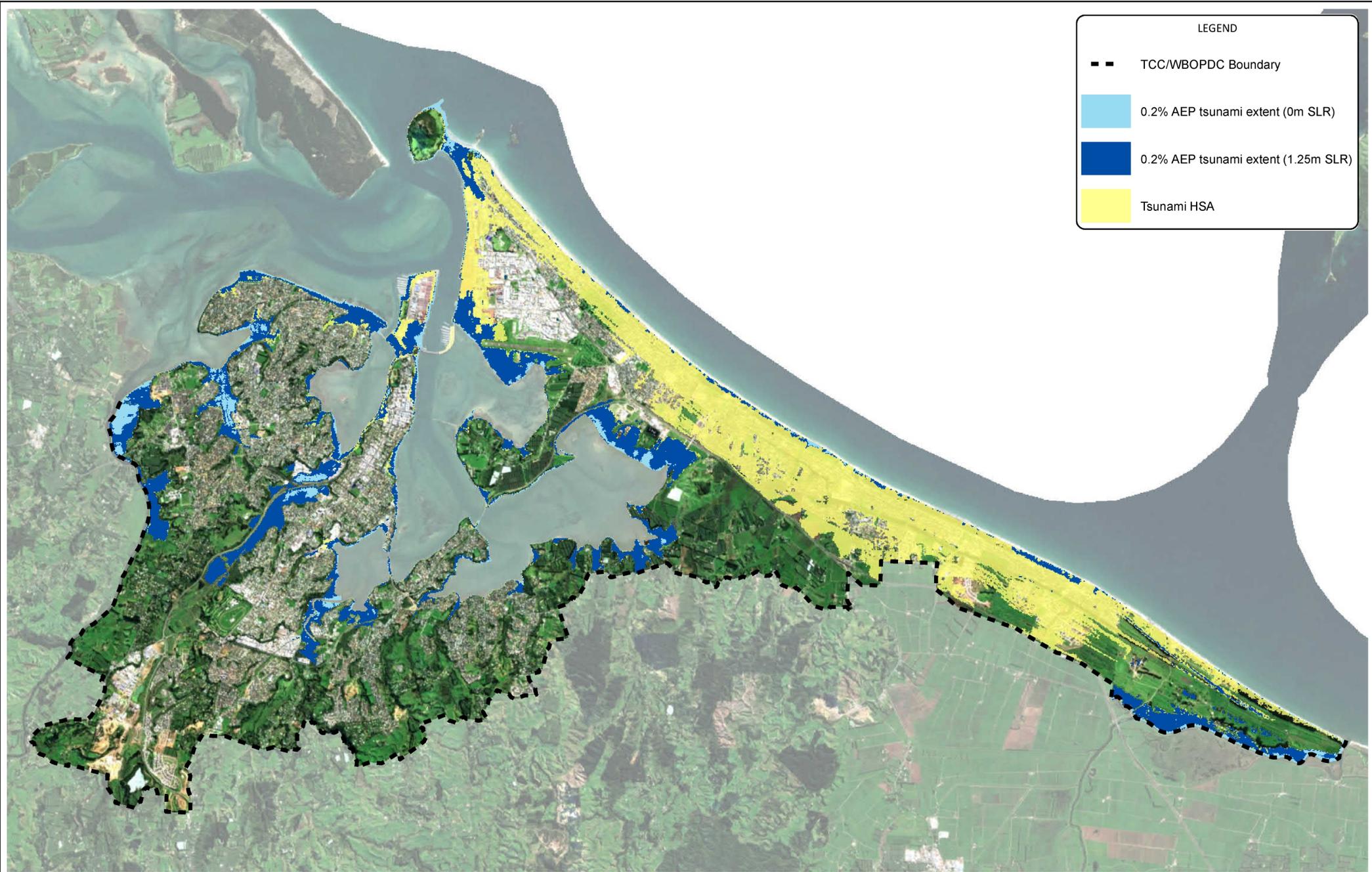


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**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**  
 Tsunami HSA

FIGURE No. **Figure B8** Rev. **0**

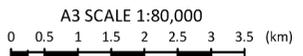


LEGEND

- TCC/WBOPDC Boundary
- 0.2% AEP tsunami extent (0m SLR)
- 0.2% AEP tsunami extent (1.25m SLR)
- Tsunami HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for tsunami is based on the 2130 maximum credible event. Refer T+T's report 'Tauranga Tsunami Inundation Modelling' dated Nov 2013 (T+T Ref 28757.v4) for more information.  
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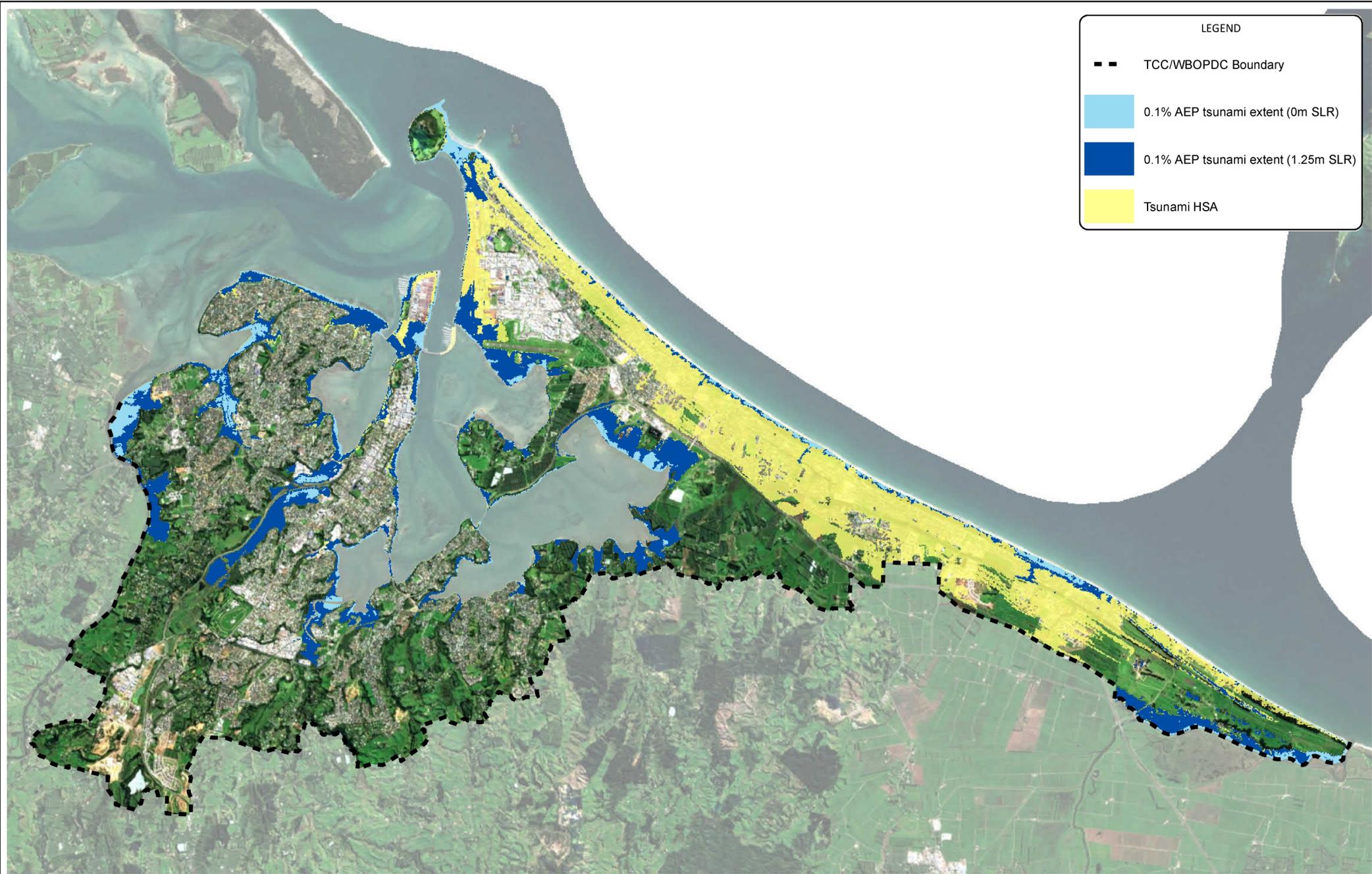


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**TAURANGA CITY COUNCIL**  
**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**  
 Tsunami (0.2% AEP)

FIGURE No. **Figure B9** Rev. **0**

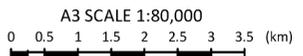


LEGEND

- TCC/WBOPDC Boundary
- 0.1% AEP tsunami extent (0m SLR)
- 0.1% AEP tsunami extent (1.25m SLR)
- Tsunami HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for tsunami is based on the 2130 maximum credible event. Refer T+T's report 'Tauranga Tsunami Inundation Modelling' dated Nov 2013 (T+T Ref 28757.v4) for more information.  
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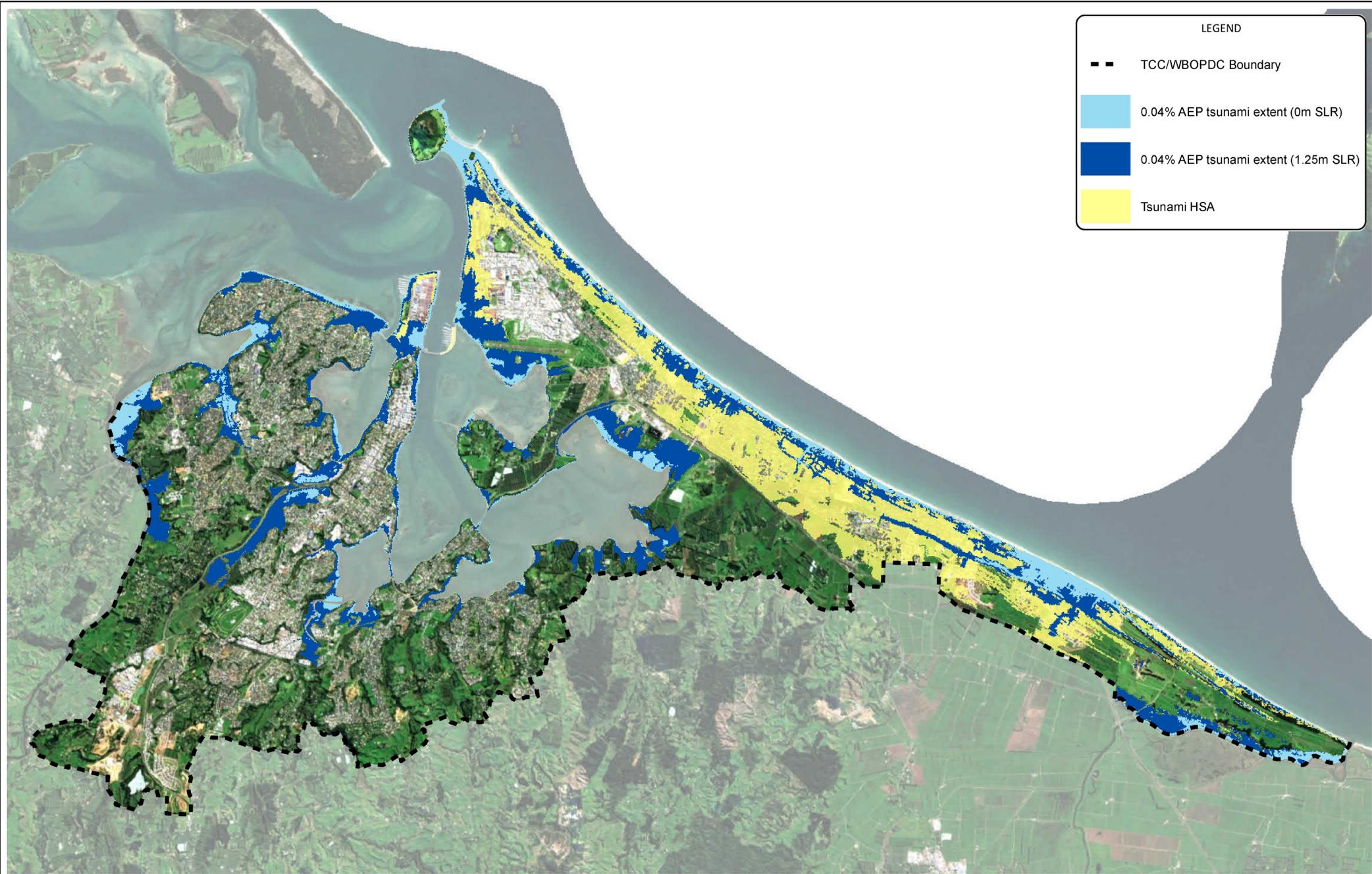


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PROJECT No.	1008440.3000

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**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**  
 Tsunami (0.1% AEP)

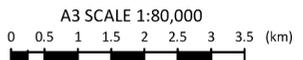
FIGURE No. **Figure B10** Rev. **0**



**LEGEND**

- TCC/WBOPDC Boundary
- 0.04% AEP tsunami extent (0m SLR)
- 0.04% AEP tsunami extent (1.25m SLR)
- Tsunami HSA

**Notes:**  
 -Hazard susceptibility area (HSA) for tsunami is based on the 2130 maximum credible event. Refer T+T's report 'Tauranga Tsunami Inundation Modelling' dated Nov 2013 (T+T Ref 28757.v4) for more information.  
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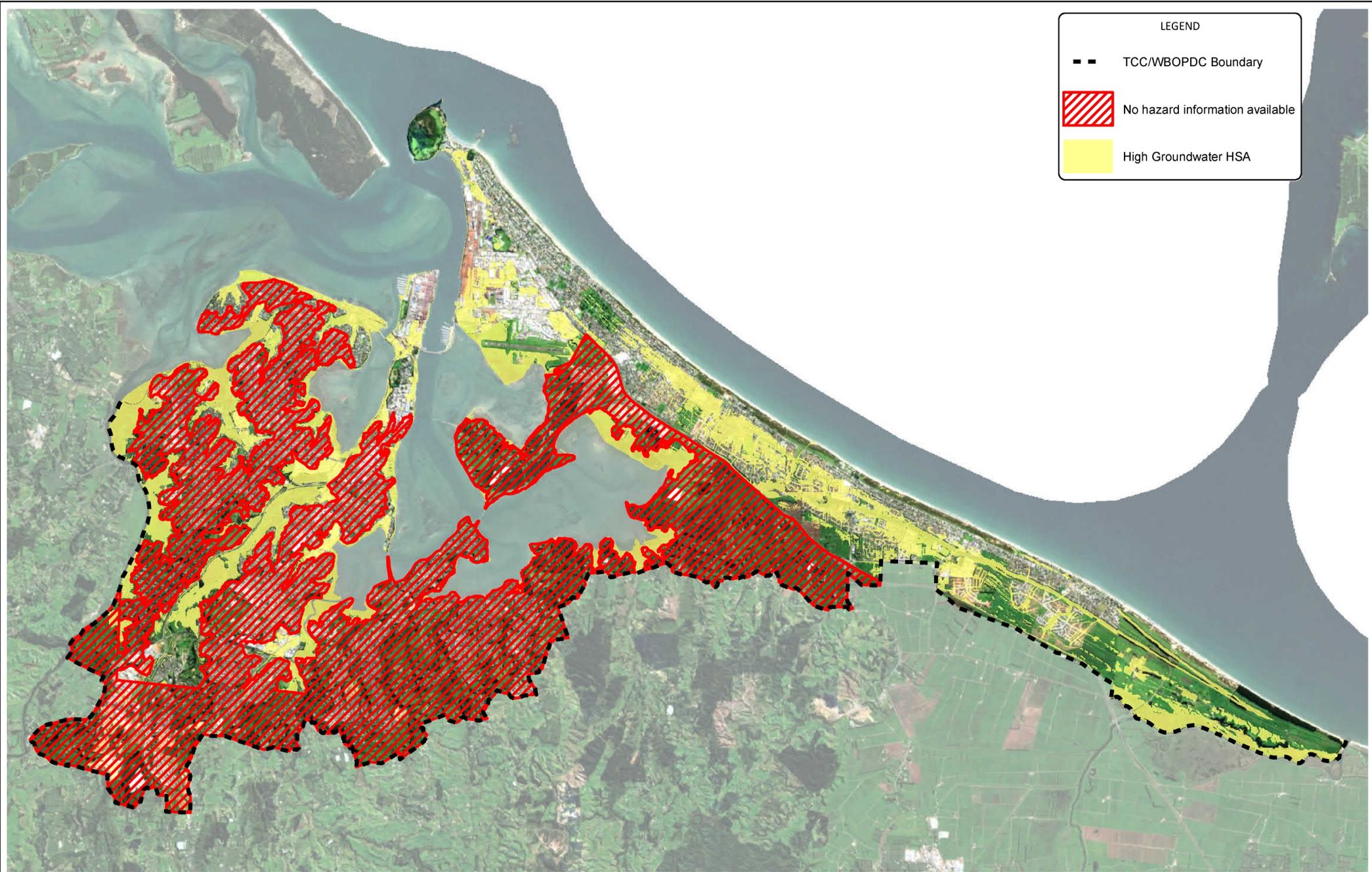
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PROJECT No.	1008440.3000

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 Tsunami (0.04% AEP)

FIGURE No. **Figure B11**      Rev. **0**

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LEGEND

- TCC/WBOPDC Boundary
- No hazard information available
- High Groundwater HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for high groundwater is based on the 95<sup>th</sup> percentile, 2130 groundwater level. Refer T+T's report 'Tauranga Groundwater Monitoring – June 2017 results' dated September 2017 (T+T ref 30485.004) for more information.  
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A3 SCALE 1:80,000



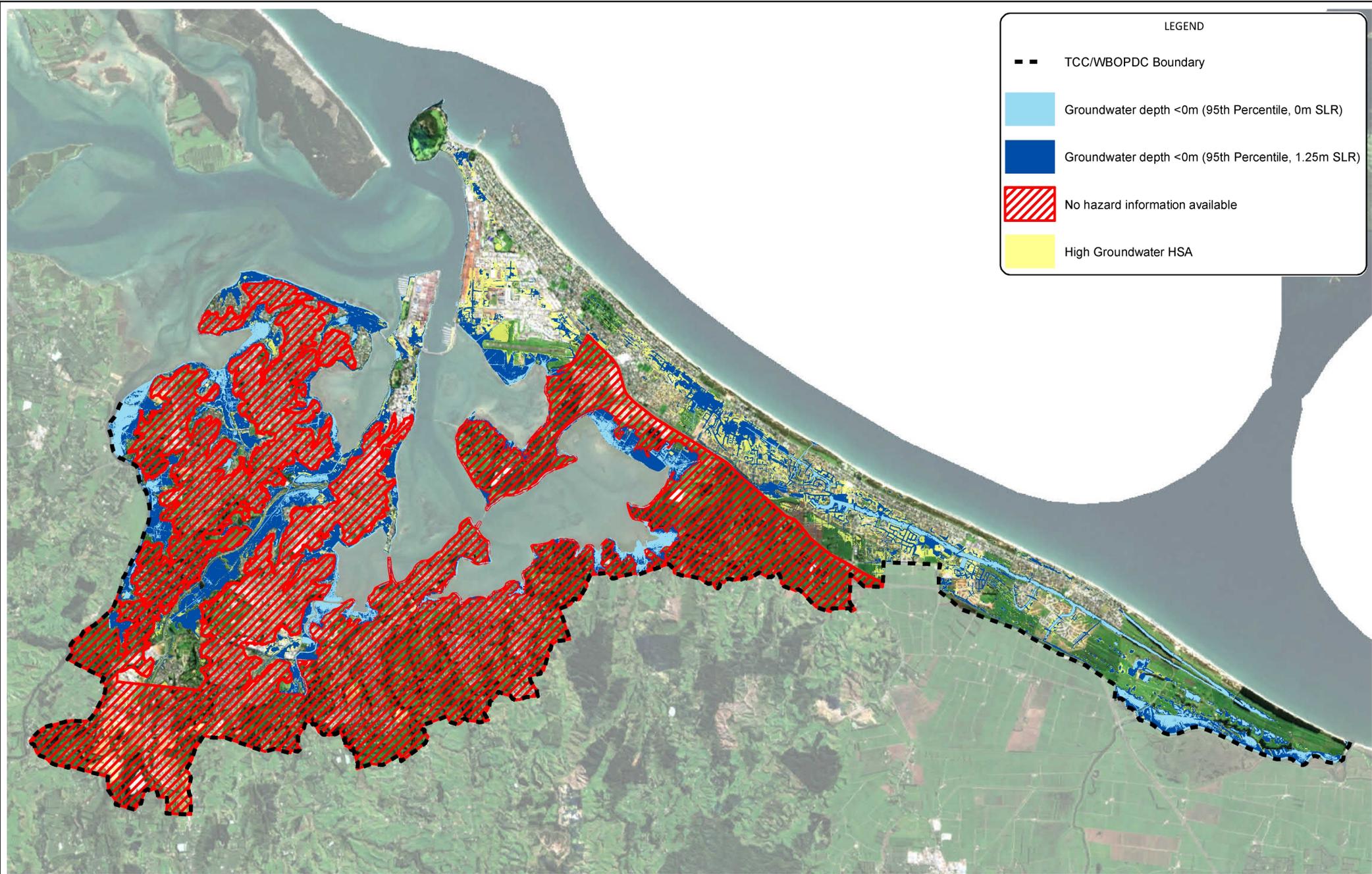
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SCALE (AT A3 SIZE)	1:80,000
PROJECT No.	1008440.3000

**TAURANGA CITY COUNCIL**  
 TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT  
 High Groundwater HSA

FIGURE No. **Figure B12**

Rev. **0**



LEGEND

- TCC/WBOPDC Boundary
- Groundwater depth <0m (95th Percentile, 0m SLR)
- Groundwater depth <0m (95th Percentile, 1.25m SLR)
- No hazard information available
- High Groundwater HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for high groundwater is based on the 95<sup>th</sup> percentile, 2130 groundwater level. Refer T+T's report 'Tauranga Groundwater Monitoring – June 2017 results' dated September 2017 (T+T ref 30485.004) for more information.  
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A3 SCALE 1:80,000

0 0.5 1 1.5 2 2.5 3 3.5 (km)



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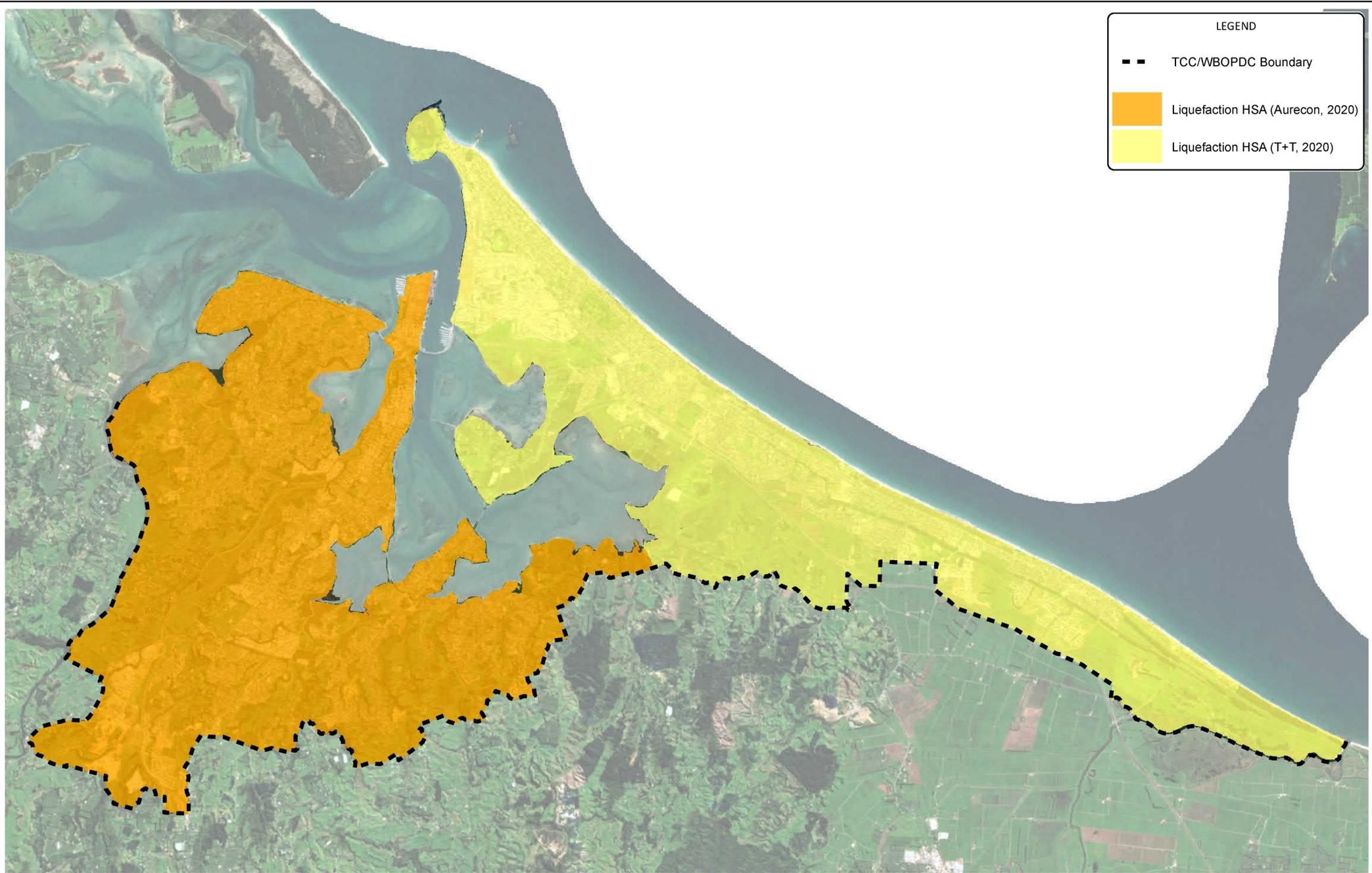
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**TAURANGA CITY COUNCIL**  
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 High Groundwater (95th Percentile)

FIGURE No. **Figure B13**

Rev. **0**

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LEGEND

- TCC/WBOPDC Boundary
- Orange Liquefaction HSA (Aurecon, 2020)
- Yellow Liquefaction HSA (T+T, 2020)

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 TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT  
 Liquefaction and Lateral Spread HSA

FIGURE No. Figure B14

Rev. 1

LEGEND

- TCC/WBOPDC Boundary
- Slope Instability HSA



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**Notes:**  
 -Hazard susceptibility area (HSA) for slope instability is based on slope geometry as described in T+T's report 'Tauranga City-wide Natural Hazards Risk Assessment' dated July 2019.  
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A3 SCALE 1:80,000  
 0 0.5 1 1.5 2 2.5 3 3.5 (km)



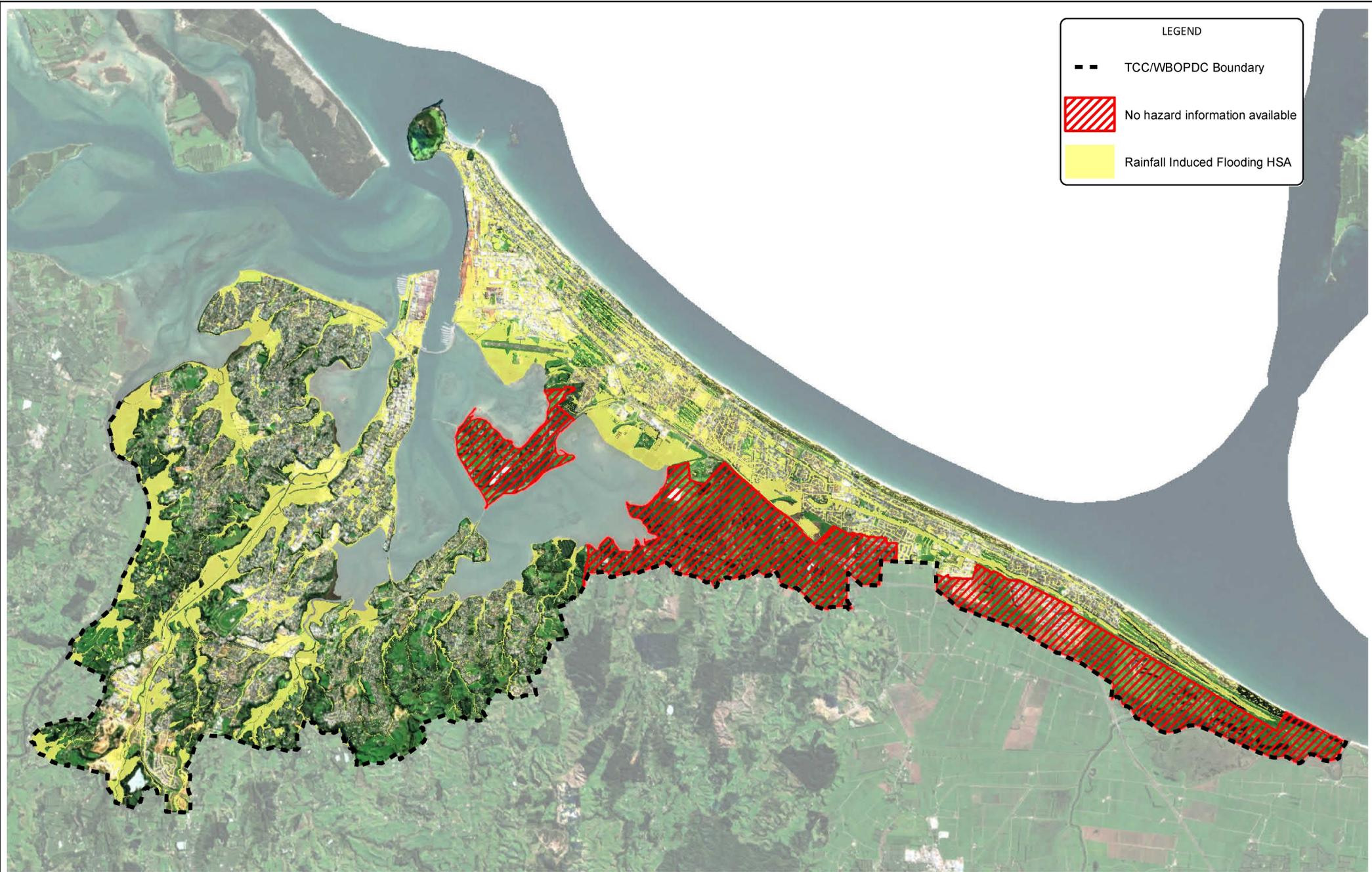
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 Slope Instability HSA

FIGURE No. **Figure B15**

Rev. **0**



LEGEND

- TCC/WBOPDC Boundary
- No hazard information available
- Rainfall Induced Flooding HSA

Path: T:\Tauranga\Projects\1008440\2000\WorkingMaterial\Reporting\HSA\_maps\Flooding\Rainfall\Flooding\_HSA.mxd Date: 13/01/2020 Time: 11:57:18 AM

**Notes:**  
 -Hazard susceptibility area (HSA) for rainfall induced flooding is based on the 0.2% AEP, 2130 event. Refer AWA's report "Tauranga City Flood Risk Assessment: Application of Bay of Plenty Regional Policy Statement Methodology for Risk Assessment TOC11/18" dated Dec 2018 (Doc Number: TOC000156.CD-355 v1.1) for more information.  
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A3 SCALE 1:80,000

0 0.5 1 1.5 2 2.5 3 3.5 (km)

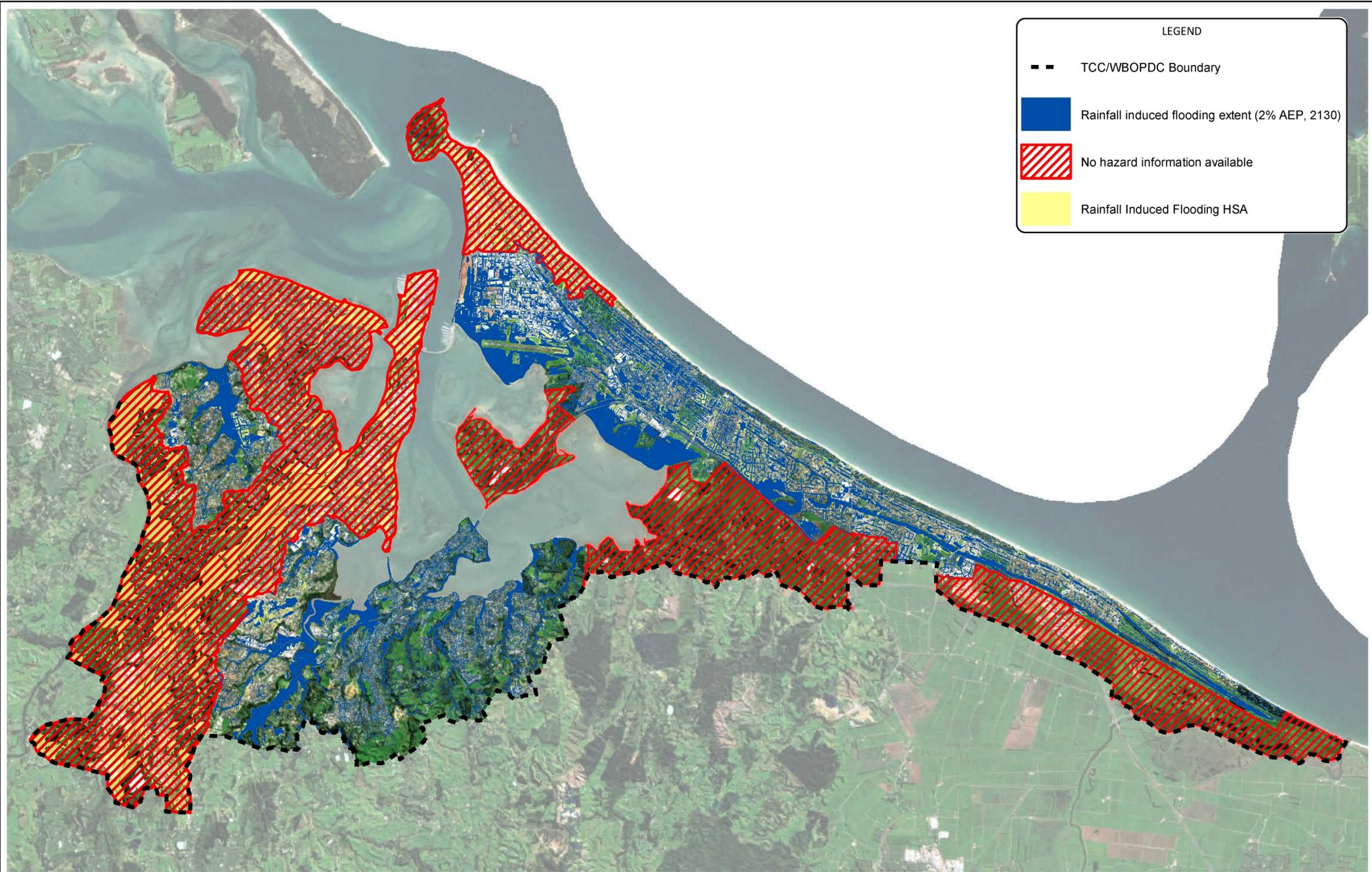


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SCALE (AT A3 SIZE)	1:80,000
PROJECT No.	1008440.3000

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 TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT  
 Rainfall Induced Flooding (HSA)

FIGURE No. **Figure B16** Rev. 0



LEGEND

- TCC/WBOPDC Boundary
- Rainfall induced flooding extent (2% AEP, 2130)
- No hazard information available
- Rainfall Induced Flooding HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for rainfall induced flooding is based on the 0.2% AEP, 2130 event. Refer AWA's report "Tauranga City Flood Risk Assessment: Application of Bay of Plenty Regional Policy Statement Methodology for Risk Assessment TOC11/18" dated Dec 2018 (Doc Number: TOC000156.CD-355 v1.1) for more information.  
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A3 SCALE 1:80,000

0 0.5 1 1.5 2 2.5 3 3.5 (km)



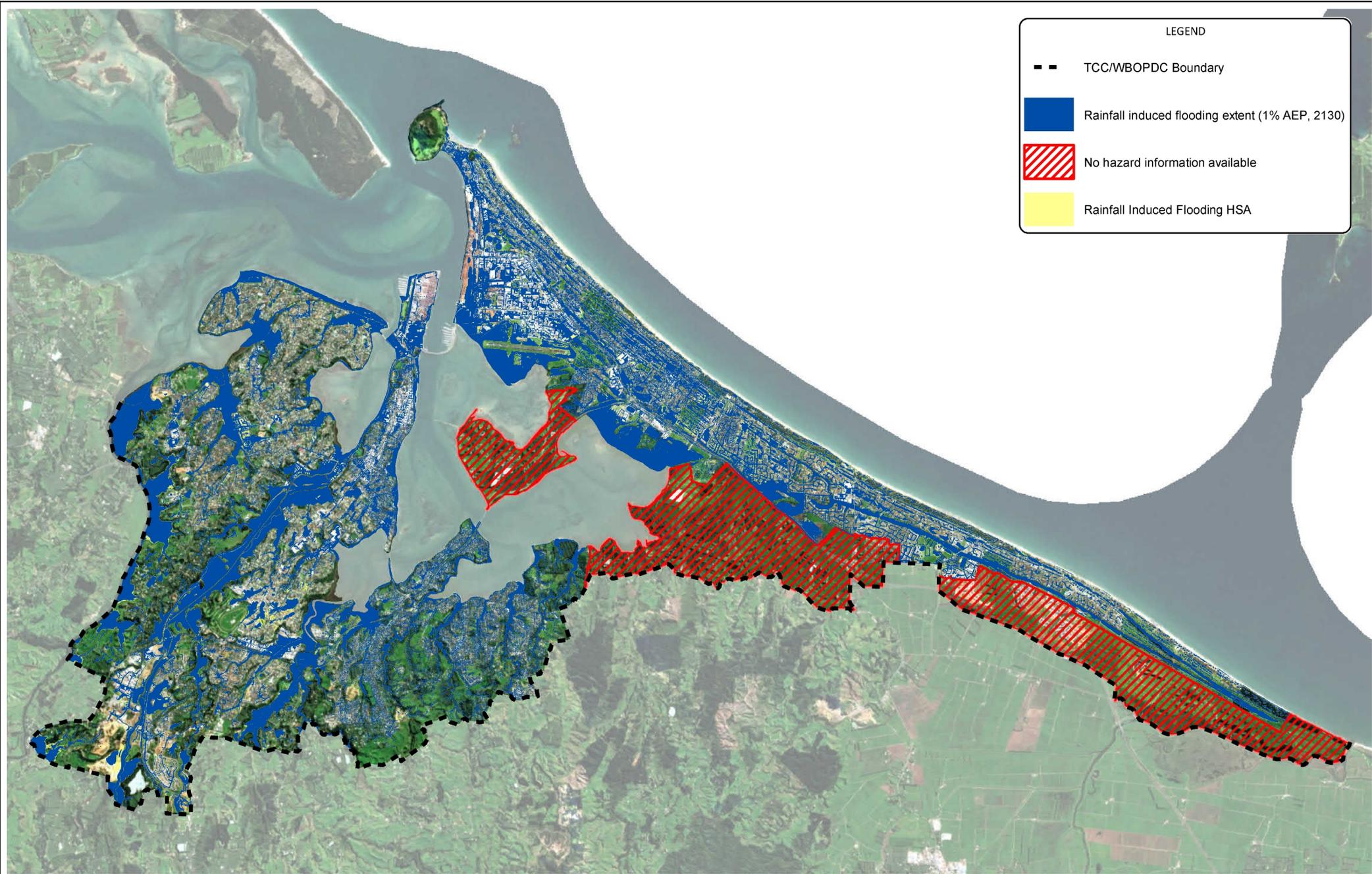
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PROJECT No.	1008440.3000

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 TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT  
 Rainfall Induced Flooding (2% AEP)

FIGURE No. **Figure B17**

Rev. **0**



LEGEND

- TCC/WBOPDC Boundary
- Rainfall induced flooding extent (1% AEP, 2130)
- No hazard information available
- Rainfall Induced Flooding HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for rainfall induced flooding is based on the 0.2% AEP, 2130 event. Refer AWA's report "Tauranga City Flood Risk Assessment: Application of Bay of Plenty Regional Policy Statement Methodology for Risk Assessment TOC11/18" dated Dec 2018 (Doc Number: TOC000156.CD-355 v1.1) for more information.  
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A3 SCALE 1:80,000

0 0.5 1 1.5 2 2.5 3 3.5 (km)



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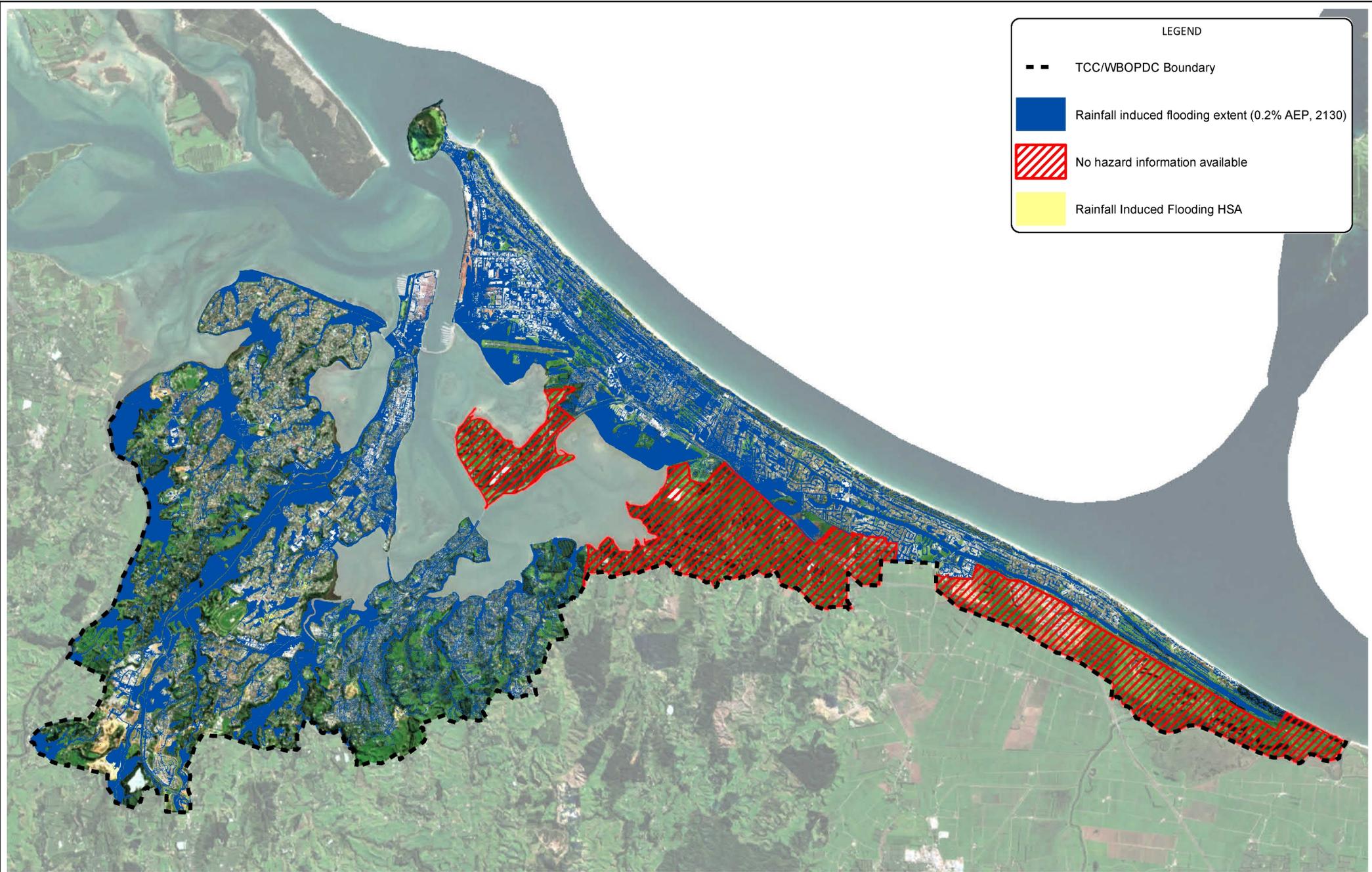
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**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**

Rainfall Induced Flooding (1% AEP)

FIGURE No. **Figure B18**

Rev. **0**



LEGEND

- TCC/WBOPDC Boundary
- Rainfall induced flooding extent (0.2% AEP, 2130)
- No hazard information available
- Rainfall Induced Flooding HSA

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**Notes:**  
 -Hazard susceptibility area (HSA) for rainfall induced flooding is based on the 0.2% AEP, 2130 event. Refer AWA's report "Tauranga City Flood Risk Assessment: Application of Bay of Plenty Regional Policy Statement Methodology for Risk Assessment TOC11/18" dated Dec 2018 (Doc Number: TOC000156.CD-355 v1.1) for more information.  
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A3 SCALE 1:80,000

0 0.5 1 1.5 2 2.5 3 3.5 (km)



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PROJECT No.	1008440.3000

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**TAURANGA CITY-WIDE NATURAL HAZARDS RISK ASSESSMENT**  
 Rainfall Induced Flooding (0.2% AEP)

FIGURE No. **Figure B19**

Rev. **0**

