Coastal inundation mapping at Te Tumu, Bay of Plenty

Prepared for Tauranga City Council

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Executive summary

As part of all planning for new community development within the Bay of Plenty, Councils are required to undertaking susceptibility mapping in accordance with the operative Regional Policy Statement, and if required further risk assessment.

Te Tumu is proposed to be a new urban growth area, providing for more than 15,500 people within Tauranga City. The proposed urban growth area is bounded by the Pacific Ocean to the north, and the Kaituna River to the south. Tauranga City Council commissioned NIWA to predict the height of sea-level events with an occurrence likelihood of 0.2%, 1% and 2% annual exceedance probability (AEP). The AEP represents the chance that at least one sea-level event reaches a certain height or higher, in any year. These scenarios are those required to be assessed as part of the operative Bay of Plenty Regional Policy Statements Natural Hazard Risk Assessment process, as outlined in Appendix L.

Tauranga City Council, in consultation with Bay of Plenty Regional Council, requested that the following high sea-level scenarios be mapped, relative to Moturiki Vertical Datum 1953 (MVD–53):

1. 2% AEP total water level + 1.25 m sea-level rise.
2. 1% AEP total water level + 1.25 m sea-level rise.
3. 0.2% AEP total water level + 1.25 m sea-level rise.
4. 1% AEP total water level + 1.97 m sea-level rise.
5. 0.2% AEP total water level + 1.97 m sea-level rise.

The 1.25 m sea-level rise scenario represents the expected median sea-level rise value by 2130 under the IPCC AR5 RCP8.5 greenhouse-gas emissions scenario, relative to MVD–53. The 1.25 m sea-level rise scenario also aligns with Policy NH 11B: Providing for Climate Change within the operative Bay of Plenty Regional Policy Statement. The 1.97 m sea-level rise scenario represents a 1.9 m minimum transitional value to use when planning for new greenfields developments or major new infrastructure, plus it includes the mean sea level from 1986–2005 relative to MVD–53, which was 0.07 m.

The five total water level elevations that were mapped for this assessment were 4.28, 4.44, 4.73, 5.16 and 5.45 m respectively, relative to MVD–53.

Maps showing the depth and horizontal extent of inundation for each of the five scenarios were supplied to Tauranga City Council as digital GIS shapefiles. Maps of the horizontal inundation extent are included in this report. The inundation maps were produced using a static, or "bathtub", mapping technique to intersect the total water levels with the Tauranga City Council designed digital elevation model of the expected land elevation after completion of earthworks during subdivision development. Areas are shown as inundated only if they have a direct hydraulic connection to the sea.

There are three major assumptions applied when creating the inundation maps, which should be considered when using the maps since they limit the maps accuracy:

(i) it was assumed that the sea levels at the open coast would also apply inside the river, but they are actually likely to be lower;

(ii) the analysis does not consider the combined influence of river and coastal flooding, which could raise water levels well above the level of coastal flooding alone, within the river;

(iii) the static, or “bathtub”, mapping method does not account for the dynamics and time-varying nature of inundation and so it produces conservatively high inundation depth and area, including mapping areas due to the direct hydraulic connection to the sea which would, under more detailed modelling, not likely be inundated. Despite these limitations, the maps outlined in this report indicate the potential future inundation hazard for at least a 100-year timeframe under the modelled scenarios, as required under the statutory New Zealand Coastal Policy Statement and the operative Bay of Plenty Regional Policy Statement.

1 Introduction

Te Tumu is proposed to be a new urban growth area, providing for more than 15,500 people within Tauranga City. The proposed urban growth area is bounded by the Pacific Ocean to the north, and the Kaituna River to the south. As Te Tumu is bounded by the open coast it is potentially vulnerable to coastal erosion, and to inundation during large wave events or high storm-tides.

The New Zealand Coastal Policy Statement (DoC 2010) requires the identification of areas in the coastal environment that are "potentially affected" by coastal hazards, and assessment of the associated risks over at least the next 100 years (Policy 24). Further, the operative Regional Policy Statement requires susceptibility mapping of natural hazards, and where susceptibility is identified, a risk assessment is required to be undertaken.

NIWA has previously developed a "Coastal Calculator" to predict the height and likelihood of large sea-level events along the Bay of Plenty coastline (Goodhue et al. 2015).

Tauranga City Council commissioned NIWA to apply the Coastal Calculator to predict the height of sea-level events with an occurrence likelihood of 0.2%, 1% and 2% annual exceedance probability (AEP) in accordance with methodological requirements of the operative Regional Policy Statement. The AEP represents the chance that at least one sea-level event reaches a certain height or higher, in any year. A sea-level "event" is usually associated with a significant storm that causes large waves to impact the coast, and/or causes a storm surge which raises the sea level. The events usually peak at high tide, and most coastal inundation events in New Zealand occur during spring tides, when the high tide is higher than during neaps (Bell 2010). The total water level results from a combination of hazard sources, such as mean sea level (MSL) + tide + storm surge + wave setup.

Coastal inundation events will become more frequent in the future, because the mean sea level is rising. With a sea-level rise of ~0.2 m since 1900, in low-lying areas of New Zealand there has already been an increased frequency of coastal storm flooding (PCE 2014; Stephens 2015). The rate of sea-level rise is projected to accelerate over this century and beyond (Nicholls et al. 2011; Church et al. 2013; Hinkel et al. 2014), which will greatly increase the frequency of flooding (e.g. Hunter 2012; Sweet & Park 2014; Stephens 2015; Slangen et al. 2017), and exacerbate coastal erosion (e.g. Dickson et al. 2007).

Along with sea-level rise, changes in storm frequency and intensity could also drive changes in the height and frequency of coastal inundation and erosion. It is difficult to predict storm intensity changes. The Waves And Storm-surge Predictions (WASP) project (Goodhue et al. 2015) suggested that changes in storm surge and wave intensity would be relatively minor around New Zealand and in the Bay of Plenty. Therefore, we have followed the common assumption that the dominant effect changing the frequency and depth of flooding events will be sea-level rise (e.g. Hunter 2010; Hunter 2012; Tebaldi et al. 2012; Buchanan et al. 2016).

Tauranga City Council, in consultation with Bay of Plenty Regional Council, requested that the following high sea-level scenarios be mapped:

1. 2% AEP total water level + 1.25 m sea-level rise.
2. 1% AEP total water level + 1.25 m sea-level rise.
3. 0.2% AEP total water level + 1.25 m sea-level rise.

4. 1% AEP total water level + 1.9 m sea-level rise above 1986–2005 mean sea level.

5. 0.2% AEP total water level + 1.9 m sea-level rise above 1986–2005 mean sea level.

The calculation of the total water level elevations and the background to the chosen sea-level rise scenarios are explained in Section 2. The coastal-inundation mapping is described in Section 3, and assumptions and limitations are discussed in Section 4. Conclusions are outlined in Section 5.

The assessment reveals that under the 1.25 m sea-level rise scenarios the developed DEM for the likely future landform for Te Tumu is not subject to inundation from storm surges under the modelled conditions within development areas. This is largely because of the existing, and largely unmodified natural dune system which protects the Te Tumu Urban Growth Area from potential inundation. Small areas of inundation are predicted under the large 1.9 m sea-level rise scenario.

2 Total water level elevation

The Coastal Calculator was applied to calculate the total water level elevation resulting from storm-tides + wave setup at Te Tumu, using the recommended “storm” beach gradient of 0.17 (Goodhue et al. 2015). The Calculator was applied using MSL = 0 relative to Moturiki Vertical Datum 1953 (MVD–53), and zero sea-level rise. The resulting total water level associated with 0.2%, 1% and 2% AEP were:

1. Maximum 1% AEP storm-tide + wave setup = 3.19 m = 1.08 m storm-tide + 2.11 m wave setup

2. Maximum 2% AEP storm-tide + wave setup = 3.03 m = 1.04 m storm-tide + 1.98 m wave setup

3. Maximum 0.2% AEP storm-tide + wave setup = 3.48 m from linear fit (Figure 2-1).

Since the lowest frequency of the Calculator is 0.5% AEP, the 0.2% AEP was calculated using a log-linear fit as shown in Figure 2-1. The total water levels are shown in Table 2-1.

Tauranga City Council also requested that NIWA calculate a maximum credible total water level, based on a building block approach that sums large values of several hazard sources. This was calculated by adding the 0.5% AEP storm-tide of 1.54 m (which includes mean sea-level anomaly + tide + storm surge) to the 0.5% AEP wave setup elevation of 2.30 m, giving a total water level of 3.84 m above MSL. Note that wave setup is the average elevation of the water level on the beach due to wave action. In addition to wave setup, wave runup is the wave uprush on the beachface, and this reaches a much higher elevation, but its effects are limited to a few metres from the frontal dune or seawall. The maximum credible storm-tide + wave runup is 7.09 m above MSL.

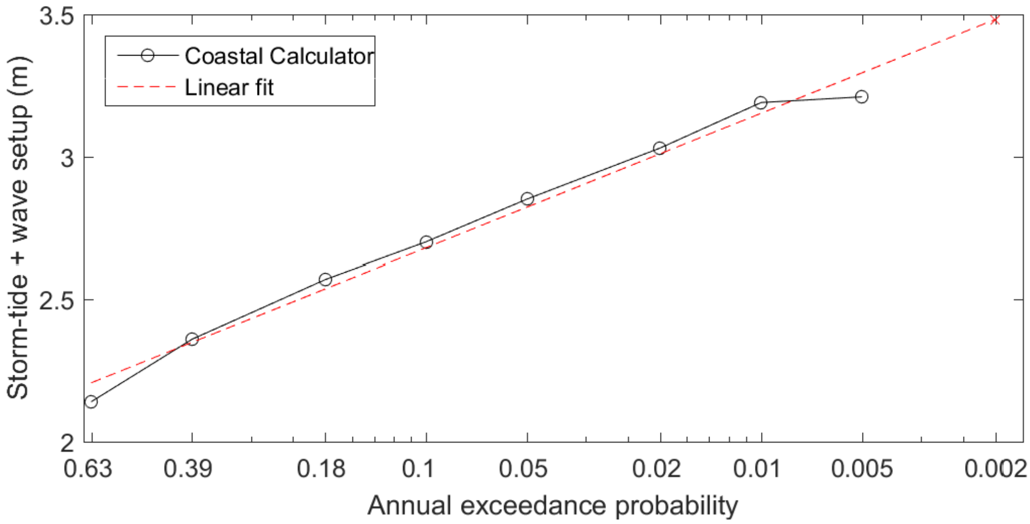

Figure 2-1: Extreme storm-tide plus wave setup elevations at Te Tumu. Elevations include no allowance for MSL relative to MVD–53. Elevations were obtained using the Bay of Plenty Coastal Calculator (Goodhue et al. 2015), using a beach gradient of 0.17.

Table 2-1: Extreme storm-tide plus wave setup elevations at Te Tumu. Elevations include no allowance for MSL relative to MVD–53, i.e. MSL = 0. Elevations were obtained using the Bay of Plenty Coastal Calculator (Goodhue et al. 2015), using a beach gradient of 0.17.

AEP (%)	63	39	18	10	5	2	1	0.5	0.2
Storm-tide + wave setup elevation (m)	2.14	2.36	2.57	2.7	2.85	3.03	3.19	3.21	3.48

The mapping scenarios consisted of the three present-day total water level scenarios (0.2%, 1% and 2% AEP), combined with two sea-level rise scenarios:

1. 1.9 m sea-level rise above 1986–2005 mean sea level = 1.97 m above MVD–53.

2. 1.25 m above MVD–53.

The first of these represents a minimum transitional value to use when planning for new greenfields developments or major new infrastructure. We understand this fits with current draft guidance prepared by the Ministry for the Environment for Coastal Hazards and Climate Change. MSL from 1986–2005 was 0.07 m MVD–53, so the total sea-level rise for scenario 1 is 1.97 m MVD–53.

The second scenario represents the expected median sea-level rise value by 2130 under the IPCC AR5 RCP8.5 greenhouse-gas emissions scenario, relative to MVD–53. The IPCC projections stop at 2100, but were extended to 2130 following Kopp et al. (2014), as explained by Stephens (2017).

The five sea-level elevations for mapping are shown in Table 2-2.

Table 2-2: Coastal inundation elevations for mapping.

AEP (%)	SLR description	Storm-tide + wave setup elevation (m relative to MSL = 0)	SLR (m MVD–53)	Elevations to map (m MVD–53)
2	RCP8.5 median by 2130	3.03	1.25	4.28

AEP (%)	SLR description	Storm-tide + wave setup elevation (m relative to MSL = 0)	SLR (m MVD–53)	Elevations to map (m MVD–53)
1	RCP8.5 median by 2130	3.19	1.25	4.44
0.2	RCP8.5 median by 2130	3.48	1.25	4.73
1	Greenfields transitional	3.19	1.97	5.16
0.2	Greenfields transitional	3.48	1.97	5.45

3 Coastal inundation mapping

Maps of the coastal inundation scenarios in Table 2-2 were created using GIS, and have been supplied to Tauranga City Council as digital GIS shapefiles. The digital GIS maps show the depth and horizontal extent of inundation for each of the five scenarios.

The inundation maps were produced by intersecting the total water levels in Table 2-2 with a digital elevation model (DEM) of the area. The DEM was created from LiDAR topography data, and was supplied by Taranga City Council. The DEM used for the mapping was that of the expected land elevation after completion of earthworks during subdivision development (Figure 3-1).

The maps were created using a static, or “bathtub”, mapping technique, which assumes that the predicted total water level elevation is achieved instantaneously everywhere within the area at or below that elevation (which has direct hydraulic connectivity). Limitations of the static mapping technique are discussed in Section 4. Those areas that were initially shown as inundated, but lacking direct hydraulic connectivity with the sea via a culvert, drain or continuous depression, were removed from the inundation zone.

Maps of coastal inundation extent for the five scenarios are shown in Figure 3-2 through Figure 3-6.

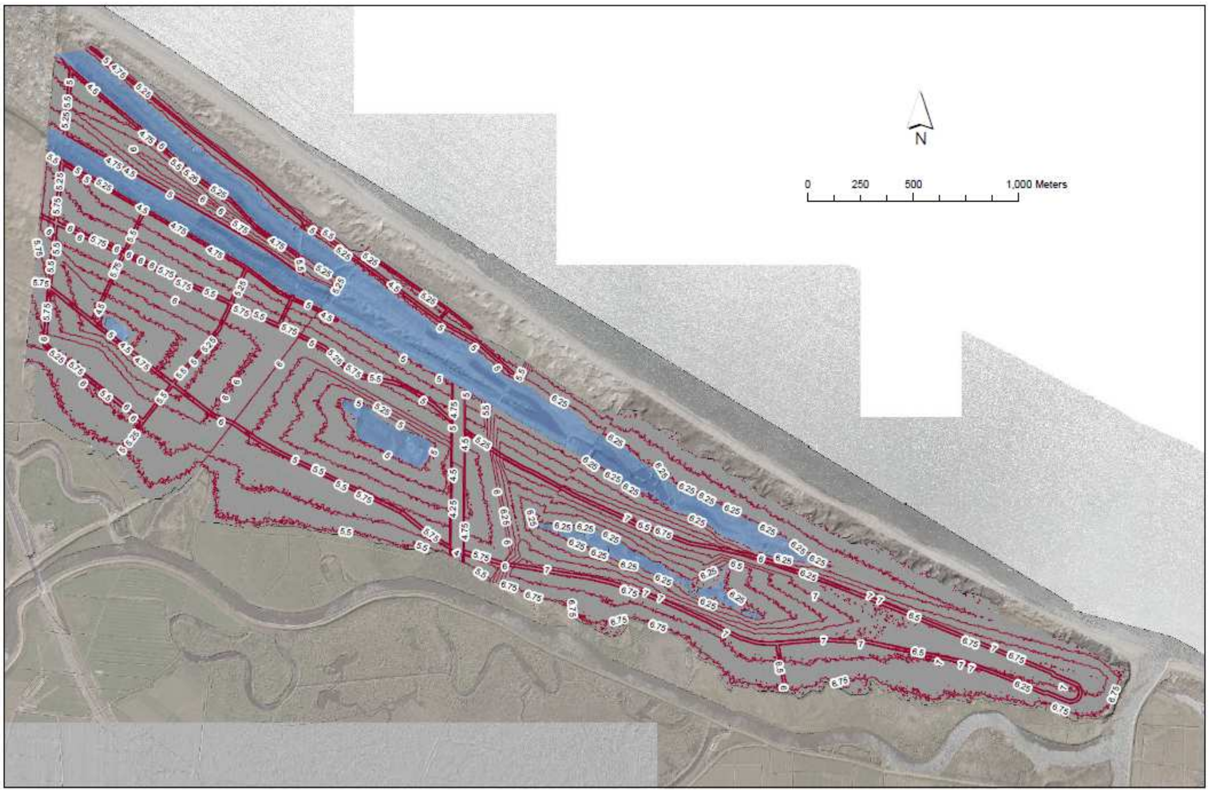

Figure 3-1: Digital elevation model of proposed Te Tumu subdivision land elevation following earthworks. Image supplied by Tauranga City Council. The lines represent elevation contours, and the blue areas represent low-elevation areas designed to hold water.

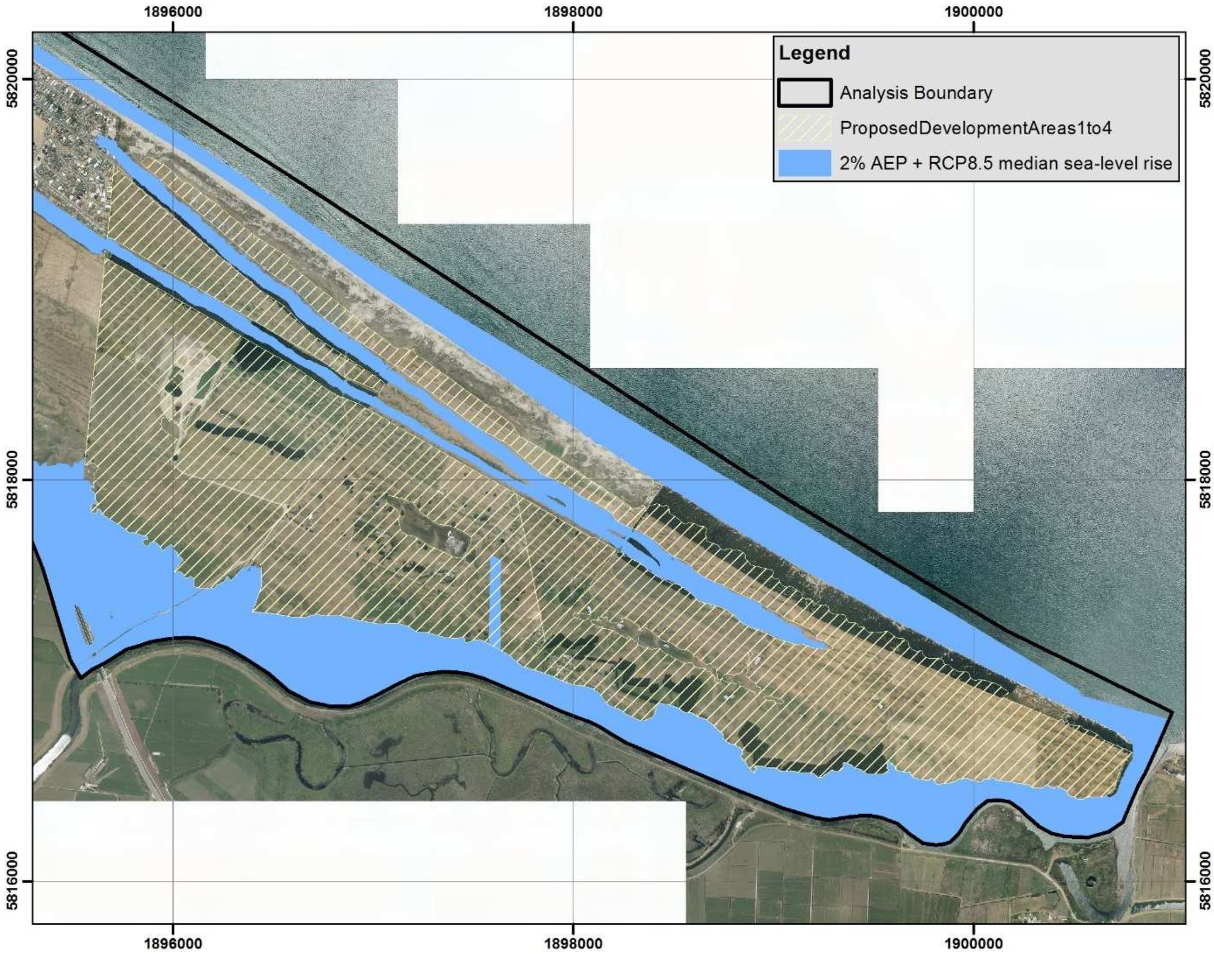

Figure 3-2: Extent of inundation for scenario 2% AEP total water level + 1.25 m sea-level rise relative to MVD–53.

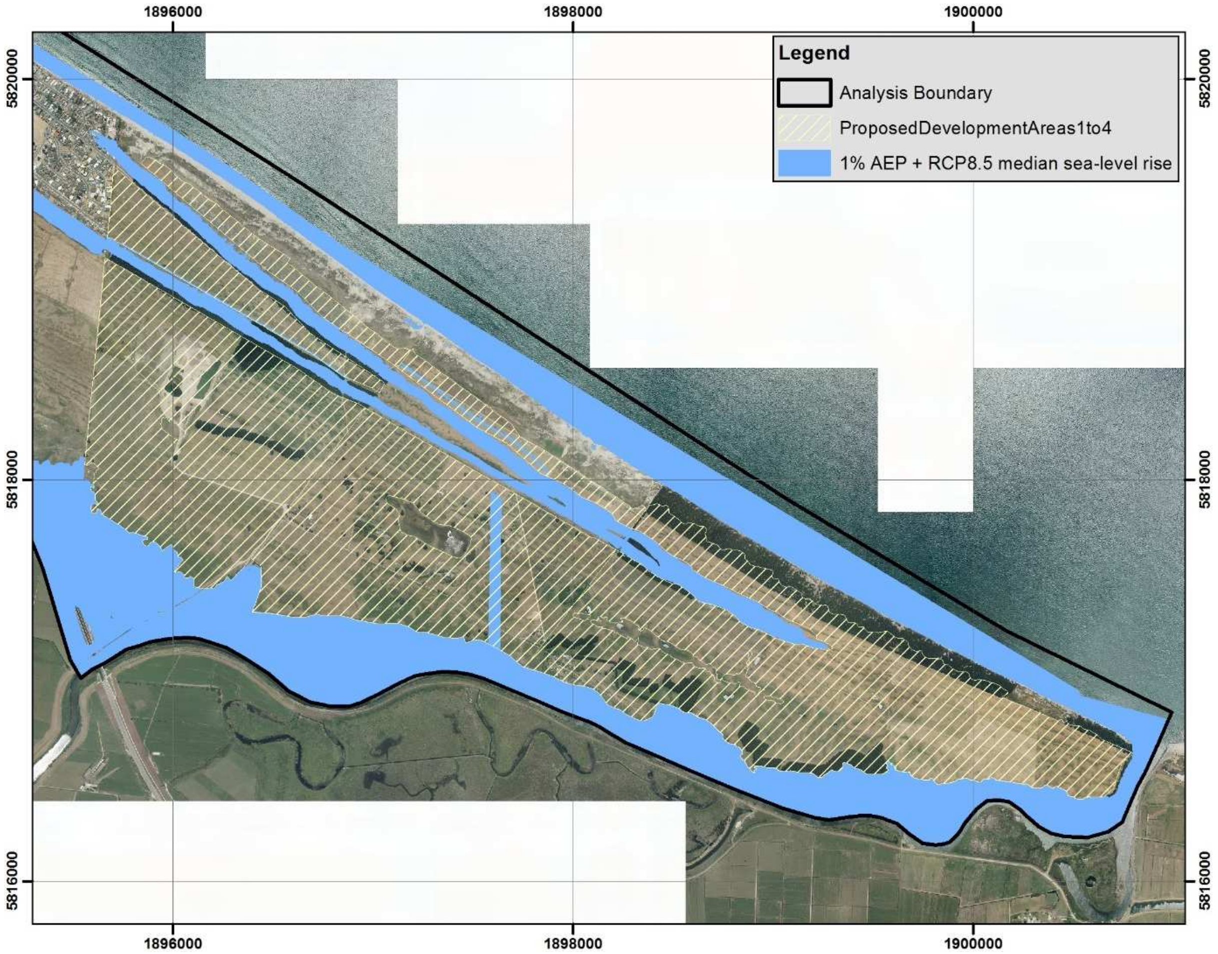

Figure 3-3: Extent of inundation for scenario 1% AEP total water level + 1.25 m sea-level rise relative to MVD–53.

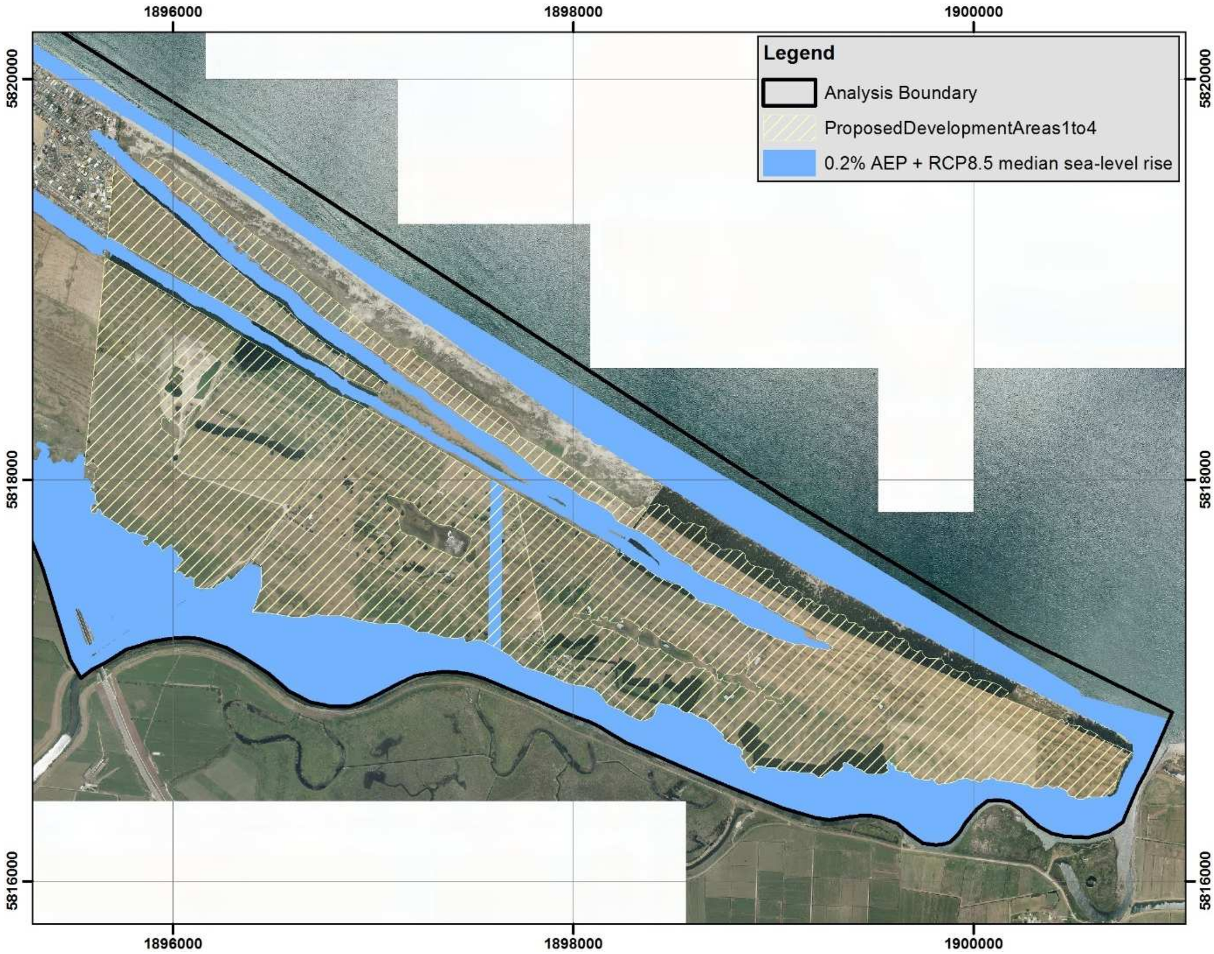

Figure 3-4: Extent of inundation for scenario 0.2% AEP total water level + 1.25 m sea-level rise relative to MVD–53.

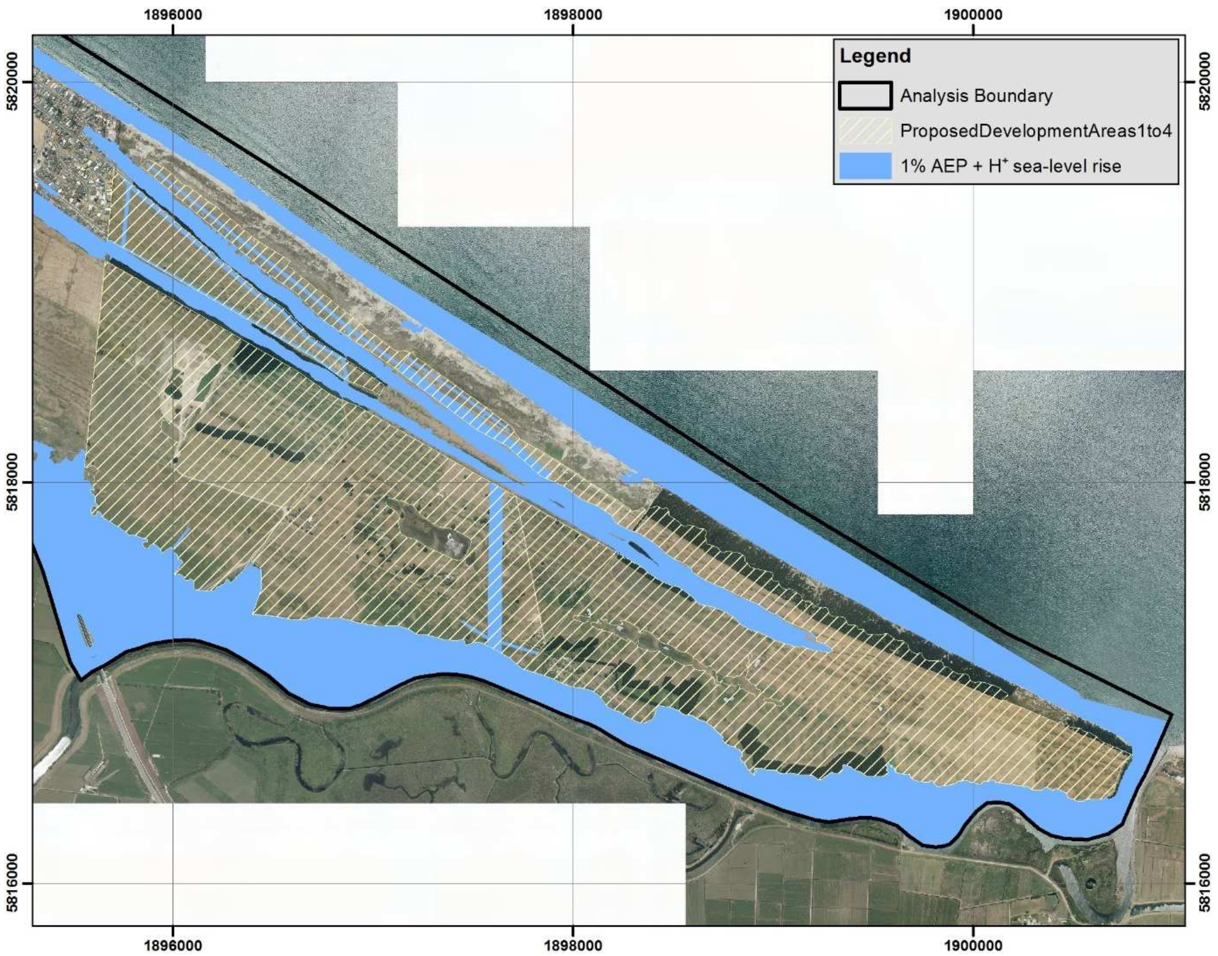

Figure 3-5: Extent of inundation for scenario 1% AEP total water level + 1.97 m sea-level rise relative to MVD–53. The 1.97 m sea-level rise is referred to as 'H^{+}' in the figure legend.

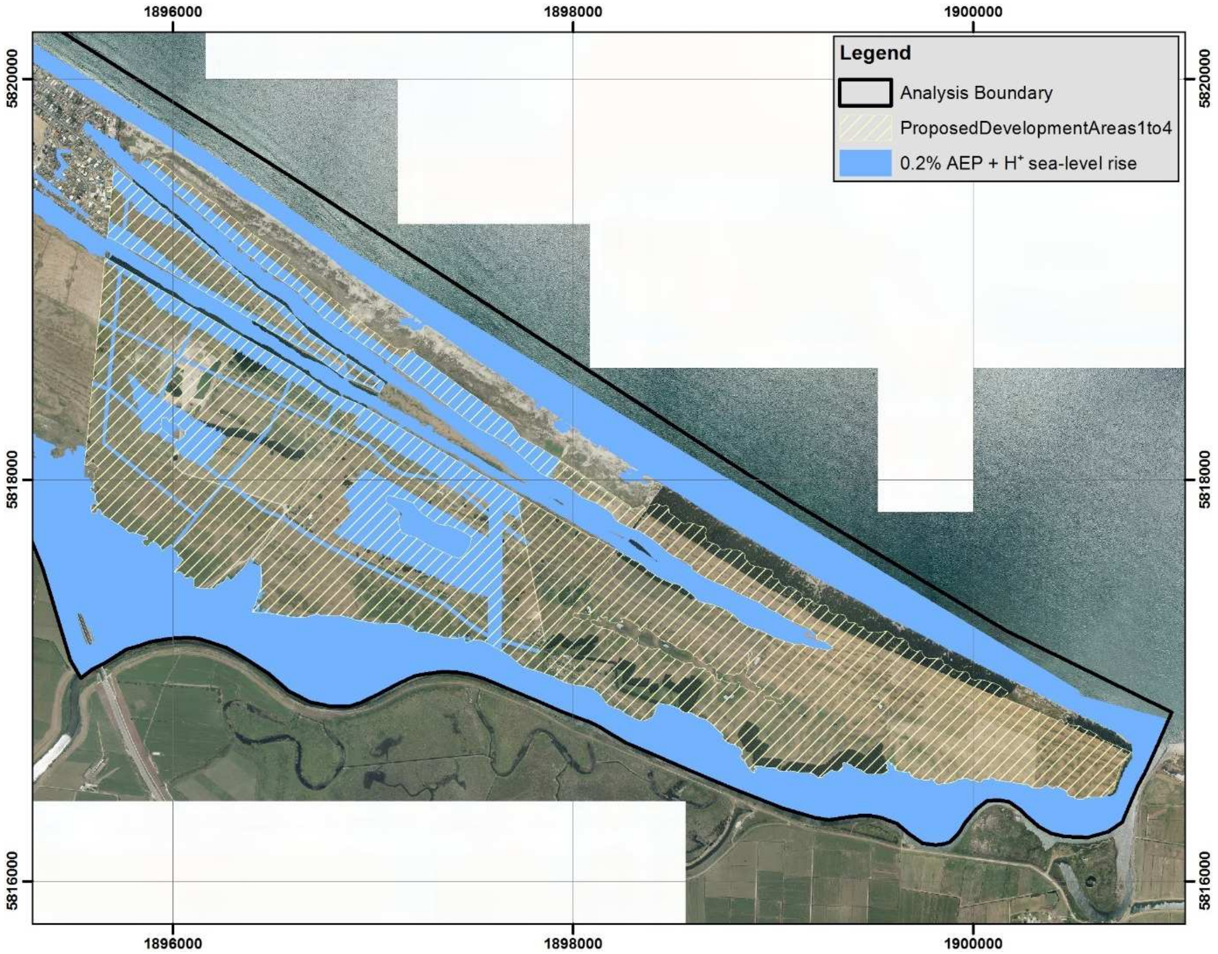

Figure 3-6: Extent of inundation for scenario 0.2% AEP total water level + 1.97 m sea-level rise relative to MVD–53. The 1.97 m sea-level rise is referred to as ‘H^{+}‘ in the figure legend.

4 Assumptions and limitations

There are three major assumptions that affect the interpretation of the inundation maps:

1. The Te Tumu Urban Growth Area is enclosed on one side by the sea, and on the other side by the Kaituna River. When calculating the total water level elevations, Tauranga City Council requested that NIWA assumes that the sea level at the coast (from the Coastal Calculator), would apply inside the river. High sea levels at the open coast will diminish up river, particularly the effects of wave setup. The total water level elevations will therefore be conservatively high on the river side of the urban growth area, when considering high sea level events in isolation from river floods.

2. The analysis does not consider the combined influence of *river* floods and future storm-tide and SLR extremes. This combination could raise water levels well above the level of storm-tide plus wave setup, within the river. It is understood that the Tauranga City Council is, as part of it natural hazards assessments for the Te Tumu Urban Growth Area undertaking flood modelling using a 2D Hydraulic Model which assess a range of intense rainfall events and storm surge combination events.

3. The static, or “bathtub”, mapping method does not account for the dynamic and time-varying nature of inundation and so it produces conservatively high inundation depth and area (more so for low-lying coastal plains that extend further inland). The method assumes that every land area below the extreme sea-level is mapped as instantly flooded in its entirety. The peak of a storm-tide only lasts for about 1–3 hours centred on high tide, and this may not be enough time to cause sufficient seawater volume to inundate a large area of the wider flat hinterland if the flow rate of the storm-tide is restricted by a narrow connection to the sea, as is the case with the Te Tumu Urban Growth Area. The static inundation mapping approach is conservative in that it tends to over-predict rather than under-predict inundation by storm-tides, although can be tempered by delays in inundation subsiding if drainage back to the sea is inadequate. The static mapping approach is best-suited to locations where the topography rises approximately continuously with distance from the coast, and without extensive low-lying areas behind coastal barriers.

These assumptions limit the accuracy of the maps, and the limitations should be considered when using the maps. The limitations could be overcome by more detailed modelling studies. Despite these limitations, the maps indicate the potential future inundation hazard for at least a 100-year timeframe, as required under the statutory NZCPS under the range of scenarios assessed.

5 Conclusions

Tauranga City Council, in consultation with Bay of Plenty Regional Council, requested that the following high sea-level scenarios be mapped, relative to Moturiki Vertical Datum 1953 (MVD–53):

1. 2% AEP total water level + 1.25 m sea-level rise.

2. 1% AEP total water level + 1.25 m sea-level rise.

3. 0.2% AEP total water level + 1.25 m sea-level rise.

4. 1% AEP total water level + 1.97 m sea-level rise.

5. 0.2% AEP total water level + 1.97 m sea-level rise.

The 1.25 m sea-level rise scenario represents the expected median sea-level rise value by 2130 under the IPCC AR5 RCP8.5 greenhouse-gas emissions scenario, relative to MVD–53. The 1.25 m sea-level rise scenario also aligns with Policy NH 11B: Providing for Climate Change within the operative Bay of Plenty Regional Policy Statement. The 1.97 m sea-level rise scenario represents a 1.9 m minimum transitional value to use when planning for new greenfields developments or major new infrastructure, plus it includes the mean sea level from 1986–2005 relative to MVD–53, which was 0.07 m.

The five total water level elevations that were mapped for this assessment were 4.28, 4.44, 4.73, 5.16 and 5.45 m respectively, relative to MVD–53.

The assessment reveals that under the 1.25 m sea-level rise scenarios, the developed DEM for the likely future landform for Te Tumu is not subject to inundation from storm surges under the modelled conditions within development areas. This is largely because of the existing, and largely unmodified natural dune system which protects the Te Tumu Urban Growth Area from potential inundation. The proposed DEM also shows that inundation from storm surge along the Kaituna River is also unlikely under the modelled scenarios within development areas. Therefore, under Scenarios

1 through 4 Te Tumu is not expected to experience inundation from storm surges, including noting the inherent conservation within the modelled scenarios.

Scenarios 4 and 5 are extreme modelled scenarios, whereby low-percentage, large storm events are combined with an elevated sea level of 1.9 m. Even under these modelled conditions, the Te Tumu DEM is not inundated to significant extents and no overtopping of the open coastal dune system, nor river margins within Te Tumu occurs. The inundation shown is due to the type of model utilised and results from direct hydraulic connection to the sea from areas outside of the proposed Urban Growth Area or via the proposed Kaituna Overflow Stormwater Swale. It is unlikely that if more detailed modelling of this scenario was undertaken that this would show inundation occurring within the Te Tumu Urban Growth Area. Further modelling of river flooding, sea level rise and storm surge combinations will be undertaken by the Tauranga City Council as part of a separate project for the Te Tumu Rezoning and Structure Planning.

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