tasman
district council

Coastal Hazards Assessment in

Tasman Bay/Te Tai o Aorere and Golden Bay/Mohua

July 2019

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1. Introduction

1.1 Purpose of Report

Coastal hazards pose a significant risk to Tasman's coastal communities. These hazards include coastal erosion, coastal inundation (seawater flooding) and sea level rise associated with climate change. Tasman District Council (Council) is required to manage the significant risks from natural hazards under the Resource Management Act 1991 and associated New Zealand Coastal Policy Statement.

This report details the methodology used to assess and map areas of the Tasman Bay/Te Tai o Arorere and Golden Bay/Mohua coastline that either have been or may be susceptible to coastal erosion and/or inundation hazards, including in circumstances of a projected climate change and sea level rise future.

Coastal erosion (sediment loss) rates have been calculated using historical data from over the last 30 years or more (prior to any erosion protection structures that may now be present), to identify and map shorelines that have experienced either low, medium or high rates of erosion. There are also a small number of areas of the coast that have experienced accretion (sediment gain).

Low lying areas which may be susceptible to inundation have been identified using a coastal land elevation model ('bathtub' method). The mapping illustrates the potential extent of inundation in a present day 1% AEP (annual exceedance probability) storm tide event and with increments of sea level rise of 0.5m intervals (e.g. 0.5m, 1.0m, 1.5m and 2m) applied. A 1% AEP event has a 1% chance of occurring in any year. Mapping layers indicate the potential extent of inundation for selected sea level rise values, rather than the potential extent of inundation *at particular dates.* The latter is uncertain and depends on the climate scenario chosen.

Known coastal protection structures have also been mapped, which includes bunds, stopbanks, intermittent rock, revetments or walls, or causeways.

The mapped outputs are presented in an interactive online GIS map tool and is referred to in this report as the *coastal hazards map viewer*. The information can be accessed on Tasman District Council's website at tasman.govt.nz/link/coastal-management.

Following best practice as set out in the Ministry for the Environment's (MfE) Coastal Hazards and Climate Change: Guidance for Local Government (2017), this mapped information will be used to develop a long-term adaptive planning approach which will inform a number of Council's functions including land use planning, infrastructure and reserve management planning and emergency management.

Please refer to Section 9 Glossary for a list of key terms used throughout this report.

1.2 Tasman District Coastline

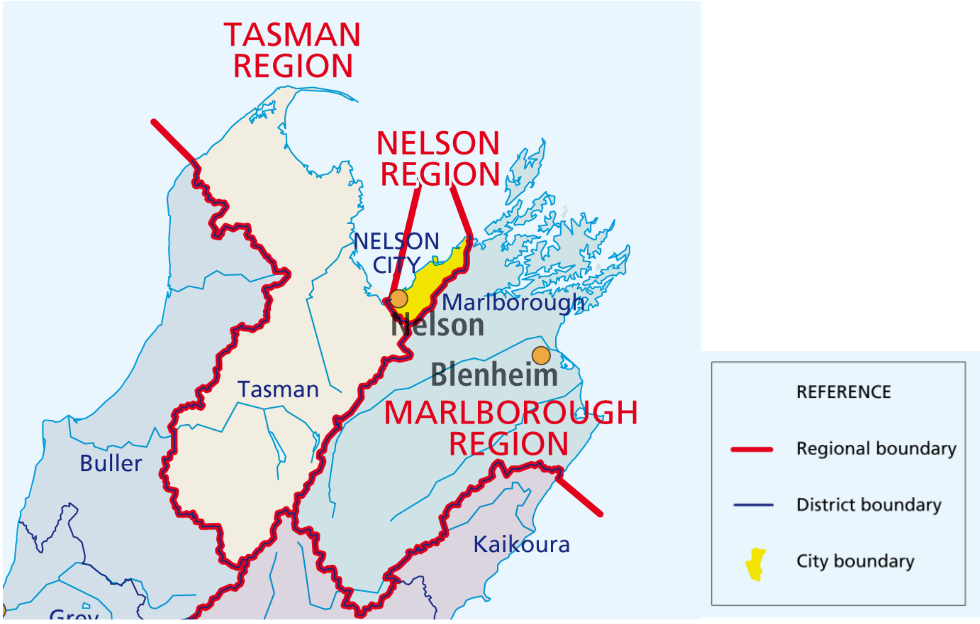
The Tasman district coastline can be divided into three distinct geographical areas - the West Coast, and Golden Bay and Tasman Bay. There is over 700km of open coast and estuary shoreline ranging from rocky and cliff landforms to dunes, sandy beaches and sand spits.

The district's coastline on the West Coast spans from Kahurangi lighthouse in the south, to Farewell Spit in the north. This coastline faces onto the Tasman Sea and is a rugged landscape that includes coastal cliffs, large sand dune features, small rivermouth delta areas and the Whanganui Inlet, the picturesque Wharariki Beach and Archway Islands and Cape Farewell.

Farewell Spit forms the northern boundary of Golden Bay. The “permanent dry land” component of the spit, from Fossil Point to Bush End Point extends some 25km eastwards into the Tasman Sea, with the intertidal/sub-tidal component of the spit extending more than 5km further east beyond Bush End Point. The spit comprises of a dune-fringed sandy beach facing the Tasman Sea, while the southern side bounds an extensive shallow mudflat. The Golden Bay coastline extends over 55km from Puponga, at the base of Farewell Spit in the north, to Separation Point to the south-east.

South of Separation Point, the expansive and diverse coastline of Tasman Bay begins. The western side of Tasman Bay is within the administrative boundaries of the Council, and encompasses the yellow sandy beaches of Abel Tasman National Park, a number of inlets and sand spits, the popular holiday locations of Marahau, Kaiteriteri and Ruby Bay/Mapua, and the Rabbit Island recreation reserve. The eastern side of Tasman Bay north of Richmond lies within the administrative boundaries of Nelson City Council and Marlborough District Council. This area includes the popular Tahunanui Beach, the internationally renowned Boulder Bank, and the western fringes of the Marlborough Sounds including D’Urville Island. Figure 1 illustrates the administrative boundaries of these three top of the South Island councils.

Figure 1: Tasman, Nelson and Marlborough Regions



(Source: adapted from LGNZ, www.lgnz.co.nz/nzs-local-government/new-zealands-councils/, 2019)

Many parts of the district’s coastline are vulnerable to coastal erosion and/or inundation. Natural processes of wind and wave erosion and seawater inundation result from wind, tide and wave action, particularly on sandy and/or low-lying shorelines. Inundation and erosion hazards can pose a risk to resources and assets that the community values such as buildings, parks and reserves, beach access, wahi tapu sites, areas for harvesting kaimoana, and the pursuit of other recreational opportunities. The probability, severity and extent of coastal inundation and erosion hazards are expected to increase as a result of climate change projections of increased storminess and sea level rise.

1.3 Statutory Requirements

The identification and avoidance or mitigation of natural hazards is a key component of Council's core functions, as required by the relevant legislation as summarised below.

1.3.1 Resource Management Act 1991

Under the Resource Management Act 1991 (RMA 1991), councils must recognise and provide for the management of significant risks from natural hazards (s.6(h)) and all decisions must have particular regard, amongst other things, to the effects of climate change (s.7(i)). Through the Tasman Resource Management Plan, the Council administers and regulates activities such as subdivision and land uses and manages the land-coastal interface.

1.3.2 New Zealand Coastal Policy Statement 2010

In addition to Section 6 and 7 matters, regional policy statements, regional plans and district plans are required to give effect to national policy statements including the New Zealand Coastal Policy Statement 2010 (NZCPS). Objective 5 and Policies 24-27 direct councils to identify areas that may potentially be affected by coastal hazards over a timeframe of at least 100 years. These policies are:

- Policy 24 lays the foundation for risk-based coastal hazard management and requires councils to identify coastal areas that will be potentially affected by coastal hazards over at least the next 100 years.
- Policy 25 sets the policy framework for planning decisions for land use and development in areas potentially affected by coastal hazards, with an emphasis on avoidance and reduction of risks.
- Policy 26 addresses the management of natural coastal landforms/features that provide natural defences (e.g. beaches, estuaries, dunes) and promotes the use of natural defences against coastal hazards.
- Policy 27 addresses areas with significant existing development and encourages councils to develop sustainable risk-reduction strategies to protect these areas from coastal hazard risks.

Other policies within the NZCPS also apply and may affect how our coastlines are managed.

1.3.3 Tasman Regional Policy Statement and Tasman Resource Management Plan

Councils must give effect to the RMA 1991, the NZCPS and other national direction through their regional policy statement and resource management plans. The TRMP has been subject to a number of 'rolling review' plan variations/changes since being notified (1996) and made operative (in staged parts over a number of years since 2008), but no district-wide coastal hazard planning review has been undertaken to date. Location-specific changes to the TRMP have been introduced to manage coastal hazards, including Plan Change 22 (Mapua/Ruby Bay) and Plan Change 10 (Richmond West).

In November 2018, Council resolved to undertake a review of its suite of resource management plans. The identification of coastal hazards as detailed in this report will be used to inform the management framework for dealing with risks from coastal hazards and include controls on the use of land for the purpose of the avoidance or mitigation of these hazards. Council will apply the principles set out in the Ministry for the Environment's (MfE) Coastal Hazards and Climate Change: Guidance for Local Government (2017) to develop this management framework as discussed further in Section 1.4.

1.3.4 Nelson Tasman Land Development Manual 2019

The Nelson Tasman Land Development Manual details engineering standards for new development in Tasman District and Nelson City areas. The Inundation Practice Note, which sits alongside the manual, provides non-statutory guidance on how to determine minimum ground and floor levels for subdivision, new buildings and major alterations in inundation prone areas including coastal locations.

1.3.5 Other Legislation

Council is required to identify and/or manage the risk of natural hazards through a range of other Council functions and statutory requirements, including:

- administration of building consents and making natural hazard information available to the pubic via Project Information Memorandum (Building Act 2004)
- making existing natural hazard information available to the public via Land Information Memorandum (Local Government Official Information and Meetings Act 1987)
- managing infrastructure assets (Local Government Act 2002)
- civil defence responsibilities (Civil Defence Emergency Management Act 2002)

1.4 Coastal Hazards and Climate Change: Guidance for Local Government (2017)

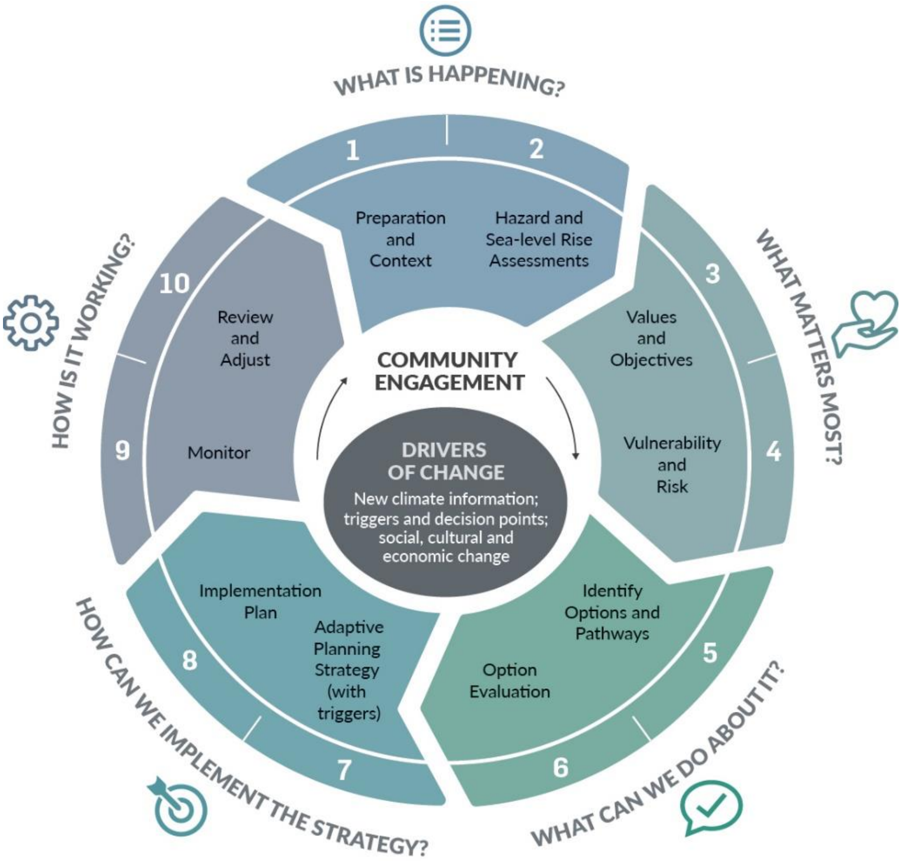
Since the early 2000s, the Ministry for the Environment (MfE) has provided local government with guidance on how to adapt to coastal hazards arising from climate change, particularly hazards associated with sea level rise. This guidance has been used by councils to inform land use and infrastructure asset planning in coastal areas.

‘Coastal Hazards and Climate Change: Guidance for Local Government’ (December, 2017) is MfE’s latest publication and provides a major revision to the previous guidance (from 2008 and 2009). The guidance provides an iterative 10 step framework, focussed around five key questions, to enable local government to undertake ‘long-term adaptive planning’ for climate change in coastal communities (shown in Figure 2).

The guidance recognises that because of the uncertainty about future climate change it is necessary to examine a range of sea level rise scenarios when developing and testing adaptation plans and policy, and for the design and adaptive development of assets and infrastructure at the coast. This guidance has been used to help inform the methodologies outlined in this report, focusing around the question of “What is happening?” and Step 2 Hazard and Sea Level Rise Assessments, as shown in Figure 1 over page.

In this report, the MfE Coastal Hazards and Climate Change Guidance (2017) is referred to as the ‘MfE 2017 Guidance’.

Figure 2: The 10-step decision cycle, grouped around five questions
(Source: MfE, 2017)



2. Scope of Report

2.1 Introduction

This report details the methodology used to assess and map areas of the Tasman Bay/Te Tai o Aorere and Golden Bay/Mohua coastline that either have been or may be susceptible to coastal erosion and/or inundation hazards, including in circumstances of a projected climate change and sea level rise future.

The west coast of the district from Cape Farewell to Kahurangi Point (including Whanganui Inlet) has been excluded from this coastal hazards assessment. This is due primarily due to the fact that there is no LiDAR derived elevation data currently available. Other factors noted is that the topography of the area is predominately high cliffs (and minimal sandy shores), there is limited hazard information, sparse population, limited access and minimal pressure for coastal development. Any assessment of coastal hazard for this stretch of coastline will need to be undertaken on a site by site basis by an appropriately qualified practitioner, if required. The map viewer will be updated when LiDAR data becomes available.

Tasman Bay has a shoreline that falls under the jurisdiction of three local authorities, namely Tasman District Council (Separation Point to Richmond), Nelson City Council (Stoke to Cape Soucis) and Marlborough District (Cape Soucis to D’Urville Island) with their respective boundaries out to the 12 nautical mile mark. Staff at Nelson City and Tasman District

Councils have coastal hazard work programmes in place and are in regular discussion to ensure alignment between coastal hazard assessment methodologies. For further information on Nelson City Council's natural hazards, refer to their website (www.ncc.govt.nz).

2.2 Natural Hazards in the Coastal Area

The coastal area is the interface between land and sea. It is a dynamic environment where a number of natural hazard processes can occur, either individually or in combination. The focus of this coastal hazards assessment is on coastal erosion and inundation including sea level rise. However, there are other natural hazards that may have an impact in the coastal area, including those discussed below. The combined effects of these natural hazards (where known) should be considered holistically when considering options for future growth and development.

2.2.1 Freshwater Inundation

Coastal areas may be subject to overland flood flows from rivers and/or flooding derived from incident rainfall (stormwater). Many of the district's coastal communities are located on river floodplains (e.g. Collingwood, Riwaka, Motueka, parts of Richmond) that include low lying areas susceptible to stormwater secondary flow paths and/or ponding (e.g. Ruby Bay). Often the same low-pressure weather systems which result in significant storm-tide events on the coast may also be accompanied by rainfall.

The combined effects of coastal storm-tides and rainfall runoff events can be greater than the effects of one or other of the individual hazards. For example, stormwater outflows to the coast can reduce or cease during a high tide, exacerbating flooding inland. This hazard may be able to be managed via stormwater detention areas specifically designed to contain stormwater runoff unable to be discharged over high tide. However, as sea levels rise the effectiveness of such infrastructure will likely decrease.

2.2.2. Groundwater

The adjacent level of the sea can influence groundwater levels at the coast. As the level of the sea rises, coastal groundwater levels (i.e. the water table) will also rise. This can reduce the capacity for rainfall to infiltrate to ground, potentially resulting in increased stormwater ponding or wider dispersion of runoff. High groundwater levels can also result in increased seepage into pipe networks and below-ground infrastructure, including the basements of buildings. In some locations, groundwater levels may rise sufficiently across a high tide period that surface ponding occurs (i.e. the water table rises above ground level) even in the absence of rain. Low-lying land close to coastal margins, particularly where the ground is relatively permeable, is the most vulnerable.

2.2.3 Earthquakes

Where the land surface ruptures along a fault during an earthquake, the land masses on either side of the fault may also be displaced relative to each other (both vertically and horizontally). Of particular interest from a flooding hazard perspective is the downward movement of the land relative to the level of the sea.

The active Waimea-Flaxmore Fault System extends in a southwest/northeast direction along the foothills of the Richmond ranges and passes through the Richmond and Nelson urban areas. Previous ruptures of this fault system have resulted in vertical displacements of up to 1.0 metre (with uplift to the southeast and subsidence to the northwest). Consequently, coastal land extending from Richmond through to Kina Bluffs can be expected to subside to some extent during rupture of the Waimea Flaxmore Fault System (Wopereis, 2019).

Earthquakes on the Waimea-Flaxmore Fault System that may result in subsidence are infrequent, with an estimated average recurrence interval of approximately 6000 years. Remaining parts of the District are not expected to be affected by significant displacement.

2.2.4 Liquefaction

Liquefaction may result when sufficiently strong and persistent ground shaking (typically from an earthquake) occurs in areas where fine-grained unconsolidated sediments and high groundwater levels are present. Should liquefaction occur, the ejection of liquefied soils along with consolidation of remaining sediments may result in ground settlement (subsidence). Areas that are unrestrained on one or more sides, such as river banks and estuary margins, are also susceptible to lateral spreading.

The generally coarse-grained and/or gravely nature of much of the underlying geology in the Tasman and Golden Bays coastal margins limits the extent liquefaction potential. However, there remains the potential for ‘pockets’ of liquefaction to occur in areas where sufficient fine grained and saturated sediments are present. As sea levels rise, coastal groundwater levels will also rise and depending on the underlying geology, areas susceptible to liquefaction may increase. Furthermore, areas subject to liquefaction during a strong earthquake will likely be subject to a degree of consolidation and subsidence, thus exacerbating potential flooding hazard.

Council has not undertaken investigations to identify specific areas that may be susceptible to liquefaction, or quantify potential subsidence because of liquefaction. The probability is very low for an earthquake to occur in the next 100 years (typical planning timeframes for residential buildings) that is sufficiently large to cause liquefaction.

2.2.5 Tsunami

Tasman Bay and Golden Bay are both susceptible to tsunami hazard from various local, regional and distant sources. Nelson Tasman Civil Defence has published a series of tsunami evacuation maps on their website (www.nelsontasmancivildefence.co.nz). The maps show three evacuation zones (dependant on wave height) for areas in the Tasman and Nelson districts that are potentially subject to inundation from a tsunami. Given the very low probability of occurrence of significant tsunami, both Tasman District and Nelson City Councils do not address tsunami hazard in their resource management plans. Instead, the Councils focus on providing education and information for evacuation through their civil defence functions. As sea levels rise the areas potentially affected by tsunami will increase and evacuation maps will be periodically updated as required.

2.3 Previous Coastal Hazard Assessments

Coastal erosion and inundation hazard assessments have been undertaken over the years for a number of locations in the district. These assessments have varied in scope, including being part of a nation-wide research project (for example Gibb, 1978), regional assessments undertaken for university research theses, and site-specific assessments undertaken as part of resource consent applications, Environment Court cases and District Plan changes.

Erosion assessments have employed varying methodologies, including successive site surveys at benchmarks located in both bays, aerial photograph and survey cadastre comparison (more recently incorporating LiDAR survey analysis). Inundation assessments include on ground or aerial flood event mapping and computer modelling for assessing inundation hazard extents for planning and resource consent purposes. The first computer coastal inundation modelling (including the effects of wave runup) was undertaken for the Ruby Bay-Mapua coastal plain as part of Tasman Resource Management Plan Change 22.

A significant body of research into and assessment of the Tasman Bay and Golden Bay wave climate and inundation impacts on the shoreline has been undertaken in recent years by National Institute of Water and Atmospheric Research (NIWA) and specialist consultants, and some of these reports are noted in Section 10 Bibliography. Collectively, these coastal erosion and inundation assessments have helped to build an understanding of the nature and variability of the district's coastal hazards.

A 2014 NIWA study considered 14 representative 'open coastline' locations exposed to extreme sea levels within the district and considered factors such as combined tide, storm surge (inverse barometric and wind-induced effects), wave setup and wave runup. The study showed that wave setup makes a modest contribution to total elevation of the sea at the coastline relative to storm tides, owing to the relatively large tidal range and sheltered wave environment within the Bays.

However, wave runup makes a significantly larger contribution, being almost four times as large as wave setup. Wave runup is very sensitive to beach slope and is calculated at the MHWS-6 level on the beach profile. The NIWA assessment also does not take into account the effects of potential future erosion when considering the risk of inundation and does not provide maps or assessment on the extent, depth or volume of inundation inland of the shoreline.

2.4 NIWA Coastal Calculator

NIWA has developed a 'coastal calculator' tool for Tasman Bay and Golden Bay, based on an analysis of storm-tide-wave records up to April 2018. The tool is designed for use in open coast settings (it excludes estuarine environments) and uses a wave setup and runup formula (developed by Stockton et al (2006)) for sandy beaches. This tool is used to identify and assess a range of shoreline parameters at a number of locations in Tasman and Golden Bay (refer to Section 6) in a 1% annual exceedance probability (AEP) event. Parameters assessed for each site include offshore significant wave height, wave setup (WS), wave runup (WR), and the storm-tide (combined effect of a storm event and predicted tide, resulting in an offshore water level having a particular probability of occurrence) plus either WS or WR. The calculator can assess these values for a range of datum and sea level rise settings.

The coastal calculator is used to determine a range of parameters as outlined via either a joint-probability or response-variable approach. The latter is used this assessment and is regarded by NIWA as a better approach for the analysis undertaken, as likelihood is evaluated on the variable of interest rather than on wider offshore conditions.

While not applied in this assessment, the coastal calculator also has an additional wave-overtopping module that enables assessment of wave overtopping discharge (in litres/second/lineal metre of shoreline structure) for a range of sea wall structure configurations. However, no contribution from wave runup and overtopping is included in the assessed potential inundation levels of land lying behind shoreline structures and mapped in the *coastal hazards map viewer*.

2.5 Climate Change and Sea Level Rise

In 2015, Council commissioned NIWA to prepare a report that describes changes in the climate over the coming century that may occur in our district and outlines some of the possible impacts of these changes. Sea level rise is a key outcome arising from climate change and this will have a significant impact on our coastline and coastal communities. Some of the key findings of the report relevant to our district and coastal hazards is:

- around New Zealand, the sea level has risen by 190mm, or approximately 1.7mm per year since 1900;
- there is an expected temperature increase by mid-century of 0.7 to 1ºC, from those experienced in the 1900s;
- a projected increase in quantum and intensity of rainfall, mostly in winter;
- an increase in the intensity of tropical cyclones and extratropical cyclones (wind speed and rainfall intensity), which will affect coastal processes such as wave climate, storm surge magnitude and swell; and
- climate change will also impact on other coastal hazard drivers such as tides, storm surge, waves, swell, coastal erosion and the movements of beach and nearshore sediments within coastal zones (Chappell et al., 2015).

3. Coastal Inundation Methodology

3.1 Overview

This section details the methodology used to identify a range of tide and wave climate parameters assessed at a number of locations within Tasman Bay and Golden Bay and presented in the *coastal hazards map viewer*.

In simple terms, coastal inundation is primarily seawater flooding. The water level occurring along the shore is determined by the combination of a number of components, including those that are predictable (eg astronomical tide heights) and those that occur as a result of particular weather events. Key components include:

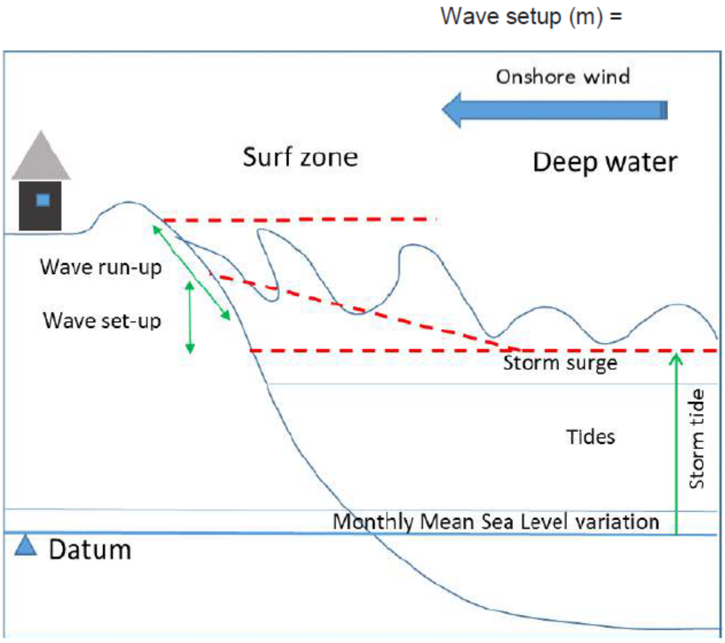
- Astronomical tide
- Barometric and wind effects, referred to as storm surge
- Nearshore wave effects, predominantly wave setup and wave runup
- Long term changes in relative sea level, resulting from climatic (eg sea level rise) or geological influences (eg shoreline uplift or subsidence, typically occurring in an earthquake).

Only climatic effects are taken into account in this assessment, although it is known that geologic change may occur in parts of the district during a significant earthquake (see Section 2.2.3). This will be addressed in a future review, as necessary.

These components interact to form either an extreme static water level (storm-tide and wave setup) or extreme dynamic water level (typically including storm-tide and wave runup). Wave effects and tide components are illustrated in Figure 3 and are described in the following sections.

Figure 3: Schematic illustrating the various water level components and processes that contribution to inundation

(Source: Stephens, S., Wadhwa, S and Tuckey, B (2016))



3.2 Astronomical Tide

Astronomical tides are the tides noted in the tide tables and nautical almanac. They can be predicted well into the future and are the tide levels calculated at standard atmospheric pressure (approximately 1014 hPa) and without any wind and wave effects. Tides in the Nelson-Tasman area are semi-diurnal (occurring twice-daily) with fortnightly spring-neap and monthly perigean-apogean cycles. Tidal forces acting on deep oceans create long waves that then propagate into the shelf areas and increase in height. The Collingwood area has the highest tide range in New Zealand, with ranges exceeding 4m arising from standing long waves generated to the west of Cook Strait (NIWA, 2013).

Standard Port Nelson Tidal Levels are shown in the table below for the period 1 July 2018-30 June 2019.

Table 1: Astronomical Tide Levels at Port Nelson

(Source: LINZ, www.linz.govt.nz/sea/tides/tide-predictions/standard-port-tidal-levels, 2019)

Tide		Chart Datum[2] (m)	NZVD2016*
HAT	Highest Astronomical Tide	4.68	2.12
MHWS	Mean High Water Spring	4.31	1.75
MHWS-6[1]	Mean High Water Spring-6	4.28	1.72
MHWN	Mean High Water neap	3.29	0.73
MSL*	Mean Sea Level	2.35	-0.17
MLWN	Mean Low Water Neap	1.44	-1.08
MLWS	Mean Low Water Spring	0.49	-2.03
LAT	Lowest Astronomical Tide	0.10	-2.42

*MSL (2008-2017), [1]MHWS exceeded by 6% of all tides based on NIWA 2013), [2]Datum used in Tide Tables

The mean high water spring (MHWS) tide mark defines the administrative boundary of the land with the coastal marine area (CMA) for resource management planning purposes (MfE, 2017).

MHWS-6 is the level of most high tides (94th percentile), at standard atmospheric pressure. Previous work undertaken by NIWA on behalf of the Council recommended applying MHWS-6 as a regionally consistent approach to defining MHWS, with only 6% of all predicted high tides exceed this MHWS-6 level. NIWA noted that some very high perigean-spring tides (king tides) can still significantly exceed the MHWS-6 level (NIWA, 2013).

3.3 Storm surge

Storm surge is the temporary increase in sea level above predicted tide level. This occurs when wind stress from winds blowing alongshore or onshore combines with low barometic pressure associated with weather systems. Storm surge excludes the wave runup and wave setup effects of storm waves at the shoreline.

Storm surge can vary around the New Zealand coastline, with studies showing that there appears to be an upper limit of just over 1m (S. Stephens pers.comm.). An MfE storm surge fact sheet notes that a 0.9m surge was recorded in the Kawhia Harbour (6 May 2013) and 0.88m surge in Tauranga Harbour during Cyclone Giselle (April 1968). The key factor that determines whether a high storm surge will cause flooding on low lying coastal land is whether it coincides with a high spring or perigean tides (MfE, 2017 (2)). A storm surge of 0.9m is considered representative of storm surge elevation having approximately an 80-100 year return period on average (MfE, 2004).

The combination of storm surge on the astronomical tide is referred to as storm-tide. NIWA (2018) have estimated long term storm-tide levels in the region and have assessed that a storm tide with a 1% annual exceedance probability (1% AEP) during present day sea levels (being mean sea level over the 2008-2017 period) reaches a level of 2.34m (NZVD2016) at Nelson Haven.

On 1 February 2018, ex-tropical cyclone Fehi generated a large storm surge that coincided with a very high tide. The storm tide water level reached RL 2.35m (NZVD2016) in Nelson Haven, assessed by NIWA as having a 1% AEP, or an average recurrence interval (ARI) of just over 100 years.

Table 2: Storm tide levels

(Source: NIWA, 2018, Nelson Fairway)

ARI (years)	NZVD2016 (m)
1	2.14
2	2.17
5	2.23
10	2.27
20	2.27
50	2.29
100	2.34
Ex-tropical cyclone Fehi 1 Feb 2018	2.35

3.4 Wave effects

Wave activity raises the effective level of the sea at the coastline above that of storm tides. The two key effects are wave setup and wave runup. Wave setup describes the increase in mean water level at the coast due to the presence and effect of breaking waves. As waves approach shallower water, they become too high relative to water depth. This causes them to become unstable and break. Wave energy is released in this process that is compensated for by an increase in water level. Wave runup is the maximum vertical extent of wave ‘uprush’ on a beach or structure and is a short term upper-bound fluctuation in water level compared to wave setup (MfE, 2017).

The wave climate in Tasman and Golden Bays is generated primarily by strong winds from the north-westerly to north-easterly quarter. However strong winds from the easterly and south-easterly direction, while less prevalent, are potentially more damaging to the east and south-east-facing shorelines of the Abel Tasman coast and northwest Golden Bay.

Wave and climate data used in the NIWA coastal calculator, to derive the various wave parameters for various sites in Tasman Bay and Golden Bay, was obtained from the Nelson Fairway Gauge and the Metbuoy in Golden Bay. For example, the Fairway wave-gauge data was used by NIWA in the coastal calculator to derive extreme wave heights in Tasman Bay. Table 3 shows these extreme wave heights, with the 1% AEP (100 year ARI) wave height assessed at 4.39m. Ex-tropical Cyclone Fehi produced wave conditions measured at 3.85m, having an ARI of approximately 23 years. However, the joint probability of the wave height and storm tide ARI for that event was estimated at just over 300 years, or approximately 0.3% AEP (NIWA, 2018).

Table 3: Extreme significant wave heights at the Nelson Fairway gauge
(Source: NIWA, 2018)

Annual Recurrence Interval (ARI) (years)	**Significant wave height H_s (m)**
1	2.53
2	2.83
5	3.21
10	3.49
20	3.78
50	4.13
100	4.39
Ex-TC Fehi 1 Feb 2018	3.85

3.4.1 Wave setup

Wave setup is generally a moderate component (about 25%) of the total sea level elevation on shorelines in Tasman and Golden Bays. This is due to the large tidal range and the limited distance (known as fetch length), within the bays over which wind can blow to generate waves. There is only a limited window for longer period (>12 seconds) swell waves, generated in Cook Strait and beyond, to propagate into Tasman and Golden Bay to affect the shoreline. This occurred, for example, during Cyclone Drena in 1997, where the swell wave that propagated into Tasman Bay from the Taranaki Bight dominated the locally wind-generated waves and caused significant shoreline erosion and inundation impacts. The NIWA coastal calculator is used to assess wave setup only at the open coast sandy beach sites.

Within the number of comparatively sheltered inlets and estuaries within Tasman Bay and Golden Bay, waves are “internally” generated by wind blowing across the water surface. Wave height is limited by wind speed and distance over water that it can blow (the fetch length), as well as water depth. Waves will break and dissipate their energy in water depths of less than around twice the wave height. Therefore the greatest waves heights will be generated by wind blowing over the longest water surface length during the highest water levels.

3.4.2 Wave runup

Waves generated within the bays are of sufficient height to cause wave runup on beaches that is generally significantly higher than that caused by wave setup. The slope and roughness of the beach and the effect of gravity affects the wave runup height reached on the shoreline. Wave runup effects are generally confined to the upper beach margin. Wave runup may overtop the beach crest and cause inundation of the land immediately behind. Inundation extent is determined by the shoreline topography, and the volume and duration of wave overtopping that occurs.

Wave runup is assessed at a number of beach locations in Tasman Bay and Golden Bay and is included in the data presented in the tables in Section 6. However, the contribution of wave runup overtopping to the mapped extent of inundation has not been included in the assessment. This is due to the lack of location-specific modelling required to determine the rate and volume of seawater overtopping for each sea level scenario. As observed during storm and cyclonic events such as ex-Tropical Cyclone Fehi in February 2018, wave overtopping can be a major contributor to the extent and depth of seawater inundation inland of the shoreline margin. This has been very much the case for inundation observed at McKee Domain/Ruby Bay/Mapua during high storm-tides and cyclonic events.

The NIWA coastal calculator uses a formula developed for sandy shorelines to calculate wave runup on the open coast in this assessment. However, as previously noted, a steeper upper beach slope calculated above the level of MHWS-6 than is used in the coastal calculator (calculated below MHWS-6) more accurately assesses and reflects wave runup heights achieved in storm events.

There may be a tendency for wave runup heights calculated using upper beach slopes to not be conservative in locations where there are upper beach slopes are very steep. In other than sandy beach situations, the coastal calculator formula no longer applies and other assessment methods are required. Wave runup figures are calculated for each beach cell using a representative average upper (sandy) beach slope for that cell.

Within the sheltered estuaries, open coast wave runup conditions do not exist and the coastal calculator method of wave runup assessment does not apply. Consistent with the methods used by Tonkin and Taylor for assessing wave runup for Nelson estuaries, a simplified approach was used, assuming wave runup height occurs that is similar to the wave height. As for Nelson estuaries, a wave runup height of 1m above still water level has been adopted in this assessment. In reality, wave runup height is very dependent on shoreline exposure, shoreline slope and type. However, wave runup effects within a sheltered shoreline setting are likely to be restricted to a moderate distance (perhaps 15-30m) from the shoreline edge.

3.4.3 Wave climate selection

The MfE 2017 Guidance poses the question as to how assessments of wave setup and wave runup should be used when developing rules controlling resource and building consents. The guidance states that:

"*Wave setup is an integral component of the total water level that potentially could cause direct or near-continuous inundation of 'green water'*[1] *onto coastal land. The combined storm*

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[1] 'Green water' is the flow of seawater onto coastal land.

tide plus wave setup level is therefore important for direct and quick-response coastal inundation.

The combined storm tide plus wave runup level is relevant to beach erosion and wave impact on seawalls and sand dunes and can result in wave overtopping. Overtopping by wave runup involves 'wave splash', 'wind spray' and sporadic shallow overwash of flowing 'green water' (depending how high the wave setup level is)… Flooding and erosion by wave runup and overtopping is often localised and site specific, and the overtopping discharge volume is unlikely to cause widespread inundation at locations 100 metres back from the coast (notwithstanding barrier collapse or landward down-sloping land." (MfE, 2017, p151).

There are some areas of the Tasman Bay and Golden Bay coastline where potential seawater inundation hazard is, at present, significantly if not totally dominated by wave runup overtopping during storm tide events. This is more likely in situations where nearshore wave energy is high, the back beach elevation is relatively low, or if the land slopes down to lower levels behind an elevated upper beach crest. Wave runup inundation was particularly evident at several locations in Tasman Bay during ex-tropical Cyclone Fehi, including Mapua-Ruby Bay, McKee Domain and Kina Peninsula.

Nevertheless, wave overtopping inundation at these locations was generally confined to relatively nearshore coastal land. As noted in the MfE 2017 Guidance, wave setup level, while occurring to a lower elevation than wave runup, can act to cause more widespread inundation of low lying land adjacent to the coast and where flow pathways exist inland than wave runup, particularly in a projected future sea level rise climate.

Therefore, in this assessment, the figures calculated for storm-tide and wave setup forms the basis for the range of water levels displayed in the coastal hazards map viewer. This is consistent with the methodology used by several agencies, including Auckland Council in their assessment *"Coastal Inundation by Storm-tides and Waves in the Auckland Region (June, 2016)"*

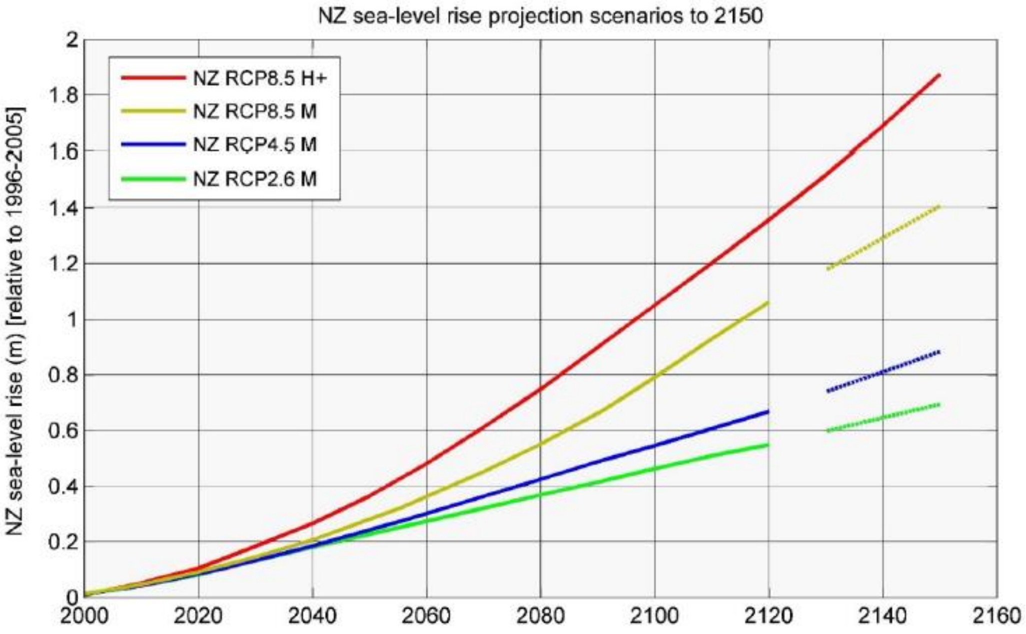
3.5 Sea level rise

New Zealand's average relative sea level rise rate is 1.76mm per year (±0.21mm). There is some regional variation of this figure, with Nelson's average relative sea level rise being 1.57mm/year (±0.22mm) (MfE, 2017). The New Zealand Coastal Policy Statement 2010 (NZCPS, 2010) requires that the identification of coastal hazards includes the effects of sea level rise over at least a 100 year planning period.

Many factors need to be taken into account when considering how future global warming will contribute to climate change and, ultimately, sea level rise. The MfE 2017 Guidance notes that because of the uncertainty about future changes in climate, it is necessary to examine a range of scenarios, known as representative concentration pathways (RCPs). Four RCPs have been developed for New Zealand, representing a range of climate model scenarios and possible sea level rise futures, as described below and shown in Figure 4:

- a low to eventual net-zero emission scenario (RCP2.6)
- an intermediate-low scenario based on the RCP4.5 median projections
- a scenario with continuing high emissions, based on the RCP8.5 median projections
- a higher H+ scenario, taking into account possible instabilities in polar ice sheets, based on the RCP8.5 (83rd percentile) projections.

Figure 4: Four scenarios of New Zealand-wide regional sea level rise projects to 2150
(MfE, 2017 (Fig 27))



New Zealand scenario trajectories are out to 2120 (covering a minimum planning timeframe of at least 100 years), and the NZ H$^+$ scenario trajectory is out to 2150 from Kopp et al (2014) (K14). No further extrapolation of the Intergovernmental Panel on Climate Change-based scenarios beyond 2120 was possible, hence the rate of rise for K14 median projections for RCP2.6, RCP4.5 and RCP8.5 are shown as dashed lines from 2130, to provide extended projections to 2150. Note: all scenarios include a small sea-level rise (SLR) offset from the global mean SLR for the regional sea around New Zealand.

For a range of sea level rise increments, the MfE 2017 Guidance identifies a bracketed sequence of years in the future when specific sea level rise increments may be reached in New Zealand, as shown in Table 4. MfE advises that these sea level rise scenarios should be used for hazard, vulnerability and risk assessments and adaption planning.

Table 4: Approximate years, from possible earliest to latest, when specific sea level rise increments (metres above 1986-2005 baseline) could be reached for various projection scenarios of sea level rise for the wider New Zealand region
(Source: MfE, 2017 (Table 11))

SLR (metres)	Year achieved for RCP8.5 H+ (83%ile)	Year achieved for RCP8.5 (median)	Year achieved for RCP4.5 (median)	Year achieved for RCP2.6 (median)
0.3	2045	2050	2060	2070
0.4	2055	2065	2075	2090
0.5	2060	2075	2090	2110
0.6	2070	2085	2110	2130
0.7	2075	2090	2125	2155
0.8	2085	2100	2140	2175
0.9	2090	2110	2155	2200
1.0	2100	2115	2170	>2200
1.2	2110	2130	2200	>2200
1.5	2130	2160	>2200	>2200
1.8	2145	2180	>2200	>2200
1.9	2150	2195	>2200	>2200

3.6 Coastal Inundation Methodology

The *coastal hazards map viewer* indicates the potential extent of inundation of land lying below the level of the sea generated at a particular location for a selection of storm-tide and sea level rise scenarios.

As the wind, wave and tide climate varies a little within Tasman Bay and Golden Bay, the shoreline within the two bays has been broken into “open coast” and “sheltered water” cells. Each cell is chosen has a reasonably representative character and aspect of the sandy shorelines, along with a wind, wave and tide climate in that locality that results in a reasonably similar 1% AEP joint probability storm-tide-wave set-up level for beaches in that cell.

Appendix A shows the extent of the coastal cells in Tasman Bay and Golden Bay, respectively. There are eight coastal cells identified in Tasman Bay and six coastal cells identified in Golden Bay.

3.6.1 Open Coast Sandy Beaches

The coastal calculator uses a wave setup and wave runup formula developed for sandy beaches. Therefore, the data presented the tables in Section 6 are derived for sandy beach locations or pockets of sand beach in locations where the shoreline character varies (eg structure presence, rocky shorelines).

The formula assumes a constant beach slope. In the coastal calculator, the beach slope is assessed below the line of MHWS-6 (1.7-1.8m NZVD2016). However, observed wave runup during storm events is greater than that computed for the observed event using the calculator beach slope. Observed and calculated wave runup elevations are similar when steeper upper beach slopes than suggested in the calculator are used. This approach is recommended to effectively calibrate the calculator (Scott Stephens, NIWA, pers. comm). This is based on matching observed runup as reported by other researchers and is also consistent with calculator applications in other regions. This approach is applied in the assessment and mapping undertaken.

An assessment of wave setup (and wave runup) for open coast shorelines in each coastal cell (presented in the tables in Section 6) is based on the average of several representative beach slopes between the 2.0m and 2.5m (NZVD2016) contours inferred from recent LiDAR data. This approach is appropriate for broad scale assessment and mapping purposes. However, for site specific design or planning purposes, it is recommended that upper beach slopes are surveyed and assessments made, with outputs calibrated against known events where possible.

For the purposes of scenario mapping, the calculator assessment assumes that the beach slope used remains constant for each sea level rise scenario selected. This may not be the case in reality, due to a number factors. These include change in shoreline topography, beach profile changes caused by erosion (or accretion), changes to nearshore sediment composition and the like.

The data in the tables presented in Section 6 are for a 1% AEP storm-tide event in a present-day climate, as recommended by MfE. For levels in a projected future climate, the coastal calculator adds the chosen quantum of sea level rise to the present-day level data. This potentially results in under-approximation of future wave setup and wave runup levels for an upper beach having similar slope. This is because the nearshore water depth will likely increase with sea level rise, resulting in an increase in breaking-wave energy at the shore. However, the nearshore seabed level and beach profile will also adjust to the increased sea levels to some degree, so this remains an inherent uncertainty. If beach profiles remain similar into the future, then the main increase in hazard exposure will be driven by sea level rise and resultant increase in nearshore wave dynamics.

3.6.2 Estuaries and Inlets

The offshore wave conditions assessed in the NIWA coastal calculator are not applicable in a sheltered estuarine environment. Instead, an approach consistent with work being undertaken by coastal practitioners Tonkin and Taylor Ltd on behalf of Nelson City Council has been applied for assessing significant wave height (H_s) and wave setup in eastern Tasman Bay estuaries. This is considered appropriate and acceptable, as the nature and scale of estuaries are similar in the Nelson-Tasman area.

The Tonkin and Taylor Ltd methodology is described thus:

- The significant wave height is based on the 1% AEP 3 second gust wind speed as set out in AS/NZS 1170.2:2011 Part 2 Wind Actions. These 3 second-gust wind speeds have then been converted to average wind speeds of an assumed 60 minute duration using procedures in the Coastal Engineering Manual (CEM) 1110-2-1100 (USACE, 2006). Fetch-limited waves are calculated based on the methods according to Wilson (1965) and revisited by Goda (2003) with the maximum directional wave height adopted.
- Wave setup within the sheltered estuary coastlines is calculated based on the empirical model of Thornton & Guza (1982), where setup = 0.17 H_s. Table 5 shows the fetch-limited wave height and wave setup for different fetch distances. The estuaries within the district typically have a fetch between 1km and 4km. However, due to the shallow water depth (typically less than 2m at high tide), waves are not expected to reach a height greater than around $H_s = 1.1$m. Thus, a similar wave height of $H_s = 1.1$m and corresponding wave setup height of 0.2m has been adopted in this assessment for the sheltered water coastal cells.
- Fetch and depth-limited wave formulae could be used for specific situations, but the simplified approach taken is considered satisfactory within the assumed uncertainty limitations/approximations.

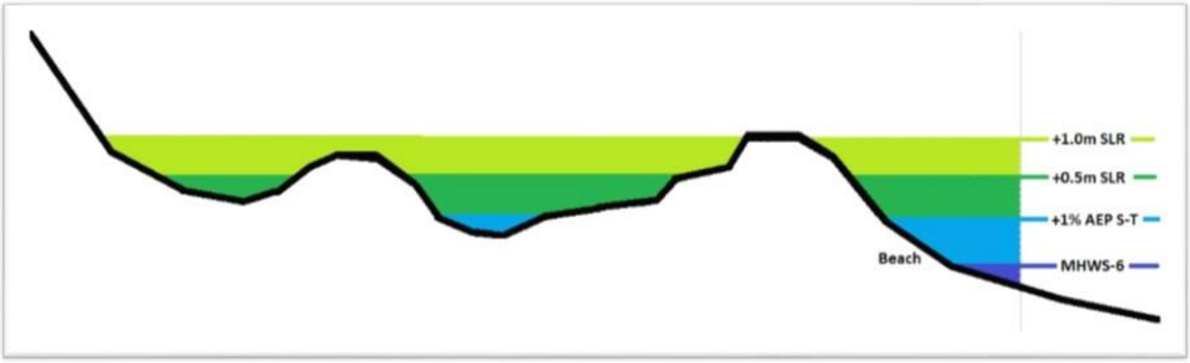
Table 5: Significant wave height and wave setup by fetch distance

Fetch (km)	Significant wave height H_s (m)	Wave setup (m)
<0.5	0.6	0.1
0.5 - 1.0	0.8	0.15
1 - 2	1.1	0.2
2 - 4	1.5	0.25

3.6.3 Sea Level Elevation Mapping

The extent of land potentially subject to coastal inundation is mapped using the static level inundation mapping technique. This method is sometimes referred to as the “bath tub” model (the line that a bath tub would fill to). This technique involves identifying and mapping all land lying below a calculated water level. In the map viewer, the levels of the present day MHWS-6 and 1% AEP storm-tide/wave setup event can be selected. To these levels can be added a quantum of sea level rise in 0.5m increments up to 2m. The 1% AEP event is the size of event recommended in the MfE 2017 Guidance. This “bathtub” inundation methodology is presented in Figure 5.

Figure 5: "Bathtub" inundation profile



The inundation extent of either present day MHWS-6 or 1% AEP storm-tide wave set-up, elevated by 0.5m increments of sea level rise, is used as a broad indicator of land that may be susceptible to seawater inundation. The extent of land subject to inundation is conservative, as it does not accurately represent the dynamic effects and variable processes over time (eg tidal cycle, wind effects) that occur during a storm-tide event, particularly along wide, low-lying coastal plains. It also does not take into account the effect of a range of features and factors that can limit inundation extent. These include causeways, tide banks and higher nearshore crest levels, culvert and bridge structures, the absence of inundation pathways to the respective land levels (and below), and the distance of the land from the coast. Council has used ARC-GIS software and a LiDAR-derived digital elevation model to map the spatial extent of land at or below the level for each extreme water level scenario.

There are areas well set back from the coast in the district that are shown as being affected by seawater inundation in the coastal hazards map viewer. One example of this is the very low-lying land north of Mapua Drive and west Stafford Drive at Mapua, formerly a flax wetland supporting a flax-milling industry. Such areas are presently affected by flooding arising from stormwater runoff, with drainage exacerbated by backwater effects during high tide levels. However, while the map viewer illustrates locations of very low lying land weakly connected to the coast at present (if at all), these areas become increasingly vulnerable to seawater inundation in circumstances where an overland flow connection to the coast becomes more strongly established in a significant sea level rise future.

The coastal inundation outputs for each coastal cell is summarised in Section 6.2. When viewing the extent of the 1% AEP joint probability storm-tide on the coastal hazards map viewer it appears as a continuous line, although on closer inspection, the joins between cells are visible where the outputs between coastal cells are different. This is because the 1% AEP storm-tide height varies a little between coastal cells, due to variance in the probability of water levels and wave height, that may result in a higher extreme water level.

In addition to the 1% AEP joint probability storm-tide, 0.5m increments of sea level rise can be selected, to aid understanding of the susceptibility to hazard exposure and potential impacts from sea level rise at various locations within Tasman Bay and Golden Bay. Following MfE's 2017 Guidance (p143), the approach taken for sea level rise was to identify increments of sea level rise heights and then relate this to likely bracketed time periods of occurrence across the range of representative concentration pathway (RCP) scenarios. Broadly speaking, the warmer the climate becomes, the faster sea levels will rise – with the warmest scenario being represented by RCP8.5H+ and lower rates of warming presented under RCP2.6.

The MfE 2017 Guidance suggests mapping sea level rise increments of 0.1m or 0.2m. However, for simplicity of display and for community engagement purposes, Council has mapped a larger sea level rise increment of 0.5m in the map viewer. Council can map these at smaller increments of sea level rise (or larger ones) if necessary.

The MfE 2017 Guidance provides increments of sea level rise up to 1.9m and corresponding time periods when each level could be reached (as shown in Section 3.5 Table 4). As the inundation map viewer provides sea level rise selection in 0.5m increments, Council has adapted the MfE information to include a sea level rise height of 2m in the map viewer. Table 6 data (below) applies the greater-than symbol ('>') to denote that the year when this may be reached under each scenario is sometime after those years provided for under 1.9m sea level rise. This specifically relates to RCP8.5 H+ and RCP 8.5 (median) as the other two scenarios are already at >2200.

Table 6: Approximate years, from possible earliest to latest, when sea level rise increments of 0.5m (metres above 1986-2005 baseline) could be reached for various projection scenarios of sea level rise for the wider New Zealand region
(Source: adapted from MfE, 2017 (Table 11))

SLR (metres)	Year achieved for RCP8.5 H+ (83%ile)	Year achieved for RCP8.5 (median)	Year achieved for RCP4.5 (median)	Year achieved for RCP2.6 (median)
0.5	2060	2075	2090	2110
1.0	2100	2115	2170	>2200
1.5	2130	2160	>2200	>2200
1.9	2150	2195	>2200	>2200
2.0	>2150	>2195	>2200	>2200

An inundation level at MHWS-6 has also been included on the coastal hazards map viewer to give an indication of the land below this level potentially subject to inundation in a present day high tide. From this level, comparison with the extent of both the 1% AEP joint probability storm-tide and influence of various sea level rise increments is possible. As the level of the sea rises due to the effects of climate change, the level of MHWS-6 will increase and its location will inevitably move inland, unless physically prevented from doing so.

The outputs are described in Section 6 and can be viewed on the Council's *coastal hazards map viewer*.

4. Coastal Erosion and Accretion Methodology

This section details the methodology use to assess coastal erosion and accretion in Tasman Bay and Golden Bay.

4.1 Coastal Erosion and Accretion Processes

Coastal erosion (sediment loss) and accretion (sediment gain) processes are generated by either tide, wave and/or wind action. Erosion or accretion occurs when there is a net loss or gain of coastal sediments from the immediate shoreline area. This results in the beach profile degrading/retreating landward (in the case of erosion), or elevating/advancing seaward (in the case of accretion), either in the short term (eg during a storm event), over a period of years, or permanently.

Beaches or shorelines will often experience a cycle of erosion followed by accretion, with the duration of the erosion-accretion phase ranging from weeks (the period of the storm event and post-storm recovery) to longer periods that reflect annual-decadal (eg El Nino, La Nina) or multi decadal (eg the Inter-decadal Pacific Oscillation (IPO)) weather patterns.

Shoreline erosion or accretion trends may also alter due to wider climatic, topographic or human-induced changes that affect the supply of sediment into the coastal environment and beach system. These include:

- Changes in catchment cover that may increase or reduce sediment runoff to river systems and subsequently the coast.
- Extreme rainfall events in river catchment systems that transport significant quantities of fine sediment (from slope failure or riverbed and bank erosion) into the coastal system.
- Extreme flood events may also alter the location of the river outflow channel to the coast (eg Takaka, 1983). This may alter how sediment input into the coastal system occurs and its subsequent mobilisation by wave and tide action onto (and along) the shoreline.
- Bridge and causeway structures may affect the local wave climate, or alter river outflow or tidal flow paths and thus affect sediment transport routes to and along the coast.
- Erosion protection and other hard shoreline structures remove the ability of that section of the shoreline to provide sediments to littoral drift processes. This often results in sediment starvation (“end effect erosion”) of the natural shoreline immediately beyond the structure and within the shoreline compartment generally.

Shoreline erosion may also occur on beaches and dune systems exposed to persistent or strong winds, in circumstances where unconsolidated or sandy soils are dry and lack sufficient vegetation cover to stabilise the land. Wind is not a significant factor in shoreline erosion or accretion processes in Tasman Bay or Golden Bay, compared to wave and tidal effects. Nevertheless, wind erosion is most prevalent on the large dune systems on the west coast and Farewell Spit, but also occurs to a lesser scale and from time to time on sandspits at Onahau, Parapara, Pohara and Wainui Bay in Golden Bay and on Rabbit Island and the Motueka sandspit in Tasman Bay. Kaiteriteri beach periodically experiences strong onshore winds that blows beach sand inland onto the adjacent carparks and road.

The effects of wind and wave erosion can be moderated or remediated whilst retaining a natural shoreline interface through mechanical beach renourishment and dune vegetation planting (Coast Care initiatives), in circumstances where natural recovery and repair may be slow or unable to occur.

4.2 Coastal Erosion and Accretion Methodology

Erosion and accretion rates vary significantly and over varying time scales and can be significantly different in shorter periods compared to a trend averaged over a longer period. In this assessment, the persistent trends of coastal erosion and accretion mapped in the coastal hazards map viewer is based on the long-term average of at least 30 years of record of natural shoreline change. This information derived from a range of sources used by both Council staff and external researchers, including historic aerial photographs, survey cadastre and beach cross section survey measurements.

Several shorelines in Golden Bay and Tasman Bay are protected from the effects of erosion by a range of (mostly rock revetment) structures. The erosion rates indicated at these locations are those that prevailed prior to structural intervention taking place. Erosion and accretion rates are categorised and mapped as:

- High erosion: >0.5m per year
- Medium erosion: 0.2m – 0.5m per year
- Low erosion: <0.2m per year
- Accretion occurring over last 30 years

On dynamic sandy shorelines, it is inevitable that periods of accretion can occur in response to storm events and climate weather patterns (including La Nina, El Nino). Accretion phases occurring in these circumstances may persist over the short to medium term (weeks to several years) and on a small to medium scale (1-2m seaward over tens to several hundred lineal metres). These smaller scale and duration accretion patterns have not been assessed or mapped in the *coastal hazards map viewer*.

A 30-year timeframe is reasonable for determining the more recent long-term erosion or accretion trends prevailing on the shoreline. How these trends or rates will change in a projected climate change sea level rise future is uncertain. However, it is considered that for most localities, erosion rates are likely to increase and areas of accretion will likely begin to exhibit an erosion trend. The latter trend is becoming evident at Collingwood, where there are indications of erosion occurring to the accretion area.

The accretion areas mapped in the viewer have occurred in areas where that accretion has been the overall, persistent and predominant shoreline trend over the last 30 years. In the two cases mapped (Collingwood and Motueka sand spit), there remains a high degree of dynamic change within the overall accretion trend. At Collingwood, the accretion phase appears to have reached a peak, with some indications of an erosion trend being observed. The Motueka sand spit, while having extended significantly southwards, has also undergone significant translation landward, particularly north of Port Motueka, as well as undergoing major elevation and width changes over the last 30 years, to the extent that is it now more regularly overtopped during very high tides. It has also shown signs of breaching and general structural fragility.

The outputs are described in Section 6 and can be viewed on Council's *coastal hazards map viewer*.

5. Coastal Protection Structures

5.1 What are Coastal Protection Structures?

Coastal protection structures include sloping-faced rock and concrete block revetments, vertical or near-vertical timber and concrete walls, stopbanks, tidebanks and causeways. All of these structures modify and/or inhibit the function of natural coastal processes (primarily erosion and inundation) on beaches and nearshore coastal land. Their purpose is to moderate or prevent the potential adverse impacts of natural processes on a built environment and/or coastal land uses.

The location of a coastal protection structure, and how coastal processes respond to the placement of that structure, may result in the degradation of the natural, cultural, habitat, ecological, access and recreational values of beaches and loss of the high tide beach. The use of coastal protection structures can also result in unintended outcomes, including adverse environmental effects (including 'end wall effects') and implications for liability, the cost of ongoing maintenance, and in some circumstances the use (and/or loss) of public land for private benefit. Policy 27 of the New Zealand Coastal Policy Statement (2010) provides guidance on the use of hard protection structures as an option for reducing coastal hazard risk in areas of significant existing development.

At several locations along the Tasman Bay and Golden Bay coastline, there are a number of coastal protection structures, built on both public and private property, to protect land, buildings and/or community assets (roads, parks and reserves, etc) from coastal erosion and/or inundation. These structures are built from a variety of materials and not all of them have formal authorisation.

5.2 Coastal Protection Structures Mapping Methodology

Coastal protection structures along the Tasman Bay and Golden Bay coastlines have been categorised and mapped as:

- **Intermittent rock**: a length of shoreline where rock protection works are present (or are likely to be present) but over discontinuous lengths and over approximately 20-50% of the shoreline.
- **Bunds or stopbanks**: A linear mound structure, typically earth material, built to exclude seawater.
- **Revetment or wall**: a structure predominantly for erosion protection purposes, but also for the purpose of seawater exclusion if higher than the land behind. Revetments are typically rock-faced shorelines and/or structures having a sloping face no steeper than approximately IV:1H, whereas walls are structures having faces with slopes greater than 1V:1H and typically vertical, made from a variety of materials.
- **Causeways**: a structure that crosses land subject to permanent, frequent or periodic seawater and/or freshwater inundation on both sides. They are generally constructed to facilitate road access along the coast or across low lying land subject to tidal effects.

The outputs are described in Section 6 and can be viewed on Council's *coastal hazards map viewer*.

5.3 Existing Management of Coastal Hazards with Coastal Protection Structures

Comparing the location of the coastal protection structures and the extent of the coastal hazards on the *coastal hazards map viewer*, the mapped outputs highlight the extent of our coastline that is actively managed using structures.

In some coastal areas of the district, coastal protection structures are in place to manage the coastal inundation risk from present day high tides (MHWS-6). Locations include both farmland and industrial land adjacent to the Waimea Inlet, coastal farmland near Riwaka, and coastal farmland at Ferntown (near Collingwood). Some low lying locations behind tide banks and areas where drainage is compromised by high tide levels presently utilise pumps to control or reduce water levels.

Council has little control over private protection structures on the coast, or certainty that they will continue to function in a protective capacity into the future. Council-owned and private coastal protection structures that have resource consents often allow maintenance to occur as required. However, their presence is uncertain beyond the consent expiry date. Shoreline management at a number of locations in the District is successfully undertaken through beach replenishment and Coast Care activities, but may become unsustainable in a projected future climate.

The coastal hazard map viewer ignores the “blocking” presence of structures for particular levels of seawater inundation; with the structures becoming inundated themselves when sea level exceeds the structure crest level. Figure 6 shows the extent of some of the low-lying coastal farmland adjacent to Moturoa/Rabbit Island that would be inundated at high tide (MHWS-6) in the absence of the existing stopbank. Over time, areas such as this will become more vulnerable to coastal inundation as a result of sea level rise.

Over time, rising sea levels will cause coastal protection structures to be overtopped by waves or high tides more regularly as MHW-6 moves inland. How individual beach profiles respond to rising seas and inundation, and subsequent coastal erosion (or accretion) will depend on a number of factors such as beach materials, slope, or the presence of existing coastal protection structures.

Figure 6: Farmland presently protected from tidal inundation during a MHWS tide (left image) but potentially affected by the tide (right image) in the absence of the tide bank

The mapping of shoreline erosion rates in various areas in the district are shown on the *coastal hazards map viewer*, often in combination with the presence of a coastal protection structure. The shoreline erosion trend in such areas is indicative of the underlying 30 year average erosion rate at that location prior to structural intervention taking place. This mapping methodology is adopted to indicate that these areas require ongoing active management (or consideration of alternative options, such as managed retreat), in the absence (or failure) of structural interventions.

For example, Figure 7 shows the location of the rock revetment wall that protects the northern Sandy Bay-Marahau Road from erosion hazard. The road was protected as it is a key transport corridor not easily relocated away from the coast. While the road provides access to a number of residential properties and tourism-related businesses in Marahau, it is also the southern gateway to the Abel Tasman National Park.

Figure 7: Coastal erosion (red line) and coastal protection structures (black line) at Marahau

Other examples shown on the *coastal hazards map viewer*, where high/medium beach erosion rates are presently managed using coastal protection structures, include Ruby Bay/Mapua, Kina peninsula, Pohara, Rototai, Rangihaeata, Patons Rock and Pakawau.

6. Coastal Inundation Hazard Assessment

6.1 Overview

As mentioned earlier, for this assessment the coastline of Tasman Bay and Golden Bay is partitioned into ‘coastal cells’ (see Appendix A). Each cell encompasses an area of the coastal environment assessed as having generally similar shoreline characteristics and extreme water levels, based on similar wave climate, shoreline aspect, upper beach slope and wave and water level conditions (based on the coastal calculator tool, NIWA, 2018). Within each cell, the inundation model illustrates the maximum extent of land exposed to potential inundation up to the extreme static water level for that cell, assuming the existence of an inundation pathway. The effects of wave run-up overtopping on inundation levels are excluded.

The NIWA coastal calculator (based on an analysis of storm-tide-wave records up to April 2018) was used (other than within estuaries) to derive the present day 1% AEP storm-tide levels and wave conditions in each coastal cell.

Some coastal cells include more than one site for which the NIWA coastal calculator can assess wave parameters. In these cells, wave parameters are assessed for each site, as noted in the tables. The coastal hazards map viewer maps the highest of the storm-tide wave set-up levels assessed, highlighted in bold in the respective tables.

There is potential for river flows to increase the extreme water levels assessed for estuaries. This is particularly the case for estuarine coastal cells with large river catchments, such as the Waimea and Ruataniwha estuaries. The assessed extreme static water levels in both the open coast and estuary cells excludes any contribution from river flows.

For each coastal cell, this section describes:

- Key features and characteristics of the coastal environment, including notable coastal protection structures and erosion/accretion trends.

- The NIWA coastal calculator was used to assess (other than within estuaries) the 1% AEP joint probability storm-tide static water level and wave run-up level.

6.2 Assessment for Coastal Cells

6.2.1 Waimea Inlet

The Waimea Inlet coastal cell extends from Champion Rd, Richmond through to Grossi Point at Mapua. The estuarine environment of the Waimea Inlet includes a number of islands, including Best Island, Bell Island and Rough Island, and the inner shoreline of Moturoa/Rabbit Island.

The coastlines within the Waimea estuary cell are relatively sheltered and are not subject to direct exposure from waves generated in Tasman Bay. Nevertheless, waves are generated within the estuary by wind blowing over the water surface, but are limited by fetch distance and water depth. Wave height and setup is calculated for the estuary environment using formulas applicable for a sheltered coast.

Table 7: Present day 1% AEP water level components and total water levels for the Waimea Inlet

MHWS-6 (m NZVD2016)	1.72
Storm tide (m NZVD2016)	2.34
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.54
Extreme runup water level (m NZVD2016)	3.34

[1] Fetch-limited wave height

6.2.2 Moturoa/Rabbit Island

This coastal cell extends over the open-coast shoreline of Moturoa/Rabbit Island between the two outlets (Mapua Channel and Blind Channel) of the Waimea Inlet to Tasman Bay. The shoreline is characterised by long-term low-level accretion at the western and eastern ends of the island, with variable but generally low-level long-term average erosion taking place on the balance of the shoreline. In recent years, erosion has been a little more pronounced (>0.2m/year average) than the long-term average in the central and eastern areas of the shoreline resulting from storm activity.

Table 8: Present day 1% AEP water level components and total water levels for Moturoa/Rabbit Island

MHWS-6 (m NZVD2016)	1.75
Joint probability storm tide (m NZVD2016)	2.29
Beach slope (mV:mH)	0.08
Wave height[1] (m)	3.41
Wave setup (m)	0.46
Extreme static water level (m NZVD2016)	2.66
Extreme runup water level (m NZVD2016)	3.39

[1] Offshore significant wave height (independent of storm-tide)

6.2.3 Mapua - Ruby Bay - Kina Cliffs

This coastal cell extends along the open-coast shoreline from the Mapua Channel, westwards along the Ruby Bay coast to the western end of the coastal cliffs on the Kina Peninsula. The shoreline is characterised by low to very low long-term erosion rates at the base of the Kina cliffs and extending eastward to the northern end of Ruby Bay several hundred metres south of the Pinehill Stream outlet. From this point south the underlying long-term erosion rates along the now structurally modified shoreline increase rapidly, to exceed 0.5m/year adjacent to Broadsea Ave and more than 1m/year along the Old Mill Walkway frontage and further east to the Mapua Leisure Park.

Table 6: Present day 1% AEP water level components and total water levels for Mapua - Ruby Bay - Kina Cliffs

MHWS-6 (m NZVD2016)	1.74
Storm tide (m NZVD2016)	2.28
Beach slope (mV:mH)	0.16
Wave height[1] (m)	2.72
Wave setup (m)	0.73
Extreme static water level (m NZVD2016)	2.91
Extreme runup water level (m NZVD2016)	3.88

[1]Offshore significant wave height (independent of storm-tide)

6.2.4 Moutere Inlet

This coastal cell comprises of the sheltered environment of the Moutere Inlet, from Kina Peninsula through to Motueka. This area is sheltered from the open coast by Kina Peninsula, Jackett Island and the Motueka sand spit. The long-term shoreline accretion-erosion trends are slight, as one might expect in a small estuary environment.

Table 10: Present day 1% AEP water level components and total water levels for Moutere Inlet

MHWS-6 (m NZVD2016)	1.73
Storm tide (m NZVD2016)	2.27
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.47
Extreme runup water level (m NZVD2016)	3.27

[1]Fetch-limited wave height

6.2.5 Kina Peninsula – Motueka – Riwaka – Tapu Bay

This coastal cell comprises the open-coastal environment from the low-lying spit tip of the Kina Peninsula through to the Riwaka tidal flats at the base of the Takaka Hill. North of Kina Peninsula lies Jackett Island. At present, the supra-tidal and subtidal formation of the Motueka spit modifies the open coast wave climate inshore of the spit and thus moderates the wave exposure and thus wave erosion to most of Jackett Island, the Motueka township and plains shoreline.

The Jackett Island foreshore, particularly the central and southern sections, nevertheless has been affected over the last 10-20 years by an increasing shoreline erosion trend. This is due to the tidal outflow out of the Moutere Inlet from the Port Motueka channel being deflected southward and eventually closer to the central-southern Jackett Island shore by the Motueka spit, as it has extended southward.

The sandspit is a dynamic feature created by longshore drift of sediment southwards from the Motueka River, with its supra-tidal (above tide) exposure varying significantly over time. The wave climate figures in the table below relate to the more open-coast Motueka site, but beach slope and wave data for the wider coastline within this cell is similar.

Table 7: Present day 1% AEP water level components and total water levels for Kina Peninsula - Motueka - Riwaka - Tapu Bay

	Kina peninsula	**Motueka**	Riwaka
MHWS-6 (m NZVD2016)	1.73	**1.73**	1.72
Storm tide (m NZVD2016)	2.27	**2.27**	2.27
Beach slope (mV:mH)	0.09	**0.12**	0.12
Wave height[1] (m)	3.46	**3.11**	2.81
Wave setup (m)	0.52	**0.62**	0.56
Extreme static water level (m NZVD2016)	2.68	**2.76**	2.71
Extreme runup water level (m NZVD2016)	3.46	**3.62**	3.51

[1] Offshore significant wave height (independent of storm-tide)

6.2.6 Kaiteriteri – Marahau – Torrent Bay – Onetahuti

This open-coast cell extends from the headland at the southern end of Kaiteriteri Bay to Awaroa Head in the Abel Tasman National Park. This includes the holiday destinations of Kaiteriteri and Sandy Bay-Marahau and a number of bays and coves in Abel Tasman National Park, including Anchorage, Torrent Bay, Bark Bay and Onetahuti. Beaches on this shoreline are characterised by their distinctive golden sand, originating from Separation Point granite.

Most of the beaches in this cell are exposed to an infrequent but potentially erosive easterly wind and wave climate. This results in episodes of beach erosion that exceeds the ability of the generally prevailing northerly quarter wind and wave climate to repair, by mobilising onshore the sediments deposited on the inter-tidal beach platform. Consequently, periodic mechanical beach replenishment is undertaken at Torrent Bay and Kaiteriteri, to maintain shoreline stability and location within a target beach profile envelope.

The long-term erosion trend at Marahau has caused general landward retreat of the coast over the last 30-50 years. This has resulted in the formation (and then merger) of the outer Otuwhero Inlet spit with the earlier-formed inner spit, the structural rock protection of the central shoreline fronting the access road and the community, and progressive retreat of the northern beach on the land owned by Wakatu Incorporated.

Table 8: Present day 1% AEP water level components and total water levels for Kaiteriteri - Marahau - Torrent Bay - Onetahuti Beach

	Kaiteriteri	Marahau
MHWS-6 (m NZVD2016)	**1.68**	1.72
Storm tide (m NZVD2016)	**2.27**	2.27
Beach slope (mV:mH)	**0.17**	0.16
Wave height[1] (m)	**3.07**	2.28
Wave setup (m)	**0.87**	0.61
Extreme static water level (m NZVD2016)	**2.97**	2.83
Extreme runup water level (m NZVD2016)	**4.10**	3.67

[1] Offshore significant wave height (independent of storm-tide)

6.2.7 Otuwhero - Awaroa Inlet

This coastal cell encompasses the Outwhero Inlet and Awaroa Inlet, adjacent to and within the Abel Tasman National Park. Erosion processes and rates generally occur at a very low rate. However, it is worth noting that the estuary shorelines immediately south of the Inlet mouth are susceptible to infrequent but moderate erosion. This has occurred periodically on the section of the shoreline of the reserve fronting the Meadowbank community west of the Venture Creek outlet to the estuary. This short-term erosion phase occurs when the very dynamic bar complex at the mouth of the Inlet is sufficiently depleted, or in such a configuration, that allows the open coast wave climate to propagate into the inlet mouth area and increase the wave activity on the shoreline. This was particularly evident (and damaging at the western extremity) during ex-Tropical Cyclone Fehi in February 2018. This cell also includes Otuwhero Inlet and other smaller inlets within the National Park.

Table 13: Present day 1% AEP water level components and total water levels for Otuwhero - Awaroa Inlet

MHWS-6 (m NZVD2016)	1.74
Storm tide (m NZVD2016)	2.27
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.47
Extreme runup water level (m NZVD2016)	3.27

[1] Fetch-limited wave height

6.2.8 Awaroa Bay – Totaranui – Separation Point

This coastal cell includes the open-coast northern section of Abel Tasman National Park from Awaroa Head to Separation Point. The coastline comprises coastal cliffs and sandy bays, formed from Separation Point granite. The beaches have been relatively stable over the assessment period, but are periodically subject to storm events causing erosion of the beach that subsequently largely recovers over time. There also occurs a very infrequent realignment/relocation of the river outflow location through theses beaches (eg Waiharakeke) and sandspits (eg Falls River, Bark Bay) to the coast.

Table 94: Present day 1% AEP water level components and total water levels for Awaroa Bay - Totaranui - Separation Point

MHWS-6 (m NZVD2016)	1.74
Storm tide (m NZVD2016)	2.27
Beach slope (mV:mH)	0.14
Wave height[1] (m)	4.92
Wave setup (m)	1.15
Extreme static water level (m NZVD2016)	3.19
Extreme runup water level (m NZVD2016)	4.74

[1]Offshore significant wave height (independent of storm-tide)

6.2.9 Ligar Bay – Tata Beach – Wainui Bay – Whariwharangi Bay

This coastal cell comprises a number of open-coast bays at the southeastern end of Golden Bay, from Separation Point to Port Tarakohe. These bays also have the distinctive yellow sands originating from Separation Point Granite and are the northern boundary of this geological feature. This cell contains the dynamic sandspit feature at the entrance to Wainui Bay. The beaches face the prevailing northwesterly wind and wave climate and experience episodic mild-moderate erosion events that overall contribute to a mostly lower long-term erosion trend.

Table 15: Present day 1% AEP water level components and total water levels for Ligar Bay - Tata Beach - Wainui Bay - Whariwharangi Bay

MHWS-6 (m NZVD2016)	1.75
Storm tide (m NZVD2016)	2.36
Beach slope (mV:mH)	0.14
Wave height[1] (m)	3.06
Wave setup (m)	0.71
Extreme static water level (m NZVD2016)	2.77
Extreme runup water level (m NZVD2016)	3.59

[1]Offshore significant wave height (independent of storm-tide)

6.2.10 Wainui Inlet/Takapou Bay

This coastal cell comprises the sheltered waters of Wainui Inlet that also incorporates Takapou Bay, which is largely sheltered from the open coast by a dynamic sandspit. The north-facing Burial Point at Takapou is subject to periodic erosion in storm events from a northerly direction, when offshore waves can penetrate into the Wainui Inlet mouth between Abel Tasman Point and the western end of the Wainui Inlet/Takapou Bay Spit.

Table 10: Present day 1% AEP water level components and total water levels for Wainui Inlet/Takapou Bay

MHWS-6 (m NZVD2016)	1.75
Storm tide (m NZVD2016)	2.36
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.56
Extreme runup water level (m NZVD2016)	3.36

[1] Fetch-limited wave height

6.2.11 Collingwood – Parapara – Patons Rock – Rangihaeata – Pohara

This coastal cell covers a large area of open-coast Golden Bay from Collingwood in the north, to Pohara in the south. This stretch of coastline includes a number of river mouths, sandy beaches and sand spits, but excludes a number of small estuaries. Shoreline erosion trends have been generally mild, with the presence of rock revetment protection works placed for a variety of reasons. These include either historical or recent placenet as a reaction to erosion events (eg Rototai, Rangihaeata west), implemented due to the proximity of the road network and built infrastructure (eg Abel Tasman Drive and Pohara camp, Rangihaeata east, Paton Rock east, Beach Rd Collingwood) or poorly located amenities (eg Takaka Golf Club greens). Yet other erosion episodes have also been successfully managed by periodic beach replenishment and Coast Care initiatives, most notably on the south Parapara Esplanade.

The sandspits at Motupipi west of Pohara, Rangihaeata west of the headland, the northern tip of Parapara spit and the beachfront of the very short, stubby spit on which Collingwood is partly located have all experienced the full range of accretion and erosion dynamic change. While the beachfront of the Collingwood CBD has experienced rapid accretion since the early 1970's to the present time, this appears to have now abated. At the other end of the scale, the heavily vegetated sandspit west of Rangihaeata Head, that almost fully enclosed the Onahau Estuary in 1948, had entered a period of significant vegetation removal and decline by 1990 and is now effectively non-existent.

Table 17: Present day 1% AEP water level components and total water levels for Collingwood - Parapara - Patons Rock - Rangihaeata - Pohara

	Rototai	**Paton Rock**	Parapara
MHWS-6 (m NZVD2016)	1.76	**1.77**	1.78
Storm tide (m NZVD2016)	2.35	**2.36**	2.36
Beach slope (mV:mH)	0.11	**0.12**	0.11
Wave height[1] (m)	2.86	**2.70**	2.25
Wave setup (m)	0.53	**0.54**	0.41
Extreme static water level (m NZVD2016)	2.64	**2.67**	2.61
Extreme runup water level (m NZVD2016)	3.28	**3.31**	3.13

[1] Offshore significant wave height (independent of storm-tide)

6.2.12 Parapara Inlet

This coastal cell comprises the sheltered waters of Parapara Inlet which is protected from the open coast by the Parapara Spit. This cell also incorporates all the smaller estuaries between Pohara and Collingwood, including Motupipi, Waitapu, Onahau and Onekaka.

Table 118: Present day 1% AEP water level components and total water levels for Parapara Inlet

MHWS-6 (m NZVD2016)	1.78
Storm tide (m NZVD2016)	2.36
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.56
Extreme runup water level (m NZVD2016)	3.36

[1]Fetch-limited wave height

6.2.13 Ruataniwha Inlet

This coastal cell covers the sheltered waters of the Aorere River mouth and Ruataniwha Inlet. Very similar water levels also apply for the Pakawau Inlet and Puponga Inlet.

Table 12: Present day 1% AEP water level components and total water levels for Ruataniwha Inlet

	Ruataniwha – Pakawau – Puponga Inlets
MHWS-6 (m NZVD2016)	1.79
Storm tide (m NZVD2016)	2.36
Wave height[1] (m)	Assume 1.0
Wave setup (m)	Assume 0.2
Extreme static water level (m NZVD2016)	2.56
Extreme runup water level (m NZVD2016)	3.36

[1]Fetch-limited wave height

6.2.14 Puponga – Pakawau – Totara Avenue

This coastal cell covers the open-coast northern reaches of Golden Bay from the Ruataniwha Inlet sandspit to Puponga Point, including Totara Avenue and Pakawau. The beaches of north-western Golden Bay are most susceptible to wind and wave climate from the east and south-east. The small community at Totara Ave are located on a sand spit. The open coast frontage has been subject to rock revetment protection works that now extends the full length of the spit.

The Ruataniwha spit is private land and has also been subject to moderate to high long-term erosion rates. Some revetment works protect housing built adjacent to the shore but the balance of the shore is natural.

Much of the road network north of Collingwood is immediately adjacent to the coast and as a consequence is also protected by either continuous or intermittent rock revetment works, mostly of a historical nature. Most of these works are relatively modest in nature, due to the relatively low-energy wave energy climate.

Possibly resulting from the extreme flood event in the Aorere River in December 2010, significant offshore sandbars and shoals are evident north of the Inlet and appear to be both increasing in size and extension northward. The effect of these sand deposits is evident in a shoreline accretion trend occurring adjacent to the rock revetment immediately north of Totara Ave and progressing northward.

This process may ultimately reverse a persistent erosion trend on the Pakawau shoreline north to Tomatea Point, thereby repeating the erosion-accretion trend mapped as occurring on this shoreline in the past. The esplanade reserve shoreline has been subject to episodic erosion events that has caused the erosion scarp to come within 2-3m of the private property boundaries in the southern end-effect area north of the camp revetment. Sand replenishment and Coast Care planting works undertaken by Council have buffered the erosion trend.

Table 20: Present day 1% AEP water level components and total water levels for Puponga - Pakawau - Totara Avenue

	Pakawau	**Puponga**
MHWS-6 (m NZVD2016)	1.79	**1.74**
Storm tide (m NZVD2016)	2.36	**2.36**
Beach slope (mV:mH)	0.07	**0.12**
Wave height[1] (m)	1.74	**1.78**
Wave setup (m)	0.20	**0.36**
Extreme static water level (m NZVD2016)	2.51	**2.62**
Extreme runup water level (m NZVD2016)	2.83	**3.09**

[1] Offshore significant wave height (independent of storm-tide)

7. Coastal Hazards Mapped Outputs

7.1 Overview

The mapping outputs are presented in the Council's *coastal hazards map viewer* which can be viewed at tasman.govt.nz/link/coastal-management.

The map uses the Council's most recent LiDAR (flown summer 2015 onwards) to construct a digital elevation model over which are applied the sea level elevations for the various scenarios across Tasman Bay and Golden Bay. The method used is simplistically referred to as a 'bath tub' model. This is where the water level calculated at the coast is translated as a level surface across the landscape, without any regard as to whether water can physically reach a particular area or achieve the calculated level.

The map shows areas at or below the level of MHWS-6, the present-day 1% AEP storm-tide event and a range of sea level rise scenarios in 0.5m increments up to 2m. Table 21 provides the individual coastal cell values of MHWS-6 and a 1% AEP extreme water levels as presented in the map viewer, summarised from the information presented in Section 6.2.

Table 21: Summary of coastal cell values for MHWS-6 and 1% AEP extreme water levels shown in the coastal hazards map viewer

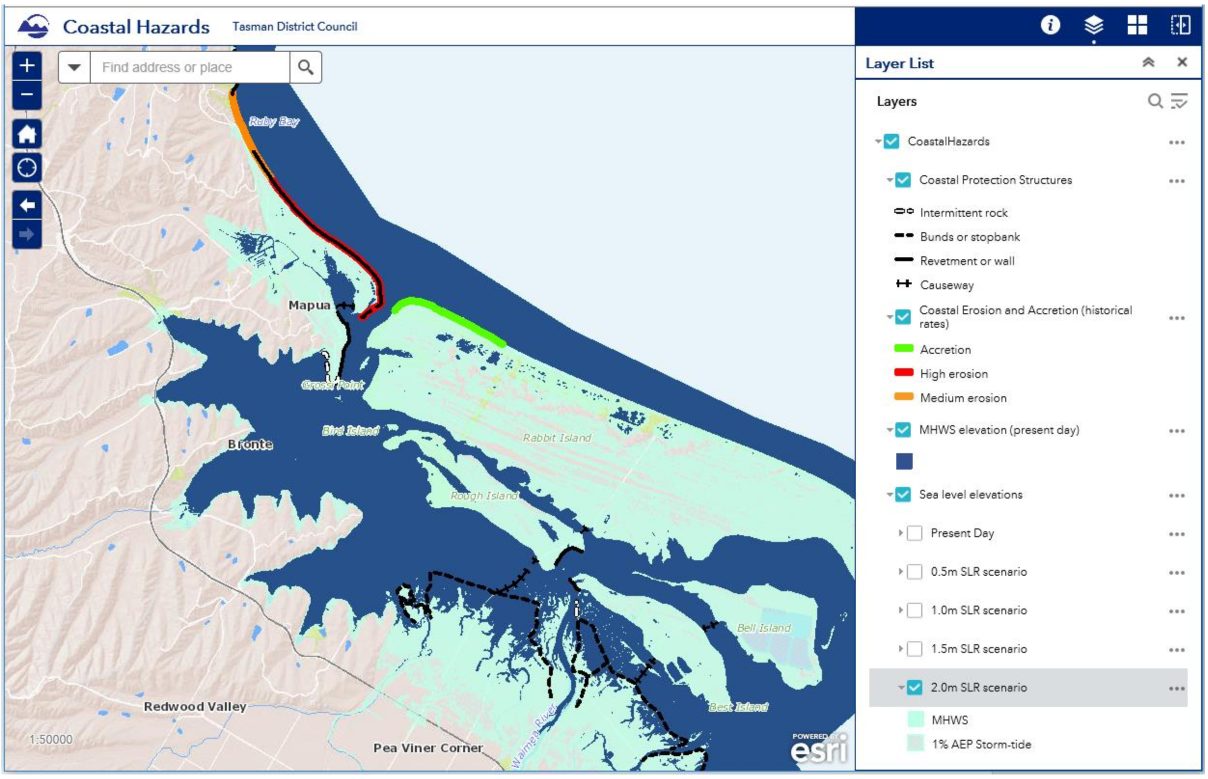
Location	MHWS-6	1% AEP EWL[1]
Waimea Inlet	1.72	2.54
Moturoa/Rabbit Island	1.75	2.66
Mapua - Ruby Bay - Kina Cliffs	1.74	2.91
Moutere Inlet	1.73	2.47
Kina Peninsula – Motueka – Riwaka – Tapu Bay	1.73	2.76
Kaiteriteri – Marahau – Torrent Bay – Onetahuti	1.68	2.97
Otuwhero - Awaroa Inlet	1.74	3.27
Awaroa Bay – Totaranui – Separation Point	1.74	3.19
Ligar Bay – Tata Beach – Wainui Bay – Whariwharangi Bay	1.75	2.77
Wainui Inlet/Takapou Bay	1.75	2.56
Collingwood – Parapara – Patons Rock – Rangihaeata – Pohara	1.77	2.67
Parapara Inlet	1.78	2.56
Ruataniwha Inlet	1.79	2.56
Puponga – Pakawau – Totara Avenue	1.74	2.62

[1] 1% AEP Extreme static water level (m NZVD2016)

Areas of historical coastal erosion and accretion, and the presence of coastal structures such as stopbanks, walls and rock revetments have also been mapped.

Figure 8 provides an example of the information available in the *coastal hazards map viewer*.

Figure 8: Example of the coastal hazards map viewer – a 2m sea level rise scenario for the Ruby Bay to Moturoa/Rabbit Island area



Layer List

Layers

- ☑ CoastalHazards
  - ☑ Coastal Protection Structures
    - Intermittent rock
    - Bunds or stopbank
    - Revetment or wall
    - Causeway
  - ☑ Coastal Erosion and Accretion (historical rates)
    - 🟩 Accretion
    - 🟥 High erosion
    - 🟧 Medium erosion
  - ☑ MHWS elevation (present day)
    - 🟦
  - ☑ Sea level elevations
    - ☐ Present Day
    - ☐ 0.5m SLR scenario
    - ☐ 1.0m SLR scenario
    - ☐ 1.5m SLR scenario
    - ☑ 2.0m SLR scenario
      - MHWS
      - 1% AEP Storm-tide

7.2 Limitations on Information and Map Use

These maps have been prepared for general information purposes only. The mapped information is intended to be used to raise awareness of coastal hazards and to help identify areas of land potentially affected by rising sea levels, historic coastal erosion and accretion trends and the presence of a range of coastal structures for coastal hazard mitigation purposes. The mapped inundation information does not take into account the additional effects that may arise from incident rainfall and stormwater flows, overland flows from river and drainage outflows and wave runup and overtopping of the shoreline margin. This information shall not be relied upon for undertaking detailed design or making site-specific decisions in relation to coastal land use and development. Site specific investigation undertaken by a suitably qualified and experienced practitioner may be required and is recommended.

The information on the maps may be amended as a result of public consultation and subsequent input from experts, the community or Council. A ‘second generation’ map viewer may be developed in the future, taking into account re-assessment of the underlying data as a result of storm events, and may incorporate the effects of wave runup and the presence and influence of tide banks and the like. There may also be a need to reassess inundation potential if the shoreline changes significantly due to erosion and/or earthquake effects.

8. Data Sources

All levels in this report are in New Zealand Vertical Datum 2016 (NZVD2016) unless otherwise stated.

Mapping is based on present day ground topography derived from LiDAR (flown summer 2015 onwards).

In mapping the potential sea level elevations for each scenario, key wave climate outputs are derived from a ‘coastal calculator’ tool developed by NIWA (2018).

Coastal erosion and accretion information was derived from a range of sources used by both Council staff and external researchers, including assessment of historic aerial photographs, survey cadastre and beach cross section survey measurements.

9. Glossary

Annual exceedance probability (AEP)	The Annual Exceedance Probability is the chance or probability of a natural hazard event (such as storm tide) of a particular size or greater occurring or being exceeded annually and is usually expressed as a percentage. For example, a 1% AEP event is an event that has a 1% probability of occurring or being exceeded annually.
Coastal accretion	Occurs when there is a net gain of sediment (such as sand) at the immediate shoreline area, resulting in the beach profile elevating/advancing seaward.
Coastal erosion	Occurs when there is a net loss of coastal sediment (such as sand) from the immediate shoreline area, resulting in the beach profile degrading/retreating landward.

Coastal protection structures	Are structures that have the purpose or effect of protecting land from a coastal hazard including inundation or erosion. Examples includes stopbanks, seawalls, rock revetments and causeways.
Inundation	Freshwater or seawater flooding of land or buildings. Coastal inundation specifically relates to flooding from seawater.
Light Detection and Ranging (LiDAR)	LiDAR is a remote sensing technique that uses high-frequency laser pulses to gather information about a surface.
Mean sea level (MSL)	An average level for the surface of the sea from which heights such as elevations may be measured. For Tasman Bay and Golden Bay this is defined as being 3.195m below Reference Mark N1 (AC4T) as defined by the NZVD2016 Datum.
Mean high water springs (MHWS)	The mean level of spring tides at standard atmospheric pressure. MHWS-6 is the 94th percentile of spring tides (i.e. 6% of spring tides are higher than MHWS-6). In Tasman and Golden Bays it ranges between 1.72m - 1.79m NZVD2016 (MSL 2008-17).
New Zealand Vertical Datum (NZVD2016)	New Zealand Vertical Datum 2016 as per standard LINZS25009.
Representative Concentration Pathways (RCP)	A standard set of scenarios (pathways) which describe different climate futures, all of which are considered possible depending on how much greenhouse gasses are emitted in future years. The different pathways include different global responses to greenhouse gas emission controls.
Sea level rise (SLR)	The rise in the level of the sea. Relative (or local) sea level rise includes both the change of the level of the sea (such as from global warming) and movement of the land (such as from earthquake subsidence) for the relevant coastal area. Tidal gauges measure relative sea level rise.
Storm surge	Storm surge is the rise in seawater level caused solely by a storm; this is caused by wind and wave action and low barometric pressure.
Storm tide	Storm tide is the observed seawater level during a storm.
Wave runup	Wave runup is the maximum vertical extent of wave uprush on a beach or structure.
Wave setup	Wave setup is the increase in water level on a shoreline due to the combined “push-up” effect of wind blowing across a water body and the effect of breaking waves on the shore.

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Appendix A: Coastal Cell Locations

For the purpose of this assessment, the coastline of Tasman and Golden Bays has been partitioned into ‘coastal cells’. Each cell encompasses an area of the coastal environment assessed as having generally similar shoreline characteristics and extreme water levels, based on similar wave climate, shoreline aspect, upper beach slope and wave and water level conditions. This Appendix summarises and illustrates the location of each of these cells.

Location	**Coastal Cell Map Code**
Waimea Inlet	TB Estuary 1
Moturoa/Rabbit Island	TB 1
Mapua - Ruby Bay - Kina Cliffs	TB 2
Moutere Inlet	TB Estuary 2
Kina Peninsula – Motueka – Riwaka – Tapu Bay	TB 3
Kaiteriteri – Marahau – Torrent Bay – Onetahuti	TB 4
Otuwhero - Awaroa Inlet	TB Estuary 4
Awaroa Bay – Totaranui – Separation Point	TB 5
Ligar Bay – Tata Beach – Wainui Bay – Whariwharangi Bay	GB 1
Wainui Inlet/Takapou Bay	GB Estuary 3
Collingwood – Parapara – Patons Rock – Rangihaeata – Pohara	GB 2
Parapara Inlet	GB Estuary 1
Ruataniwha Inlet	GB Estuary 2
Puponga – Pakawau – Totara Avenue	GB 3

Figure 1: Overview Map of Coastal Cell Locations in Tasman and Golden Bays

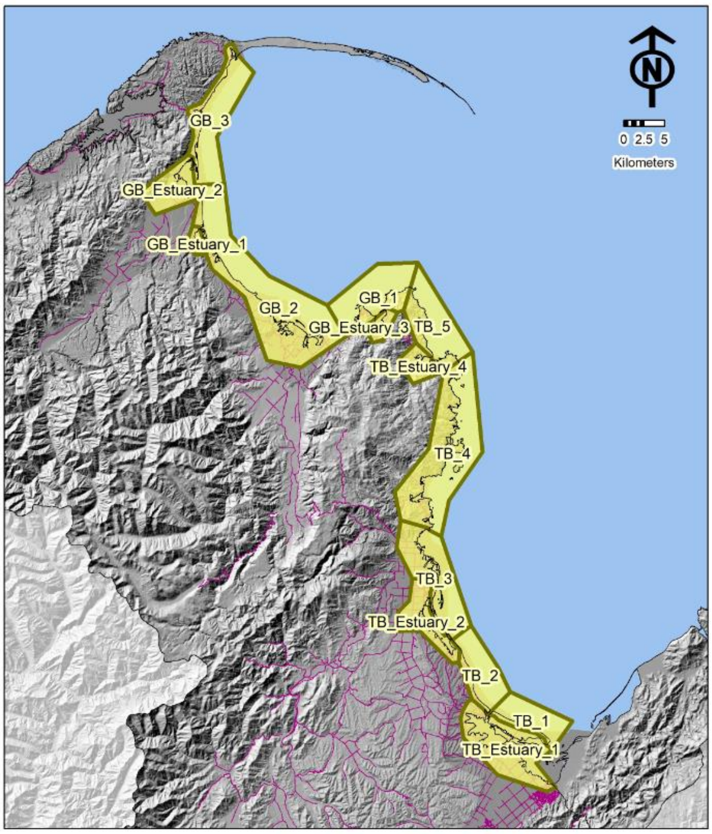
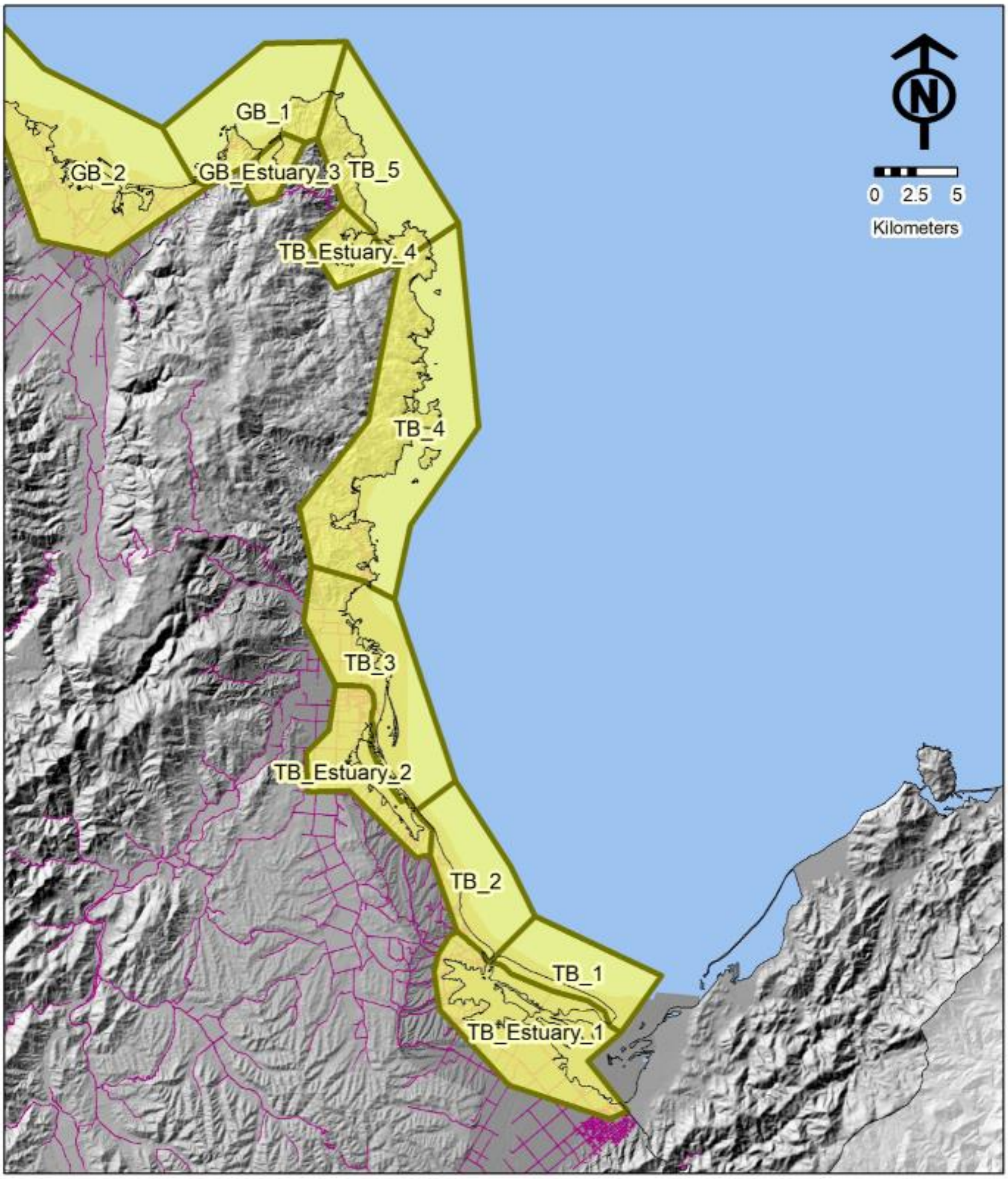
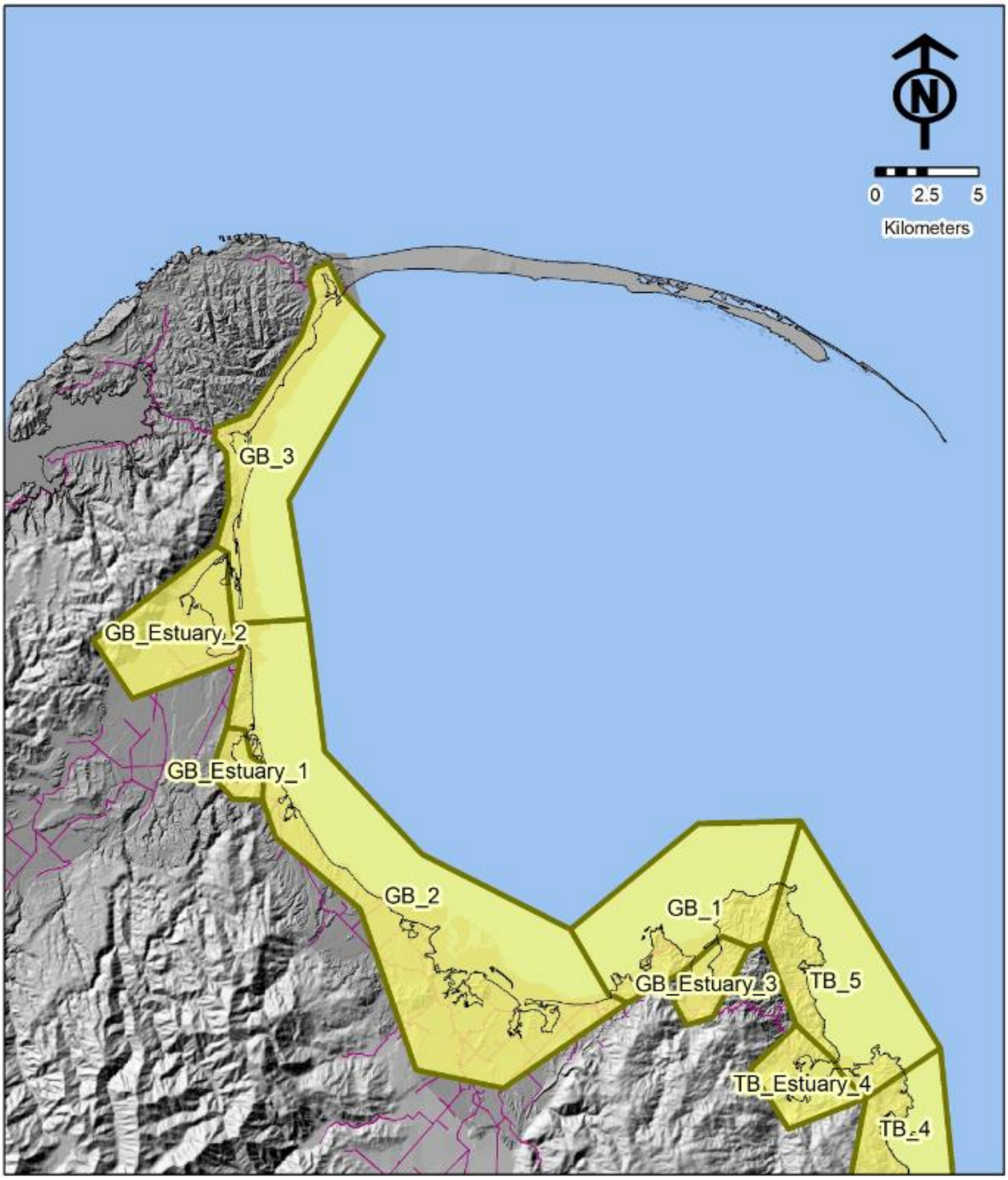


Figure 2: Coastal Cell Locations in Tasman Bay



Location	Coastal Cell Map Code
Waimea Inlet	TB Estuary 1
Moturoa/Rabbit Island	TB 1
Mapua - Ruby Bay - Kina Cliffs	TB 2
Moutere Inlet	TB Estuary 2
Kina Peninsula – Motueka – Riwaka – Tapu Bay	TB 3
Kaiteriteri – Marahau – Torrent Bay – Onetahuti	TB 4
Otuwhero - Awaroa Inlet	TB Estuary 4
Awaroa Bay – Totaranui – Separation Point	TB 5

Figure 3: Coastal Cell Locations in Golden Bay



Location	Coastal Cell Map Code
Ligar Bay – Tata Beach – Wainui Bay – Whariwharangi Bay	GB 1
Wainui Inlet/Takapou Bay	GB Estuary 3
Collingwood – Parapara – Patons Rock – Rangihaeata – Pohara	GB 2
Parapara Inlet	GB Estuary 1
Ruataniwha Inlet	GB Estuary 2
Puponga – Pakawau – Totara Avenue	GB 3